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College of Design, National Taichung University of Science and Technology



Conference Papers

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Conference Papers

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KINETIC- DESIGN GENERATION SYSTEM BASED ON MATHEMATICAL MODELING OF CURIOSITY AND INTEREST

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ABSTRACT

Motion design plays a crucial role in enhancing both product functionality and visual appeal, fostering an emotional connection with users and promoting engagement. This study aims to develop metrics for assessing curiosity and interest in motion by creating a computational framework that generates motions stimulating inquiry. Conceptualizing curiosity and interest as emotional drivers of inquiry, we suggest that optimal prediction error, representing deviations from anticipated motion patterns, enhances interest, while fluctuations spark curiosity. Our analysis is grounded in the inquiry cycle, a mathematical model of emotions based on the free energy principle governing brain function. Metrics for curiosity, motion, and interest were derived from the model, focusing on variations and reductions in prediction error. The developed system allows independent control over prediction errors and their fluctuations within a given open-loop mechanism. By deviating from the trajectory of energy-minimizing motions, this system produces motions that modulate the magnitude of prediction errors. Using the semantic differential method, we found that interest correlates upward-convexly with prediction error, and its variability induces curiosity. These findings align with our theoretical framework. Experimentally, we validate the efficacy of introducing moderate prediction errors and fluctuations to enhance interest and curiosity in kinetic design, providing valuable design insights for engineers and designers seeking to elevate the allure of product motions.

Keywords: Kinetic Design, Surprise, Free Energy Principle

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1 INTRODUCTION

In engineering design, products' behavior and structure closely determine their function (Umeda et al., 1990). For instance, a clock's function, accurately indicating time, relies on the constant rotation of its hour and minute hands. Collectively known as "motion," behavior and structure also contribute significantly to a product's aesthetic appeal. Motion is considered as crucial an aesthetic element as shape, color, and material (Hopson, 2009). Nam et al. (2007) additionally argue that product motion can strengthen the emotional bond between users and products. Attractive product motion enhances user experience, fostering continued use and affection for the product.

This study delves into the enduring enrichment provided by kinetic design, focusing on the philosophical concept of eudaimonia, denoting a higher form of happiness involving personal potential development, self-realization, and growth (Deci and Ryan, 2008). Eudaimonia realization involves intellectual curiosity, interest, and a spirit of inquiry (Kashdan et al., 2008), with curiosity driving novelty pursuit and problem-solving (Berlyne, 1966), and interest rewarding the resolution of uncertainties triggered by curiosity (Graf and Landwehr, 2015). Curiosity and interest act as motivators for acquiring new knowledge and fostering personal growth through inquiry.

Research in Human-Computer Interaction (HCI) explores motions aiming to foster emotional connections. HCI utilizes motions to guide avatar gestures based on emotions estimated from speech (Qi et al., 2023). In robotics research, there's exploration into generating robot arm motions expressing emotions to enhance human interaction (Fernandez et al., 2023; Hagane and Venture, 2022). While these approaches describe integrating emotional expressions into motions, they mainly aim to convey predefined emotions from robots to humans and do not induce specific emotions in users through kinetic design.

This study mathematically models curiosity and interest arising from product motions and examines conditions to enhance these emotions. Based on this formalization, we implement a computational system to generate motions evoking curiosity and interest. Evaluation experiments of the generated motions are conducted to validate the model and system.

2 FORMALIZATION OF CURIOSITY AND INTEREST

The discrepancy between the predicted and observed values perceived by humans constitutes prediction error. Curiosity drives behaviors like novelty-seeking and problem-solving (Berlyne, 1966). Diversive curiosity, which increases prediction error by pursuing novelty, contrasts with specific curiosity, which reduces prediction error through problem-solving. Interest, a pleasant emotion arising from reduced prediction error due to specific curiosity, is noted (Graf and Landwehr, 2015). To enhance users' curiosity and interest, this study focuses on cognitive prediction error when humans perceive objects.

2.1 Formalization of Prediction Error Variation

Prediction error formalization employs variational free energy (VFE) (Friston et al., 2006), representing the gap between prediction and perception in organisms, including humans. VFE serves as the loss function during variational inference, where the state is estimated based on predictions and observations, updating predictions accordingly.

VFE decreases in two stages during perception: "recognition" and "prediction update" (Yanagisawa and Honda, 2023). Recognition marks state estimation completion, with VFE reduction termed Kullback-Leibler divergence (*KLD*). The minimized VFE through recognition is termed surprise (*S*). Additionally, VFE reduction due to prediction update is termed Bayesian surprise (*BS*). The sum of *KLD* and *BS* is information gain (IG).

Authors (Yanagisawa and Honda, 2023) show through numerical analysis that reductions in *KLD*, *BS*, and *IG* form convex functions concerning surprise. Surprises maximizing *KLD*, *BS*, and *IG* are termed S_{KLD} , S_{BS} , and S_{IG} , respectively, with S_{IG} denoting the optimal arousal level.

2.2 Formalization of Curiosity and Interest

Curiosity and interest encourage exploratory behavior. In the authors' exploratory cycle model (Yanagisawa and Honda, 2023), ideal inquiry involves alternately decreasing surprise towards S_{KLD} (specific curiosity) and increasing surprise towards S_{BS} (diversive curiosity), resulting in surprise fluctuations around the optimal arousal level. Interest, stemming from reduced prediction error, is indicated by the decrease in VFE due to recognition and prediction updating (*IG*).

Curiosity, driving prediction error fluctuations, benefits from significant variance around the optimal arousal level. Thus, temporal surprise variance (V_s) serves as a curiosity indicator.

2.3 Conditions for Generating Motions to Foster Curiosity and Interest

Figure 1 illustrates that *IG* forms an inverted U-shaped function concerning surprise *S*. Observations realizing the optimal arousal level S_{IG} , as defined by the generative model, are predicted to maximize interest. Moreover, if curiosity arises from fluctuations in surprise centered around the optimal arousal level, motions with a large V_S are expected to foster curiosity. Based on this discussion, the following theoretical hypotheses are deduced:



Figure 1. Schematic of inquiry cycle model.

- TH1: Interest follows an inverted U-shaped function with respect to surprise S.
- TH2: Fluctuations in surprise V_s around the optimal arousal level S_{G} enhance curiosity.

3 MOTION GENERATION SYSTEM

Based on our formalization of curiosity and interest, we propose a motion generation system that independently controls surprise S and the variance of surprise V_s . For a more detailed explanation of the system, please refer to our previous report (Honda and Yanagisawa, 2024).

Consider an open-loop mechanism comprising *N* elements connected in rotational pairs, each equipped with an actuator. Motion generation involves placing *M* control points between the start and end points in the t-y coordinate system at time t and interpolating between them using B-spline interpolation. The optimization target is the y-coordinates of the control points. From the motion, we infer the states of representative position, velocity, and acceleration for each element, totaling 3*N* states. The algorithm proceeds as follows, with a flowchart provided in Figure 2:



Figure 2. System flowchart: Dashed arrows indicate the use of values from their origin in subsequent processes.

1. Define the target values S^* and V_S^* for surprise and the variance of surprise, along with the motion structure, equations of motion, and the start and end points of the motion.

For the specified structure, determine the Lagrangian L of the system and the external forces f_i applied by each actuator.

2. Discover the (predicted typical) motion *P*, serving as the prior distribution, by minimizing the work exerted by the actuators on the system.

We considered appropriate to utilize naturally recalled motions from the structure as the prior distribution. In human kinetics, there exists a hypothesis suggesting that motions such as walking and arm flexion are determined to minimize the work required by muscles (Alexander, 1997; Maalouf et al., 2016). Based on this hypothesis, we adopt as the prior distribution the motion where all actuators minimize the work done on the system from the starting point to the end point.

3. Determine the state $s_{P,\tau}$ of motion P at each time step.

Under these settings, calculate the state $s_{P,\tau}$ for motion *P* obtained in step 2 for all time steps using the marginal message passing (MMP) method (Parr et al., 2019). MMP is a computational method that updates states to minimize variational free energy.

4. Iteratively compute the motion K^* that achieves the desired S^* and V_S^* .

Formulate motion K by interpolating the control points. Compute surprise S and the variance of surprise V_S from motion K, and apply particle swarm optimization to the M-dimensional vector of the y-coordinates of the M control points to minimize the difference between the target values S^* and V_S^* .

4 EXPERIMENT

To validate the formulations outlined in Chapter 2, we conducted a participant experiment utilizing the generated motions as evaluation stimuli. Subjective evaluations regarding the impressions received from the motions were collected during the experiment.

4.1 Hypotheses

The experimental hypotheses were defined as follows, corresponding to the theoretical hypotheses in Section 2.3:

- EH1: Geometric mean of subjective evaluations of "interestingness" and "clarity" regarding the surprise *S* of the motion follow a concave-up function.
- EH2: Motions with a larger variance of surprise V_S are evaluated as having higher "engagement" than motions with a smaller V_S .

In this experiment, the evaluation of interest utilized the geometric mean of "interestingness" and "clarity." Graf and Landwehr (2015) suggest in their proposed aesthetic evaluation model that interest is aroused when uncertainty is resolved, and confusion is caused when uncertainty cannot be resolved. Therefore, it is necessary to consider a balance between "interestingness" and "clarity" when evaluating interest. Additionally, "engagement" was used as the evaluation term for curiosity.

4.2 Samples

A 2-degree-of-freedom manipulator was provided for the sample structure, and motions were generated using the system outlined in Chapter 3 with surprise *S* controlled in 8 levels (levels 1-8) and two conditions of variance V_S (large and small). Figure 3 displays the motion trajectory used as samples. All motions are controlled to complete one revolution from the 12 o'clock position within 5 seconds. The motion *P* with the minimum surprise was determined to



be uniform circular motion.

Figure 3. Motion trajectories used as samples.

4.3 Participants

The participants consisted of 51 students (27 females and 24 males) aged 18 to 29 from the University of Tokyo. They were recruited from individuals without visual impairments or disabilities. Recruitment was conducted using a combination of participant recruitment sites https://www.jikken-baito.com/ and personal connections. The experimental plan received approval from the Research Ethics Committee of the Graduate School of Engineering, the University of Tokyo (Approval No. KE23-83).

4.4 Evaluation Items

Participants viewed the sample motions for at least 5 seconds and responded on a 5-point scale to the following three evaluation items. The expressions in parentheses indicate annotations. Subsequently, the following items are expressed as "interestingness", "clarity", and "engagement", respectively:

- Is this motion interesting? (Memorable and interesting impression)
- Is this motion confusing? (Difficult to understand)
- Is this motion not boring to watch? (Want to keep watching)

4.5 Analysis

For aggregation, a 5-point Likert scale based on the SD method was used for subjective evaluations of "interestingness," "clarity," and "engagement," and normalized (Z-scored) within participants. Additionally, for samples where responses indicated that associations influenced the evaluation in the post-experiment questionnaire, evaluations by responding participants for those samples were treated as missing values. MATLAB's multivariate maximum likelihood estimation method was used for imputing missing values.

4.6 Results

EH1: Multiplication of subjective evaluations of surprise and "interestingness" and "clarity"

Figure 4 shows a scatter plot with the level of surprise in motion on the horizontal axis and the geometric mean of subjective evaluations of "interestingness" and "clarity" on the vertical axis. A quadratic single regression analysis was conducted with the level of surprise in motion as the explanatory variable X and the geometric mean of subjective evaluations as the dependent variable Y. The regression equation was found to be $Y = -0.402 + 0.312X - 0.039X^2$ (coefficient of determination R2 = .79). The results of the variance analysis confirmed the significance of the regression relationship (F = 9.4, p < .05). Furthermore, as the coefficient of the quadratic term was significantly negative (p < .05), this result supports hypothesis EH1.



Figure 4. The Geometric Mean of the Evaluation of "Interestingness" and "Clarity" in Relation to Surprise.

EH2: Impact of surprise variance on the evaluation of curiosity

A two-way between-subjects analysis of variance was conducted for the evaluation of "engagement" for all participants. The factors were surprise *S* and the two factors of variance *Vs*. The results of the variance analysis did not confirm a main effect of surprise variance on the evaluation of "engagement." Therefore, hierarchical cluster analysis (Ward's method) based on the correlation matrix of participants was conducted. This method allows grouping of participants with similar evaluation tendencies. Participants are divided into two clusters based on their tendency to rate "engagement" using cluster analysis.

The subjective evaluations of "engagement" for participants belonging to the majority cluster are depicted in Figure 5. A two-way between-subjects analysis of variance was performed for the majority cluster, confirming a significant main effect (F = 3.9, p < .05) of surprise variance V_s on the evaluation of "engagement." This result supports hypothesis EH2.



Figure 5. Subjective evaluations of "clarity" for majority cluster.

5 DISCUSSION

5.1 Limitation

In our experiment, it's crucial to recognize potential biases in participant and sample selection.

(a) Participant selection bias: Our participants were solely University of Tokyo students, potentially possessing diverse educational backgrounds. This could affect their subjective evaluations. Moreover, being in their late teens to twenties, the results may reflect characteristics unique to this age group. Future studies should include participants from varied demographics to enhance generalizability.

(b) Sample selection bias: Numerous motions can achieve similar surprise levels, depending on optimization parameters. We used one motion per surprise level in this experiment, generated from specific initial values. Future research should expand sample size and use motions with diverse initial values.

5.2 Conclusion

The congruence between predictions and experimental results suggests that designing motions slightly deviating from typical ones is ideal for eliciting user interest. Designers can employ this generation system to craft product motions tailored to structure, with the aim of exploring optimal surprises. These findings offer insights for designers and underscore the potential of design support tools grounded in design knowledge.

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CONDITIONS FOR HIGH PRICES FOR LUXURY BAGS IN THE SECONDARY MARKET

QUANTITATIVE COMPARATIVE ANALYSIS (QCA)

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Abstract

This study aimed to clarify the factors determining the popularity of popular models of luxury bags. In particular, we examined whether collaborations, which have become a popular topic in recent years, lead to popularity. The research method used was logistic regression analysis and qualitative comparative analysis (QCA) on 4,700 luxury bags sold on the online shopping site of KOMEHYO, Japan's largest second-hand luxury goods retailer. The results showed that for a bag to be popular, it must not be traded in a new condition on the secondary market. This was equivalent to the brand not opening a store in an outlet mall. In addition, there were two configurations of factors that led to popularity. One was the products of Hermès, Chanel, and Goyard, namely, the brands the founding family was a major shareholder or privately held. The other was an artist collaboration model of a brand with a listed company originating in leather goods, such as Louis Vuitton. A limitation of this study is the limited number of countries examined. In practice, this means that even if the founding family is not a stakeholder, a company originating in leather goods can create a popular model by creating a limited-edition model in collaboration with another artist or brand. The originality of this study is that it is a qualitative analysis of popular models of luxury brand bags, incorporating collaboration as an explanatory variable and inventing the regular distribution rate of the original.

Keywords: luxury brand, secondary market, reuse, brand equity, QCA

1 INTRODUCTION

Louis Vuitton's collaboration bags with Yayoi Kusama are a big hit every time they are released. There has been a lot of research on Louis Vuitton collaborations in previous studies. Louis Vuitton's collection line bags in collaboration with Takashi Murakami (Bengtsen, 2017; Riot et al., 2013) were sold at prices above list prices in the secondary market. These art collaborations have been defined by Hagtvedt & Patrick (2008) as "art infusion effects." For

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traditional brands, storytelling and celebrity partnerships are important (Gupta et al., 2024). At Louis Vuitton, music producer Pharrell Williams, rather than a fashion designer, was appointed creative director in 2023 (Choufan, 2024). Collaborations with the street brands, such as Supreme (Ostillio & Barberi, 2022), have extended beyond classical art to the street scene (Baumgarth & Wieker, 2020). These collaborations between traditional brands and street culture are said to be important for branding activities by Joy & Belk (2020). In addition to the above, other previous studies have examined Louis Vuitton's collaborations (Michel & Willing, 2020; Blinicheva & Vankovichm, 2020), but Masè & Cedrola (2017) found that Louis Vuitton's collaborations with artists increase the rarity. Therefore, this study examined the following research questions based on the popularity of trading at premium prices.

RQ: What factors contribute to the popularity of popular models of luxury bags? Do collaborations lead to popularity?

Ide and Kazama (1997) found that working women were attracted to CHANEL, LOUIS VUITTON, PRADA, Salvatore Ferragamo, and FENDI as the most popular brands of bags. They also found that the factors that made women want to own these brands were "luxury and simplicity", "buzz and practical", and "self-orientation and other orientation". In this study, popularity was defined as being trading at a premium price in the secondary market, and we clarified the product characteristics that lead to premium prices through qualitative analysis.

2 METHODOLOGY

The study was conducted on all bags sold on the online shopping site of KOMEHYO (https://komehyo.jp). KOMEHYO is a second-hand luxury goods retailer in Japan, and it is listed on the Tokyo Stock Exchange. In Japan, the second-hand luxury goods industry has been a huge market that has achieved unprecedented development worldwide, with companies such as Valuens, Shuppin, and Daikokuya listed in addition to KOMEHYO (Ando, 2022). According to the Yano Research Institute (2023, p26), Japan's luxury goods market was worth 2.9 trillion yen (approximately US\$19.3 billion) in FY2022. According to The Reuse Economic Journal (2023, p. 11), Japan's second-hand luxury goods market will be worth 300 billion yen (approximately US\$2 billion) in FY2022. According to KOMHYO HOLDINGS (2023), KOMEHYO's luxury brand business had sales of 80 billion yen (approximately US\$530 million) in FY2023, of which KOMEHYO's online shopping site had sales of 10 billion yen (US\$67 million). In other words, KOMEHYO's online shopping site accounted for 3% of Japan's second-hand luxury goods market. KOMEHYO's online shopping site also covers its real stores' inventory information, and its online shopping site had by far the largest inventory of luxury bags, with approximately 4,700 items (all as of April 2024), compared to the 600 items of Daikokuya (https://www.daikokuya78.com), the second largest online shopping site operated by a second-hand luxury goods retailer. While we could not rule out the possibility of regional and company differences by focusing on a single Japanese company, there is a huge market for second-hand luxury goods in Japan, and by focusing on the largest company in the market, we tried to minimize regional and company differences. In addition to unused and used goods purchased from customers, second-hand luxury goods retailers in Japan also deal with new products. New products are purchased by

second-hand luxury goods retailers outside the authorized distribution channels and are different from unused products purchased from customers.

The research method consists of the following steps.

Step 1. Brand selection

The first step was to select brands for which KOMEHYO had at least 10 items for sale in "used and unused" condition (not new condition). This was to focus only on brands that were actively traded in the market. The stock information was as of April 2024. The target bags were all types of bags for men, women, and unisex, including not only handbags but also backpacks and suitcases stocked in KOMEHYO.

Step 2. Collection Selection

Among the brands discussed in Step 1, we selected collections in used and unused condition with at least 20 items for sale. We set 20 as the standard because we needed to target products that had more than a certain number of items for sale without being affected by scarcity. Also, reducing the number of items to less than 20 would result in only Louis Vuitton products with a wide variety of items. Of the selected collections, those with at least one collaboration model in stock were also counted as collaboration collections in addition to the regular collections. Collaboration models are limited-edition models created in collaboration with artists or brands outside the brand. The regular collections and the collaboration collections were then examined as the subjects of this study.

Step 3. Logistic regression analysis and Qualitative Comparative Analysis (QCA)

Logistic regression analysis (stepwise) using the SPSS software and QCA (csQCA) using the fsQCA software, were conducted using the following variables and conditions. QCA is an analytical method proposed by Ragin (1987). Causal relationships are extracted using a dataset of causal conditions and outcomes expressed as 0 and 1.

Outcome: Price. A value of 1 was assigned if one or more unused items from the collection were traded at prices above the list price in the secondary market. A value of 1 was also assigned if one or more used items were traded at prices above the list price.

X1 = Timeless (collection-specific factor), an alternative characteristic for "never out of fashion" in luxury brand attributes (Kapferer, 1998). This was the "legitimacy and excellence factor" (Kumagai & Nagasawa, 2016). In logistic regression analysis, it was the number of years since the launch. In QCA, the collection was assigned a value of 1 if it was launched before 2000 and 0 if it was launched after 2000. Collections launched before 2000 are considered iconic products because the conglomeration of the luxury industry settled down around 2000.

X2 = Collaboration (collection-specific factor), an alternative characteristic for "buyers are very few" in luxury brand attributes (Kapferer, 1998). This is the "rarity factor" (Kumagai & Nagasawa, 2016). A value of 1 was assigned for collaboration collections with artists such as Yayoi Kusama and other brands, and a value of 0 for regular collections.

X3 = Leather goods origin brand (brand-specific factor), an alternative characteristic for "tradition and savoir-faire" in luxury brand attributes (Kapferer, 1998). This is the "legitimacy and excellence factor" (Kumagai & Nagasawa, 2016). Brands with origins in leather goods, such as bags, were assigned a value of 1, while brands with origins other than leather goods, such as fashion designer origin, were assigned a value of 0. Brands with origins in fashion designers, such as Chanel and Christian Dior (Diaz et al, 2023), were assigned a value of 0.

X4 = Family business (brand-specific factor), an alternative characteristic for "belonging to a minority" in Luxury brand attributes (Kapferer, 1998). This is the "rarity factor" (Kumagai & Nagasawa, 2016). In the logistic regression analysis, the shareholding of the founding family was entered; in the QCA, a value of 1 was assigned if the shareholding was 50% or more. Chanel and Goyard were assigned a value of 1 because they are privately held firms. Louis Vuitton, Fendi, and Christian Dior were assigned a value of 0 because the Arnault family, which is not the founding family, is the major shareholder. Family businesses control the volume of distribution.

X5 = Authorized distribution rate (brand-specific factor). We calculated the rate of the number of used items divided by the number of new items for the brands selected in Step 1 in KOMEHYO and defined this as the out-of-authorized distribution rate. The authorized distribution rate was defined as "1 - authorized out-of-distribution rate."

3 RESULTS

For Step 1, there were 45 brands of bags on KOMEHYO's online shopping site. Of the 4,700 luxury bags on the site, the number of Louis Vuitton bags was about 1,700, the number of Chanel bags was 700, and the number of Hermès bags was 450. Louis Vuitton bags dominated the inventory, and bags from these three brands accounted for 60% of the total number of bags.

Brand	New bags	Used and unused bags	Out-of-auth orized distribution rate	Authorized distribution rate (X5)	Stores in outlet malls
Louis Vuitton	0	1754	0%	100%	No
Chanel	1	728	0%	100%	No
Hermès	5	502	1%	99%	No
Gucci	54	139	39%	61%	Yes
Christian Dior	4	96	4%	96%	No
Bottega Veneta	29	82	35%	65%	Yes
Celine	18	77	23%	77%	Yes
Fendi	27	71	38%	62%	Yes
Loewe	15	58	26%	74%	Yes
Prada	34	52	65%	35%	Yes

Table 1. Brands with at least 10 used and unused bags for sale in KOMEHYO online shopping site

Goyard	0	31	0%	100%	No
Balenciaga	19	27	70%	30%	Yes
Saint Laurent	2	16	13%	87%	Yes
S. Ferragamo	14	11	127%	-27%	Yes

As Table 1 shows, the following brands were identified in the collection selection as having at least 10 used or unused items for sale: Louis Vuitton, Hermès, Chanel, Gucci, Christian Dior, Bottega Veneta, Celine, Fendi, Loewe, Prada, Goyard, Balenciaga, and Saint Laurent. Brands with an authorized distribution rate of 96% or higher corresponded to brands that do not have stores in prominent outlet malls in France, Italy, Japan, and the United States. Hermès, Goyard, Louis Vuitton, and Chanal were above 99% and have never opened a store in an outlet mall. Christian Dior had 96%, the next highest. Christian Dior had a store in Gotemba Premium Outlets in Japan until 2015. Brands that had new products in second-hand luxury goods retailers such as KOMEHYO had distribution that was not intended by the brand. In other words, brands with high authorized distribution rates controlled the quality of their distribution.

Among these brands, there were 28 collections with at least 20 used and unused items for sale. In addition, there were eight collections from these 28 collections that had at least one collaboration model in stock. Qualitative analysis was conducted on a total of 36 collections, 28 regular collections, and 8 collaboration collections. Of the 36 collections obtained, 23 were priced at a premium. These 23 collections were sold at premium prices not only on KOMEHYO's online shopping site, but also on the French online marketplace Vestiaire Collective (https://us.vestiairecollective.com/) as of July 2024. This was evidence that there were no regional differences in the prices of second-hand bags.

Collection	Y	X1	X2	Х3	X4	X5
LouisVuitton Neverfull	0	17	0	1	0	1
LouisVuitton Neverfull (Collaboration Model)	1	17	1	1	0	1
LouisVuitton PochetteAccessoires	0	32	0	1	0	1
LouisVuitton PochetteAccessoires (Collaboration Model)	0	32	1	1	0	1
LouisVuitton Alma	0	32	0	1	0	1
LouisVuitton Alma (Collaboration Model)	1	32	1	1	0	1
LouisVuitton Speedy	0	94	0	1	0	1
LouisVuitton Speedy (Collaboration Model)	1	94	1	1	0	1
LouisVuitton Keepall	0	100	0	1	0	1

 Table 2. Variables in logistic regression analysis (1/2)

LouisVuitton Keepall (Collaboration Model)	1	100	1	1	0	1
LouisVuitton Onthego	0	5	0	1	0	1
LouisVuitton Onthego (Collaboration Model)	1	5	1	1	0	1
LouisVuitton SacPlat	0	58	0	1	0	1
LouisVuitton SacPlat (Collaboration Model)	1	58	1	1	0	1
LouisVuitton Papillon	0	64	0	1	0	1
LouisVuitton Papillon (Collaboration Model)	1	64	1	1	0	1
LouisVuitton Looping	0	24	0	1	0	1
Chanel 11.12	1	40	0	0	1	1
Chanel 11.13	1	40	0	0	1	1
Chanel 69900	1	40	0	0	1	1
Chanel ChainWallet	1	27	0	0	1	1
Chanel BoyChanel	0	13	0	0	1	1
Chanel Chanel22	1	2	0	0	1	1
Chanel CocoHandle19	1	9	0	0	1	1
Chanel CocoHandle22	1	9	0	0	1	1

 Table 2. Variables in logistic regression analysis (2/2)

Collection	Y	X1	X2	Х3	X4	X5
Hermès Birkin	1	40	0	1	0.67	0.99
Hermès Kelly	1	69	0	1	0.67	0.99
Hermès Bolide	1	101	0	1	0.67	0.99
Hermès Constance	1	55	0	1	0.67	0.99
Hermès Evelyne	1	46	0	1	0.67	0.99
Hermès GardenParty	1	132	0	1	0.67	0.99
Hermès PicotinLock	1	16	0	1	0.67	0.99
Hermès Lindy	1	17	0	1	0.67	0.99
Goyard SaintLouis	1	94	0	1	1	1
Fendi Peekaboo	0	16	0	0	0	0.62
ChristianDior LadyDior	0	30	0	0	0	0.96

Logistic regression analysis was performed using the explanatory variables in Table 2. The results showed no correlation between the explanatory variables. The obtained regression equation was as follows.

Logit(Pr(premier price))=-3.229+5.175*collaboration+7.310*family business

In QCA, the explanatory variables used in the logistic regression analysis (the values of X1 and X4 were converted to 0 and 1, respectively) were used. The authorized distribution rate (X5) was a necessary condition. The threshold of Proportional Reduction in Inconsistency (PRI) consistency was set at 0.75 to complete the truth table.

	raw coverage	unique coverage	consistency
~X2*X4 (Non-collaboration*family business)	0.695652	0.695652	0.941176
X2*X3*~X4 (Collaboration*leather goods origin brand*non-family business)	0.304348	0.304348	0.875

Table 3. INTERMEDIATE SOLUTION of TRUTH TABLE ANALYSIS

Regarding the intermediate solution of the truth table analysis (Table 3), the solution coverage of these configurations was 1 and the solution consistency was 0.92. Then, as sufficient conditions, two configurations were obtained: (1) non-collaboration*family business and (2) collaboration*leather goods origin brand*non-family business. In other words, the family business and collaboration in the logistic regression equation were separated into different combinations. That is, a high authorized distribution rate was a prerequisite for a premium price, and the configurations of (1) and (2) brought a premium price on top of that. (1) included the rarity of family business as a brand, and (2) included the rarity of collaboration as a model. In other words, while (1) controlled the rarity by brand and achieved a premium price, (2) could not control the rarity by brand, so it controlled the rarity by model and achieved a premium price in the secondary market.

The configuration of (1) corresponded to Hermès, Chanel, and Goyard, while (2) corresponded to Louis Vuitton's collaboration collection. Louis Vuitton was the best-selling leather goods brand in the Japanese primary market, followed by Hermès in second place, Chanel in third, Gucci in fourth, and Coach in fifth (Yano Research Institute, 2023, p142). In the secondary market, however, Hermès and Chanel bags were priced above list prices, while Louis Vuitton bags were not priced above list prices unless they were limited editions. Gucci and Coach bags were not traded at the above list prices. In other words, it became clear that the strategy to increase sales in the primary market differed from the strategy to be traded at a premium price in the secondary market.

4 IMPLICATIONS FOR THEORY AND PRACTICE

The result of the logistic regression analysis suggested that the production of a collaboration model would likely command a premium price, but QCA revealed that if the brand is not a

family business, it is also important that the brand has its origins in leather goods. In other words, if a bag from a non-family business and a brand with fashion designer origins, such as Christian Dior, made a collaboration model, it would likely not command a premium. This is because the brand does not have an origin in leather goods. According to our internet search in July 2024, we could not find any Christian Dior collaboration bags on the secondary market for more than the list price. For example, the Dior and Rimowa collaboration bags, which were released in 2019, were sold on the online shopping site KOMEHYO, but for less than the list price. In addition, to trade at a premium price, the bags should be from brands with high authorized distribution, so bags from brands that have stores in outlet malls cannot trade at a premium price. For example, in the same LVMH group as Louis Vuitton, Fendi, and Loewe are also leather goods origin brands like Louis Vuitton, but unlike Louis Vuitton, they have stores in outlet malls, so their collaboration models are not likely to be traded at premium prices. The authorized distribution rates of these brands were around 70%. In other words, even if collaboration limited-edition models are created, they do not meet the requirements, so they cannot take advantage of the rarity. From the customers' point of view, some may feel that these products can be purchased in outlet malls in the future. Fendi's Peekaboo collaboration model with Versace, released in 2022, was not picked up in Step 2 because it was not sold on the KOMEHYO online shopping site we checked in April, but the model's configuration was "collaboration*leather goods origin brand*non-family business" and could be traded at a premium price. However, as of July 2024, no one was selling the bag above the list price on the Internet. This was because Fendi has stores in outlet malls such as Gotemba Premium Outlets in Japan. In addition, Prada has a high level of ownership by the founding family, and Furla and Longchamp are family business brands, so they should be able to control the number of bags produced. However, since these brands have stores in outlet malls, bags from these brands were not traded at a premium price. Prada's authorized distribution rate was 65%, while Furla and Longchamp were hardly traded in the second-hand market. Even though they can control the quantity as a family company, they do not sell their products properly. This confirms the importance of distribution management to increase the rarity of luxury brands as advocated by Kapferer & Bastien (2009, p.243). Hermès, Goyard, and Chanel, which had high authorized distribution rates and are family businesses, achieved premium prices only through non-collaboration. Since these brands control the rarity as brands, it can be said that controlling rarity on a model-by-model basis through collaboration models is unnecessary. A limitation of the study is the limited number of countries examined. Also, it cannot explain price differences between collaboration models of the same type of bag. For example, in the case of Louis Vuitton's Speedy bags, the difference between the graffiti model and the Yayoi Kusama model cannot be explained. Nor can it account for changes over time. For example, the Louis Vuitton and Supreme collaboration model was popular in the past but is no longer traded. This study captures premium prices at present, and further verification of the impact of time difference is needed.

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CONTROLLING AGE AND SIMILARITY TO USER'S FACE FOR TRUSTWORTHINESS OF INTERACTIVE AGENT: GENERATIVE FACES AND ACCEPTABILITY

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ABSTRACT

To extend the healthy life and enhance the motivation for exercise among the elderly, our past work tried to mix the user's own face and the others' averaged face for a trainer agent, and demonstrated a correlation of the trustworthiness of the agent and the user's motivation with the blending rate between the faces. On the other hand, mixing the elderly's own face sometimes negatively affects trustworthiness, potentially due to age-related facial features like wrinkles. Therefore, we conducted experiments to evaluate trustworthiness by varying the age and blending ratio of the user's face. The optimal age and blending ratio for trustworthiness were investigated for both elderly and young participants. Results showed that the highest trustworthiness for elderly men was at age 25 with a blending ratio of their own faces at 0, and for elderly women at age 25 with a blending ratio of 0.75, while for young women, it was at age 25 with blending ratios of 0.4 or 0.25. These findings indicate that modifying the age of a self-face and blending it with an agent's face can enhance trustworthiness and potentially increase motivation, paving the way for effective motivational face image agents.

Keywords: similarity to user's face, morphing, trainer agent, age

1 INTRODUCTION

Our healthy lives are shorter than the length of our lives. It is important to continue our motivation for training or rehabilitation of our body for extending our healthy lives. Here, trainers are one of the big keys for motivation of our training. To overcome the fewer number of trainers per trainees, we focused on a virtual trainer to stimulate the user's motivation and positive attitudes.

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There are many parameters of trainers, such as active motions, facial expressions, appearance, etc. Our study has treated the appearance of the realistic virtual trainer especially focusing on the similarity to the user's own face. Our past impression evaluations of the agents for elderly people showed the trustworthiness related to the similarity; however, the effect was negative contrary to previous research [1]. We assumed that the negative effect was caused by the aging effects such as wrinkles when mixing the others' faces and the aged user's face as well as the effects of aged skin and hairs [2].

Therefore, we hypothesized that by rejuvenating and blending one's own facial image through image processing, we could prevent the blending of aged elements such as wrinkles and improve trustworthiness. Enhancing trustworthiness could enable the creation of agents that boost motivation. As an experiment, we conducted a trustworthiness evaluation of facial images with varying ages and blending ratios of the participants' own faces among the elderly, investigating whether changes in age and blending ratios could enhance trustworthiness. We included the blending ratio of one's own face as an experimental condition because we considered it an important parameter for face blending. The evaluation method involved using the trustworthiness ratings of each facial image obtained from impression evaluation experiments, where human participants rated the composite facial images of the training agent. From the obtained trustworthiness ratings, we used Bayesian estimation for surface approximation to determine the age and blending ratio that yielded the highest trustworthiness for each face. The results showed that the highest trustworthiness was achieved for elderly men at the age of 25 with a blending ratio of 0, and for women at the age of 25 with a blending ratio of 0.20 [5]. In this study, we conducted similar experiments on younger participants and analyzed the impact of age manipulation and blending ratio on trustworthiness across a wider age range in conjunction with the previous results.

2 RELATED RESEARCH

Regarding the effect of the facial appearance with aging elements, previous studies have reported that increasing the age of facial images negatively impacts impressions. Dylan et al. conducted an experiment where participants were shown facial images of varying ages and asked to evaluate their attractiveness. The results indicated that facial age significantly influenced attractiveness ratings, with younger faces being rated as more attractive than older faces [4]. Natalie reported that when presented with both young and old facial images, the impressions of attractiveness, likeability, goal orientation, energy, and mood were significantly lower for older faces. She suggested that changes in skin, hair, and other features due to aging could be contributing factors [3]. These studies suggest that in the context of blending one's own face, age-related facial features such as wrinkles may be introduced, negatively impacting trustworthiness.

On the other hand, there are studies suggesting that many people may have negative emotions regarding aging. Koyano et al. conducted a survey among Japanese adults aged 30 to 59, asking about their knowledge of old age and aging. They indicated that Japanese adults might hold negative misconceptions about aging [4]. Weiss et al. hypothesized that older adults might distance themselves from their age group to avoid the negative consequences associated with being part of that group, and conducted a survey. The results suggested that older adults with more negative views about aging were more likely to psychologically dissociate from their age group [5]. These previous studies imply that blending one's own face with age-related features may evoke a sense of aging and have negative effects on elderly individuals.

3 CONTROLLING AGE OF SELF-FACE IMAGE AND BLENDING WITH OTHER FACE IMAGES

In this study, we created facial images for the experiment by blending the participants' own faces with faces altered to different ages. To measure the effects of changes in the age of one's own face while excluding the influence of gender, we used average facial images of the same gender as the participants. The creation of the average face, the alteration of the age of one's own face, and the blending of these faces were conducted using the following procedures.

1. Collection of neutral facial images: Eight neutral facial images of each gender were obtained from facial expression databases [6] [7].

2. Creation of average faces: Using the eight neutral facial images collected in step (1), average faces were created.

3. Creation of age-altered facial images: Age-altered facial images were created using the average faces from step (2) and the participants' own facial images.

4. Morphing: The facial images created in steps (2) and (3) were morphed together.

The age transformation of the facial images was performed using SAM [8]. SAM is a deep learning method that can generate facial images corresponding to the specified age when given a facial image and an age input. SAM was used in this study because it allows the age input to be specified numerically. To eliminate the influence of hairstyles and clothing when presenting the facial images created using the above procedures during the experiment, we used FaceSwap1 to swap the faces of one male and one female image used in step 1 with the created facial images. Since the ATR facial image data is used with permission from ATR-Promotions, Inc. in accordance with the database usage guidelines [6], this paper does not include generated images using them.

4 EVALUATION EXPERIMENT ON THE IMPACT OF MANIPULATING SELF-FACE AGE AND BLENDING RATIO ON TRUSTWORTHINESS

4.1 Evaluation settings

We tried to investigate appropriate self-face ages and blending ratios that can enhance trustworthiness when blending one's own face. This experiment was conducted both on CrowdWorks⁴ through crowdsourcing and in-person. The overall procedures of the experiment are outlined as follows:

⁴ https://crowdworks.jp/

- 2.1 Explain the experiment to participants and obtain their consent.
- 2.2 Capture participants' self-face images.

2.3 Ask participants evaluate the impressions of facial images on a browser page of their communication device.

In the context of Experiment Procedure 2, participants' self-face images were obtained through the chat function within CrowdWorks for crowdsourcing and through immediate capture on-site for in-person sessions. Regarding Experiment Procedure 3, for the evaluation of facial image impressions, participants on CrowdWorks used their own communication devices, while those in-person were requested to respond using a laptop PC (Dell NEWALIENWARE m15 R2). Figure 1 outlines the browser page used during the impression evaluation of facial images in Experiment Procedure 3. This page sequentially displays facial images, questions about impressions, and questions about similarity for each presented facial image or set of questions.



Figure 1. A browser page used in evaluation experiment

The criteria for evaluating facial impressions included trustworthiness and friendliness. Previous research [9] has shown that friendliness is influenced by the blending ratio of one's own face, thus prompting a comprehensive investigation into both age variation and blending ratio of one's own face. Trustworthiness was assessed with the item "I felt this person is trustworthy," while friendliness was assessed with "I felt this person is friendly," using a 7-point Likert scale (1: not at all applicable, 7: very applicable), and participants were asked to respond accordingly. Additionally, similarity (how closely participants perceived the facial image stimulus resembled themselves) was rated on a scale from 0 to 100 (0: not at all similar, 100: identical to my own face). To ensure participants provided accurate responses and avoided random answers during crowdsourcing, they were informed about the presence of check items before evaluation. Specifically, they were instructed: "There are check items at questions 3 and X to ensure you are observing carefully. For question 3, please respond '100' to 'Please rate the similarity between this face and your own face from 0 to 100.' For question X, please answer according to the question prompt."

The experiment was conducted with 11 elderly men and 11 elderly women aged 60 years and older (67.7 \pm 4.6 years). Initially, the experiment was conducted via crowdsourcing with 8 men

and 1 woman, but as sufficient participants were not recruited, the remaining participants were recruited through a silver talent center and the experiment was conducted in-person. A total of 20 facial images were prepared, combining self-face age variations (25, 40, 55, 70 years) and self-face blending ratios (0, 0.25, 0.5, 0.75, 1.0), along with 2 instructional facial images for presentation. The presentation order of the facial image stimuli was fixed for the two questions to prevent random responses during instruction, and otherwise, a Latin square design was used for order crossover. Furthermore, to eliminate order effects in the analysis, data from the 11th participant of each gender were excluded, resulting in data analysis with 10 men and 10 women (66.6 ± 4.2 years).

Additionally, to investigate the effects of age-transformed self-face blending on younger participants for comparison with the elderly, an experiment was conducted via crowdsourcing with 10 men and 10 women aged 18 to 29 years (24.4 ± 3.5 years). Following a previous study [1] that indicated a positive impact of self-face blending ratio of 0.4 on trustworthiness conducted outside Japan, 24 facial images were prepared, including 20 facial images conducted with elderly participants, using the same Latin square design for order crossover.

<u>Evaluation metrics</u>: The evaluation metrics included the age of the presented facial images, the blending ratio of the self-face, impression ratings, and the age of the participants. The age of the facial images was quantitatively represented by the self-face age of the individuals depicted in the images presented during the experiment. The self-face blending ratio ranged from 0 (average face) to 1 (fully self-face).

<u>Data analysis methodology</u>: To analyze the optimal self-face age and blending ratio that maximize trustworthiness and likability, we approximated surfaces using Bayesian estimation with self-face age, blending ratio, and impression ratings as axes. For surface approximation, we assumed that the obtained evaluation values followed a normal distribution and estimated parameters for the approximation formula. We explored the optimal fitting surface that best approximates the evaluation values by estimating parameters for each combination of age axis, formula shape, and value correction term. Details for each condition are provided below.

- [Age axis] We prepared three methods for the manipulation of input age during approximation. The first condition uses the minimum age of 25 and the maximum age of 70 from the experimental conditions, applying min-max normalization to the self-face age (hereafter referred to as "ranged age"). The second condition assumes a human lifespan, setting the minimum value to 0 and the maximum value to 100, and applying min-max normalization to the self-face age (hereafter referred to as "life-spanned age"). The third condition calculates relative age by subtracting the participant's age from the self-face age and then applying min-max normalization to these values (hereafter referred to as "relative age").

- [Formula shape] Two formulas were used for the approximation. The first is a multivariable polynomial of n dimensions considering the interaction between age and self-face blending ratio (hereafter referred to as the "interaction formula"). The second is a formula that approximates each age and each self-face blending ratio with an n-dimensional function and sums these values (hereafter referred to as the "summation formula"). The dimensionality n of
the formulas was set to [3, 5], and the coefficients of the formulas were estimated using Bayesian estimation. Letting x represent age, y represent self-face blending ratio, and zrepresent the evaluation value, the formulas are as follows. x and y are within [0, 1], and since their values decrease as they are raised to higher powers in the formulas, it was assumed that the range of possible coefficient values would become large, making estimation difficult. Therefore, instead of using x and y directly, x+1 and y+1 were used in the formulas for calculations.

- [Value Correction Term] To enhance the accuracy of the approximated surfaces, we considered the presence or absence of a correction term inspired by the Gaussian kernel. Given combinations of age x and self-face blending ratio y as (x_i, y_i) $(1 \le i \le n)$, the correction term for (x_i, y_i) is as follows. The parameters k and σ in the formula were estimated using Bayesian estimation.

$$\sum_{i=1}^n k_i \times exp(-\frac{(x_i-x_j)^2+(y_i-y_j)^2}{2\sigma^2})$$

The condition where both relative age and the presence of the value correction term (VCT) were included resulted in an immense computational load, making it infeasible to compute. Thus, comparisons were made excluding these conditions. The evaluation of the surfaces was conducted using the Root Mean Square Error (RMSE) between the predicted values calculated from the surfaces created under each condition and the actual values. The surface with the smallest RMSE was considered the optimal one. The actual value for each combination of age x and blending ratio $y(x_i, y_i)$ ($1 \le i \le n$) under the experimental conditions was defined as the average of the evaluation values at each (x_i, y_i) . The predicted values were the values on the surfaces at (x_i, y_i) , and RMSE was calculated accordingly.

4.2 Evaluation results

4.2.1 Best Conditions and Evaluation of Surface Approximation

Surface approximation was performed for each age group, gender, and evaluation value of the subjects. The conditions of the optimal surface and the RMSE obtained are shown in Table 1, and the surfaces at that time are shown in Figures 2-A and B. Except for the familiarity of elderly women, the best surface was obtained under the conditions of ranged age, summation formula (n = 5), and with correction term. For the familiarity of elderly women, the best surface was obtained age, summation formula (n = 5), and with correction term. For the familiarity of elderly women, the best surface was obtained under the conditions of ranged age, summation formula (n = 4), and with correction term. In all these surfaces, the RMSE was at most 0.13, indicating that each surface closely approximated the obtained evaluation values and their trends.

4.2.2 Exploration of the Optimal Age and Mixing Ratio of Self-Face for Maximum Trustworthiness and Familiarity

From the obtained surfaces, we explored the age and mixing ratio of self-face that maximized trustworthiness and familiarity. For the age and mixing ratio (both age and mixing ratio were converted to values in the range [0, 1]), grid points were created with intervals of 0.005, and the predicted values of the optimal approximation surface were calculated for each grid point. Among these, the age and mixing ratio of the self-face that yielded the highest predicted value are shown in Table 2. It was found that the most trustworthy self-face age and mixing ratio for elderly men and the most familiar self-face for elderly women were 25 years and 0, respectively. In these cases, the highest trustworthiness and familiarity were achieved without mixing the self-face.

For elderly men, the highest familiarity was achieved by mixing a young self-face aged 25 with a mixing ratio of 0.1, and for elderly women, the highest trustworthiness was achieved by mixing a young self-face aged 25 with a mixing ratio of 0.2. In contrast, for young men, the highest trustworthiness was achieved by mixing a self-face aged 54.93 with a mixing ratio of 0.75, and the highest familiarity was achieved by mixing a self-face aged 39.85 with a mixing ratio of 0.4. Both cases involved mixing a self-face older than their own age. For young women, both the highest trustworthiness and familiarity were achieved by mixing a self-face of the same age group, 25 years, with a mixing ratio of 0.4. It should be noted that the combination of age and mixing ratio that includes a self-face mixing ratio of 0.4 may have potential bias, as mentioned earlier, and this needs to be considered.

These results confirm that elderly women can improve their trustworthiness by mixing a self-face with age changes, and this also provides insight into the potential for enhancing motivation, which is related to trustworthiness. Additionally, similar to the elderly group, the results suggest that mixing a self-face with age changes may also enhance motivation among young individuals, assuming a relationship between trustworthiness and motivation.

Age	Gender	Evaluation Item	Conditions (Age Axis, Formula Shape, VCT)			
Older	Mala	Trustworthiness	ranged age, summation formula (n = 5) with VCT	0.04		
	IVIAIE	Friendliness	ranged age, summation formula (n = 5) with VCT	0.04		
	Female	Trustworthiness	ranged age summation formula (n = 5) with VCT	0.04		
		Friendliness	ranged age, summation formula (n = 4) with VCT	0.06		
	Mala	Trustworthiness	ranged age, summation formula (n = 5) with VCT	0.03		
Voung	IVIAIE	Friendliness	ranged age, summation formula (n = 5) with VCT	0.05		
Young	Famala	Trustworthiness	ranged age, summation formula (n = 5) with VCT	0.13		
	Female	Friendliness	ranged age, summation formula (n = 5) with VCT	0.10		

Table 1. Best surface approximation condition and RMSE at that condition





Younger age group



Age	Gender	Evaluation Item	Self-face Age	Self-face blending rate	Evaluation values
Older	Male	Trustworthiness	25.00	0.00	4.88
		Friendliness	25.00	0.10	4.82
	Female	Trustworthiness	25.00	0.20	5.26
		Friendliness	25.00	0.00	4.78
Younger	Male	Trustworthiness	54.93	0.75	4.66
		Friendliness	39.85	0.40	4.45
	Female	Trustworthiness	25.00	0.40	4.58
		Friendliness	25.00	0.40	4.68

able 2. Self-face age an	d morphing rate with	n highest familiarity	and trustworthiness
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Table 3. Best surface approximation condition and RMSE at that condition for the younger age groupexcluding morphing rate of 0.4

Gender	Evaluation Item	Conditions (Age Axis, Formula Shape, VCT)	
Male	Trustworthiness	ranged age, summation formula (n = 5) with VCT	0.03
	Friendliness	ranged age, summation formula (n = 5) with VCT	0.05
Female	Trustworthiness	ranged age, summation formula (n = 5) with VCT	0.14
	Friendliness	ranged age, summation formula (n = 4) with VCT	0.11

Table 4. Self-face age and mixing ratio with the highest familiarity and trustworthiness for the

younger age group excluding morphing rate of 0.4

Gender	Evaluation Item	Self-face Age	Self-face blending rate	Evaluation values
Male	Trustworthiness	54.93	0.75	4.66
	Friendliness	40.08	0.50	4.27
Female	Trustworthiness	25.00	0.25	4.45
	Friendliness	25.00	0.25	4.42



Figure 3. Best approximated surfaces for each gender and impression item for the younger age group excluding morphing rate of 0.4

4.2.3 Exploration of Self-Face Age and Mixing Rate Excluding the Self-Face Mixing Rate of 0.4 for the Younger Group

We performed surface approximation and maximum value exploration, excluding the combination of age and mixing rate where the younger group's self-face mixing rate of 0.4 existed. As mentioned earlier, there is a possibility that the combination of age and mixing rate where the younger group's self-face mixing rate of 0.4 exists is biased. Therefore, it is believed that the results of this exploration, along with those that included the 0.4 mixing rate, can deepen our understanding of the optimal age and mixing rate of the self-face. The conditions of the obtained optimal surface and RMSE are shown in Table 3, the surface at that time is shown in Figure 4, and the age and mixing rate of the self-face with the maximum predicted value obtained are shown in Table 4. The RMSE in all surfaces was at most around 0.14, indicating that each surface closely approximated the obtained evaluation values and their trends.

The trustworthiness for males was maximized at the age of 54.93 years and a mixing rate of 0.75, with no difference observed whether the self-face mixing rate of 0.4 was excluded or not. Therefore, it is believed that the optimal age and mixing rate of the self-face for male trustworthiness is uniquely determined. On the other hand, male likability was maximized at the age of 40.08 years and a mixing rate of 0.5, while female trustworthiness and likability were maximized at the age of 25 years and a mixing rate of 0.25. Thus, it is believed that by using the corresponding age and mixing rate of the self-face, males can increase their likability, and females can increase both trustworthiness and likability. Additionally, it is believed that using the age and mixing rate shown in Table 2, there is a possibility to achieve an increase.

5 CONCLUSION

This study explored the optimal age and blending ratio of self-faces to enhance perceived reliability. Using Bayesian estimation on experimental data, we identified the conditions that maximized reliability. For older adults, the highest reliability was at age 25 with a blending ratio of 0 for men, and age 25 with a blending ratio of 0.20 for women. For younger adults, the highest reliability was at age 54.93 with a blending ratio of 0.75 for men, and age 25 with a

blending ratio of 0.4 or 0.25 for women. The study also found that self-face blending can improve familiarity.

1. Effect of Age-Altered Self-Face Blending in Younger Adults: The experiment showed that blending self-faces altered to age 25 increased reliability and familiarity for women, consistent with previous research indicating positive impacts on these traits through self-face blending. However, for men, the highest reliability and familiarity were achieved with self-faces older than the participants. This suggests that younger men may associate older self-faces with their fathers, thereby transferring trust and familiarity from their fathers to these images. Thus, aligning the age of blended self-faces with their fathers' age might enhance these traits for younger men.

2. Comparison Between Younger and Older Adults: Differences in the optimal age and blending ratio for favorable impressions between younger and older adults were observed. These differences likely result from changes in values and environments with age. Cultural influences and life experiences significantly shape these values, suggesting that the optimal conditions for enhancing reliability through self-face blending might vary across cultures. Future research should explore this phenomenon in different cultural contexts to determine if similar effects are present and to identify the most effective age and blending ratios for self-faces in those settings.

These results indicate that altering the age of self-faces can enhance reliability and potentially improve motivation. Future research should focus on practical applications to measure the effects on motivation and physical function improvement.

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INSIGHT AND IN-DEPTH INTERVIEWS AN INTERDISCIPLINARY APPROACH WITH THE META-PERSPECTIVE STRUCTURE AND INSIGHT DISCOVERY MAP

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ABSTRACT

This study examines the concept of 'insight' across various academic fields, including psychology, behavioural economics, business administration (marketing), design studies, and Kansei engineering. It aims to consistently define 'insight' across disciplines and develop a methodological framework for its discovery. We introduced and empirically validated two innovative tools: the 'Meta-Perspective Structure' and the 'Insight Discovery Map'. These tools were validated through more than 100 semi-structured interviews, demonstrating their utility in capturing and analysing consumer insights deeply. This interdisciplinary approach not only highlights the differences in insight conceptualization but also proposes practical applications for these findings in industry. Further empirical research is necessary to validate and refine these methods. The unique contribution of this study lies in its comprehensive integration of interdisciplinary insights and their practical applications.

Keywords: Insight, in-depth interviews, focus groups, meta-perspective structure, insight discovery map

1 INTRODUCTION

The growing prominence of behavioural economics (Said et al., 2015) stems from the issue that traditional economics, based on rational models, fails to fully capture actual human behaviour (Robbins, 2007). Behavioural economics attempts to gain a deeper understanding of human behaviour and decision-making processes by incorporating psychologically observed factors such as behaviour, thinking, habits, cognitive biases, emotions, and social context into economic theory. A similar trend can be seen in marketing. For instance, Kotler's recent books, *Marketing 5.0: Technology for Humanity* (Kotler et al., 2021) and *H2H Marketing* (Kotler et al., 2021), incorporate methodologies for deep human understanding, such as human-centred design

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(Norman, 2005), design thinking (Brown, 2008), and service-dominant logic (Vargo & Lusch, 2008). There is an increasing need to deeply understand human behaviour not only in economics and marketing but also in the fields of development and design. For example, Kansei engineering was developed to scientifically analyse and integrate human sensory impressions and emotional responses elicited by products and services into design and engineering (Said et al., 2015). Against this backdrop, the importance of N = 1 (one person) is being actively discussed in Japan's practical fields of marketing, digital transformation (Stolterman, 2004), product development, and new business development. Consequently, the concept of 'insight' has become a key focus. Insights are described as latent desires and feelings discovered through consumer interviews. However, while the importance of understanding N=1 is growing, the framework for human understanding and the specific definition and discovery methods for insights are lacking. The concept of insight has mainly developed in psychology, but only a few studies in other disciplines have focused on it. Therefore, this study proposes, through interdisciplinary research in psychology, behavioural economics, marketing, design studies, and Kansei engineering, a definition of insight that can be used in industry and a theoretical framework for its discovery methods.

2 LITERATURE REVIEW ON INSIGHT: DEFINITIONS AND DISCOVERY METHODS FOR EACH DISCIPLINE

In addition to psychology, which is the root of the concept of insight, this literature review also focuses on other academic disciplines that apply insights in practical fields. These disciplines include psychology (to gain a basic understanding since the concept of insight was developed in psychology), behavioural economics (to understand the irrational decision-making of humans), marketing (to understand consumer needs and behaviours), design (to understand practical applications centred on user experience), and Kansei engineering (to scientifically analyse sensory and emotional responses and understand their application methods).

2.1 Definition and Etymology of Insight

The Oxford English Dictionary defines 'insight' as entering with the eye of understanding into the inner or hidden nature of things. 'Insight' is said to have its origins in Middle English, where it was derived from the meaning 'to look within' (in + sight). It refers to both physical sight and 'mental understanding and perception', forming the concept of 'the ability to see things from the inside' and giving meaning to 'deep understanding'. The term 'insight' has been extended to various fields, including psychoanalysis, psychology, business, and science.

2.2 How to define and discover insight from psychology

In psychology, 'insight' refers to a sudden understanding or problem-solving insight traditionally associated with Gestalt psychology (Köhler, 1967). Today, its definition remains ambiguous and has been explored in three dimensions: phenomenological, issue, and process (Öllinger & Knoblich, 2009). Phenomenologically, it is known as an 'aha' experience—a sudden, surprising moment when solutions unexpectedly appear, characterised by suddenness, ease and positive emotions (Topolinski et al., 2010). Methods to induce insight include looking at the problem from a new angle to reveal solutions,, breaking problems into smaller parts, and removing self-imposed constraints to encourage freer thinking (Öllinger & Knoblich, 2009).

Lonergan (1957) viewed human understanding as the integration of knowledge through insights that lead to new questions.

2.3 How to define and discover insight from behavioural economics

Behavioural economics (Kao & Velupillai, 2015) is a branch of economics that incorporates the irrationality of human behaviour, which is overlooked by traditional economics. It offers a different approach to understanding and analysing economic behaviour, focusing on the limits of rationality and complexity in the decision-making process. Saylor (2008) and Kahneman (2013) were key influencers of the modern approach. This approach, based on experimental economics and psychological research, reveals the irrationality of market and consumer behaviour. Interestingly, the term 'insight' is not used in behavioural economics as it is in psychology and marketing. This is because, given the academic background and nature of the research, the aim of behavioural economics is to discover insights. Behavioural economics uses experimental economics, survey research, case studies, choice experiments, economic history narratives, anthropological research, field studies, and interviews (Altman, 2023).

2.4 How to define and discover insight from business administration (marketing)

Modern marketing emphasises the creation of value and the management of customer relationships, moving from simple 'exchange' to 'co-production' and 'co-creation' of value through interaction, with a focus on 'value-in-use' where customer interaction creates value (Grönroos, 2006). Insights (Anne et al., 2015), which are critical to improving marketing effectiveness, are derived from a deep understanding of consumer behaviour, emotions, and desires, targeting what is known as the consumer's 'sweet spot' (Fortini-Campbell, 1992). The use of insights dates to the early 20th century, when pioneers such as Claude Hopkins (1968) and Edward Bernays (1928) used psychological theories to create effective advertising campaigns. Today, insights are also formed by combining consumer data with customer relationship management techniques (Ertemel, 2015) and social network services (Chamlertwat et al., 2012) and employing various research methods such as ethnography and in-depth interviews to understand consumer contexts (Yallop et al., 2022).

2.5 How to define and discover insight from design with a focus on design thinking

Design can be broadly defined as 'the act of creating meaning', focusing on user interpretation and the integration of products into everyday life (Krippendorff, 2005). Understanding consumer perspectives is the foundation of design. Insight usage in design emerged with design thinking (Buchanan, 1992; Rowe, 1991) and has been a vital part of methods used by firms, such as IDEO, to innovate from user research findings (Perry, 1995). Insights provide new perspectives and deepen the meaning of design, aiding in uncovering real user needs and advancing innovation (Laurel, 2003). Consumer insight is crucial in new product development and influences processes (Grunert et al., 2011). It utilises in-depth methods such as interviews, ethnographic studies, and prototyping (Chasanidou et al., 2015; Cooper, 1999; Gruner et al., 2011; Myers et al., 2016; Stickdorn et al., 2018). During the design process, insights are visualised through storyboards, user journey maps, and personas, helping designers balance user needs with technical possibilities.

2.6 How to define and discover insight from Kansei engineering

Kansei engineering (Nagamachi, 1995) combines the scientific analysis of sensory impressions and emotional responses with design processes to enhance consumer satisfaction. This approach incorporates emotional and psychological responses along with technical characteristics into product design, called Kansei quality (Yanagisawa, 2011). Recent developments include the mathematical modelling of sensitivity using Bayesian models (Yanagisawa et al., 2020) and the free energy principle (Yanagisawa, 2021). Insight, defined in Kansei engineering as the synthesis of the sensory mass, reflects qualitative perceptions of the environment (Beuttel and Yamanaka, 2010). Research methods include sensory evaluation experiments, psychophysical tests, emotional scales, and electroencephalogram measurements to assess how design elements such as shape, colour and material influence consumer responses. Observation and interview methods provide qualitative insights.

3 METHODOLOGY

This study was conducted in collaboration with NEW STANDARD Inc., a Japanese start-up company that functions as a design consultancy, marketing and creative agency, and think tank. The research was conducted according to the marketing, digital transformation, design, and brand development practices of NEW STANDARD Inc. and its client companies. The methodology of this study (Figure 1) adopted the framework of design science (Japan Institute of Design, 2019), which integrates scientific research with practical application, allowing for a reciprocal relationship between theory and practice. The design science framework used in this study involves iterative cycles of problem identification, solution development, and evaluation. This approach ensures that the insights gained are both theoretically sound and practically applicable.



Fig. 1. Methodology of this study

4 RESEARCH FINDINGS

4.1 Literature review and discussion on insight

This section reviews the literature on the definition and discovery methods of insight across different disciplines (Table 1). Although how each discipline captures and defines insights differs, an overall deep understanding of human beings plays a crucial role in solving specific challenges and problems in each field.

Field	Definition of insight	Contribution of insight research	Insight discovery methods	Methods of using insights
Psychology	Deep awareness based on 'aha experiences', which refer to moments of problem solving and understanding.	Expanded research in Gestalt psychology, providing multidimensional understanding.	Representational transformation, chunk decomposition, constraint relaxation, puzzle and problem solving tasks, idea generation tasks, brain imaging techniques using fMRI and EEG.	Discovery of new solutions and generation of new knowledge in problem-solving processes.
Behavioural economics	Understanding of the irrationality of economic behaviour.	Framework extensions in economics, elucidation of the limits of rationality and decision-making processes.	Experimental economics, survey research, case studies, market simulations, auction experiments, behavioural data analysis, field studies.	To identify irrationalities in market and consumer behaviour and use them to improve economic theory and policy.
Marketing	Core information that brands and products appeal to consumers, based on a deep understanding of consumers.	Core information that brands and products appeal to consumers, based on a deep understanding of consumers.	Ethnography, in-depth interviews, online open-ended research, focus groups, consumer surveys, big data analysis, social media sentiment analysis.	Used to inform product development and advertising strategies, in the process of creating and delivering value to customers and managing customer relationships.
Design with a focus on design thinking	Deep understanding and useful discoveries found within the design context, providing new perspectives and deepening meaning.	Establishing methodologies for the design process and integrating insights into the user experience.	Diverse methods within the design process, such as user interviews, observation, ethnographic studies, prototyping, storyboarding, user journey maps and persona creation.	Developing new products and improving service design and user experience.
Kansei engineering	Scientific analysis of the sensory impressions and emotional responses that products give people.	Quantification and mathematical modelling of sensory evaluation, integration of sensory elements into the product development process.	Sensory evaluation methods, protocol analysis, log analysis, EEG measurements, sensory evaluation experiments, psychophysical tests, observations, interviews, biosensors, and eye tracking techniques	Improving the sensory quality of product design, maximising consumer satisfaction and improving the market adaptability of products.

Table 1. Summary of how insight is defined, discovered, and utilised

Interviews are also used in many fields because they provide access to the subjects' deeper feelings, thoughts, and experiences. The format and questions of interviews can be flexibly tailored according to the purpose and context of the research, and this ease of customisation makes interviews a useful tool in various research fields. However, systematic theories and methodologies for interviewing as a method of discovering insight remain lacking.

4.2 Literature review and discussion on interviews

Building on the insights from the literature review, a review of interviews was conducted as a qualitative research method. Interviews are a qualitative research method used in a wide range of fields. There are two main methods of interviewing: in-depth interviews and focus groups (Johnstone, 2017). In-depth interviews are used to delve deeper into individuals' perceptions and experiences and usually last between 45 minutes and 2 hours on a one-to-one basis, while focus groups are designed to facilitate extensive discussions with multiple participants and provide an opportunity for participants to freely exchange ideas. These methods can be used independently or in combination to complement each other. The advantages and disadvantages of focus groups and in-depth interviews are summarised in Table 2 (Milena, 2008).

Method	Advantages	Disadvantages
Focus groups	Diverse opinions can be collected	Opinion bias due to group pressure
	New insights gained through interaction	Limited generalisability of data
In-depth interviews	Acquisition of deep individual insights	Time-consuming and costly
	Easy for participants to express their own opinions freely	Influenced by researcher bias

Table 2. Pros and cons of focus groups and in-depth interviews

Focus groups have external advantages such as speed and cost, but individual in-depth interviews have internal advantages in terms of the quality of the results. In qualitative market research, both methods identify key issues related to buying motivations and processes, target markets, and branding. However, focus groups do not provide a detailed and deep understanding of individuals as in-depth interviews do (Stokes & Bergin, 2006). According to Keegan and Ward (2003), in-depth interviews are characterised by replicating the process by which social knowledge is constructed through dialogue within the interview, providing a deep understanding of individual experiences and feelings and using the expressive power of language to reveal meaning. Interview methods are classified as structured, semi-structured, or unstructured. The steps of an in-depth interview are as follows: (i) preparation (setting objectives and methods), (ii) selection of interviewees, (iii) question design (including design of follow-up questions), (iv) pilot testing, (v) interview practice, and (vi) data interpretation (Turner, 2010).

4.3 Defined insight and insight discovery methods

Insights are defined as 'Latent desire × Motivation to move people (body and mind) = information and discoveries that prompt new behaviours and emotions and enable new value creation and problem solving'. Insight discovery requires contextualised observations of important factors such as consumer values, behaviours, habits, situations, attitudes, markets, and environments (Yallop et al., 2022). It also necessitates a focus on discrepancies or contradictions between behaviour and awareness (Öllinger & Knoblich, 2009). Furthermore, interview guides for understanding people (Granot et al., 2012) and understanding narratives and context (Mccormack, 2004) are essential for successful in-depth interviews. Based on our definition of insight and the success factors for insight discovery identified in the literature review, this study proposes a theoretical framework, called the meta-perspective structure (Figure 3), to deeply understand each consumer's perspective, aiming to explore the overall context of human cognition and emotion. This framework is a guide for in-depth interviews and facilitates human understanding and insight-discovery. The meta-perspective structure serves as a guide for indepth interviews, helping to gain a deeper understanding of human sensibilities and desires and enabling exploration of upbringing, current environment, cultural background, thinking habits, and daily behaviour. Additionally, it systematically explores behaviour, habits, thoughts, context, and environment and reveals discrepancies and contradictions between behaviour and awareness in a structured way to uncover insights. An insight discovery map was also created to distinguish between insights, common issues, needs, and unrecognised behaviours, integrating post-interview findings for new interpretations (Figure 4). Finally, based on the literature review, we summarised seven key factors for successful in-depth interviews: 1) Trained interviewers; 2) Building trust/rapport; 3) Understanding context and narratives; 4) Framework for understanding humans; 5) Adopting semi-structured interview techniques; 6) Data collection and interpretation; and 7) Ethical considerations.



Fig. 2. Meta-perspective structure



Fig. 3. Insight discovery map and examples of its use

4.4 Results

This study administered over 100 detailed interviews through client work at NEW STANDARD Inc. to improve methodologies and conduct empirical validation. The interviews provided insights and facilitated unprecedented consumer understanding and deep insights among clients of NEW STANDARD Inc., leading to high evaluation and the creation of new value. This research was conducted in parallel with the 'Innovations in Meaning' study (Kushi & Yanagisawa, 2024). This study proposes an important methodology for addressing consumer insights within the design thinking process. However, the experiments were limited due to the constraints on subjects and environments. Future comparative experiments using existing interview methods and investigations into the usage status of users are necessary.

5 DISCUSSION

This study explored the different definitions of insight across various disciplines and its discovery methods; however, it was not able to accurately describe the whole picture in detail. The process of insight discovery seemed similar to the act of turning tacit knowledge into formal knowledge, as illustrated in the 'socialisation, externalisation, combination, and internalisation' model (Nonaka, 1994). Knowledge management insights could be useful for developing this research. We would also like to explore the possibility of combining this with quantitative measurement methods such as the semantic differential method, which is a specialty in Kansei engineering. Future studies could extend this field of research to marketing, digital transformation, design, and development practices. Integration of each process and detailed

utilisation are also recommended for further investigation. To test the study's validity, extending the application of meta-perspective structures and insight discovery maps and conducting more reliable comparative experiments are vital.

6 CONCLUSION

This study explored the concept of 'insight' across several disciplines, establishing a theoretical framework for its definition and discovery. By applying the 'Meta-Perspective Structure' and 'Insight Discovery Map', we developed effective tools for understanding deep consumer motivations, enhancing our research methodology. However, further empirical testing is required to validate the findings. This study contributes to the integration of interdisciplinary knowledge, deepens our understanding of consumers, and provides new directions for academic and practical applications. We would like to express our sincere thanks to the staff of NEW STANDARD Corporation for their invaluable support and assistance throughout this research. Finally, we would like to acknowledge the contributions of all the customers who participated in our study. Their perspectives and experiences were central to this study.

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IMPROVING MOTIVATION IN A FOREIGN LANGUAGE LEARNING APPLICATION USING VR

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ABSTRACT

As society becomes more globalized, foreign language education has become essential, and some users find it challenging to maintain motivation for learning. This study aimed to shed light on the relationship between motivation for learning and the use of a VR learning environment by developing a Chinese vocabulary learning application with gamification elements and an English vocabulary application with adjusted information volume and types. The experiment involved participants using the actual applications, examining the impact on motivation through evaluations and interviews. The results showed differences in motivational aspects between experienced and inexperienced language learners, with inexperienced learners being more positively influenced by extrinsic motivation and rewards. Moreover, it was found that there is an appropriate amount of information that can enhance motivation depending on the user's abilities.

Keywords: virtual reality, motivation, gamification

1 INTRODUCTION

With the spread of XR technologies, methods using VR and AR for foreign language vocabulary learning have been proposed. Kimoto and Soga (2021) constructed a VR environment for learning Spanish vocabulary, demonstrating its effectiveness in making learning enjoyable and making the meaning of words easier to understand [1]. Mine and Nakagiri (2021) developed a learning support system with gamification elements, showing that such content helps sustain motivation and enables continuous learning [2]. Thus, it has been reported that in

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addition to effective learning environments, using content with gamification elements can maintain motivation and support continuous learning.

However, the amount of information and the difficulty level of learning can affect motivation in foreign language vocabulary learning. For instance, some vocabulary books cover only the bare essentials, while others include detailed information, and there are noticeable differences and deficiencies in information amount between existing learning content and commercial vocabulary books. It is necessary to investigate the appropriate amount of information to maintain motivation for learning.

This study developed a VR learning environment and attempted to create a Chinese vocabulary learning application incorporating gamification elements. Additionally, an English vocabulary learning application was developed with adjusted information volumes to explore the relationships between reward presentation, information amount during learning, and motivation.

2 APPLICATION DEVELOPMENT

The applications were developed using Unity as the development platform, with the programming language C#.

2.1 Chinese Vocabulary Learning Application

In this experiment, a collection-type reward system was adopted, and behaviors when participants were unable to obtain rewards were examined.

2.1.1 Exploration/Learning Scenes

The scenes are themed around school, where Chinese vocabulary is studied. There are a total of five scenes, with difficulty levels set based on the degree of similarity between Japanese and Chinese characters. The classroom features five words of standard difficulty, the art room has five words of low difficulty, the gym contains five words of standard difficulty, the pool includes seven words of standard difficulty, and the nurse's office presents ten words of high difficulty. After tapping an object, the pronunciation of the word can be heard, and a character along with the Chinese word moves in front of the participant (Figure 1). The character changes depending on the location. After the lesson, a test can be taken by selecting the test button.

2.1.2 Test Scene

The test presents the learned Chinese words, and the participant selects the Japanese meaning from four options. A perfect score leads to progression to the reward scene. If the score is not perfect, the participant advances to the next exploration/learning scene.

2.1.3 Reward Scene

In the reward scene, the same number of characters as the words learned in the exploration/learning scenes appears in four different environments, and users can move freely within these environments (Figure 2). The acquired characters can also be grasped. Following this, the user moves on to the next exploration/learning scene. To compare the impact of

rewards on motivation, the initial classroom scene does not have a reward set. Moreover, as a total reward, the user can view all characters obtained in the previous reward scenes in a new environment.

2.2 English Vocabulary Learning Application

In this experiment, the amount of information during learning was adjusted to examine changes in motivation.

2.2.1 Exploration/Learning Scenes

The user taps objects in settings such as an operating room, studying five English words per scene. The words used are specialized terms of Level 6 or higher, referencing the Eijiro Web dictionary. Additionally, to prevent motivation differences between levels, the same difficulty is maintained. There are three scenes in total (hereafter referred to as Level 1, Level 2, and Level 3). The amount of information contained in each word increases with each level. Level 1 involves learning an English word, its meaning, and pronunciation. Level 2 adds etymology to the information from Level 1. Level 3 includes related words and example sentences in addition to the information from Level 2.

2.2.2 Test Scene

The test not only involves the meaning of the words but also etymology and related words, including all the information presented.





Figure 1: Example of Exploration/Learning Scene

Figure 2: Example of Reward Scene

3 CHINESE VOCABULARY LEARNING EXPERIMENT

3.1 Experiment Overview

In the Chinese vocabulary learning experiment, the design specifications of the Chinese vocabulary learning application were verified. The motivation of participants who used the application was evaluated, and the effectiveness of rewards was examined. Additionally, differences in motivation and outcomes due to individual learning experiences were compared and analyzed. The experiment was conducted with the consent of 33 university students in their twenties.

3.2 Experimental Method

Participants wore the head-mounted display Meta Quest Pro, sat on a provided chair, and experienced the foreign language vocabulary learning application while holding Meta Quest Touch Pro controllers in both hands. After the experience, evaluations and interviews were conducted.

3.3 Results and Discussion

3.3.1 Regarding Difficulty Settings

In subjective evaluations of "difficulty," "number of words," and "fatigue," there was a tendency for participants to rate the experience as more difficult and tiring as the set difficulty increased. T-tests and Bonferroni corrections performed between the scenes revealed numerous significant differences, indicating that the increase in word count and the difficulty settings of each scene were accurately reflected.

3.3.2 Regarding Overall Motivation

For "curiosity about words" in the VR-enabled learning environment, evaluations showed an increasing trend with learning. Table 1 shows the evaluation items related to the overall, and the mean values (Standard deviation) for each item, which were rated on a five-point scale. The "enjoyment" item in Table 1 scored an average of 4.5 (SD: 0.7), indicating a high level of satisfaction. From this, it was evident that the exploration/learning scenes using VR had a positive impact on learning motivation.

	Enjoyment	Total number of characters	Desire to collect	Change of reward scene	Grabbing function
Average(SD)	4.5 (0.7)	4.2 (1.2)	4.0 (0.9)	4.4 (0.8)	3.7 (1.2)
Mode	5.0	5.0	4.0	5.0	5.0

The rewards were overall highly rated as rewarding. The evaluations for "desire to collect" and the "grabbing function" in Table 1 were relatively low, and opinions expressed in interviews included desires to "see the characters' faces after grabbing them," "it would have been better

if the characters appeared to live naturally," and "wanted to collect different types instead of simply collecting more," suggesting a need for more interaction after collecting characters.

3.3.3 Comparison of Motivation between Experienced and Inexperienced Chinese Language Learners

Table 2 shows the evaluation items related to motivation and the mean values and significant differences between the values for each item, which were rated on a five-point scale. From Table 2, the item "desire to study more" in the exploration/learning scenes showed that experienced learners rated higher than inexperienced learners, with a significant difference observed. This indicates that those with previous learning experience have a higher motivation for exploration activities in the VR space.

Regarding "the collection of characters as a reward", inexperienced learners rated this aspect higher than experienced learners, showing a significant difference. This indicates that inexperienced learners have a higher interest in collecting rewards.

The retry rate for the most difficult nurse's office scene was 83% for inexperienced learners and 67% for experienced learners. The evaluation of rewards was higher from inexperienced learners, with many reattempting to achieve perfect scores to receive rewards. This shows that depending on whether there is prior learning experience, different learning scenarios can lead to motivation, and for participants motivated by rewards, rewards had a more positive impact.

	Desire to study more			The collection of characters as a reward		
	Experienced learners	Inexperienced learners	p-value	Experienced learners	Inexperienced learners	p-value
Classroom	4.2(1.0)	3.4(1.3)	0.10			
Art room	4.3(0.8)	3.4(1.2)	0.03*	3.3(1.0)	3.7(0.8)	0.23
Gym	4.3(0.5)	3.4(1.2)	0.01**	3.0(1.1)	3.9(0.9)	0.04*
Pool	3.9(1.0)	3.6(1.1)	0.48	3.3(1.1)	3.7(0.9)	0.27
Nurse's office	4.5(0.5)	3.8(1.0)	0.04*	3.9(1.1)	4.1(0.9)	0.56

Table 2. Means (SD) and Significance Tests of Evaluation Items

*p < .05, **p < .01, Yellow: significant difference present

4 ENGLISH VOCABULARY LEARNING EXPERIMENT

4.1 Experiment Overview

In the English vocabulary learning experiment, the design specifications of the English vocabulary learning application were verified, and the relationship between the amount of information provided during learning and the participants' motivation was investigated. Differences in motivation and outcomes due to individual learning experiences were also compared and analyzed. The experimental method was similar to the Chinese vocabulary learning experiment, involving 33 university students in their twenties, and was conducted with the participants' consent.

4.2 Results and Discussion

4.2.1 Regarding Difficulty Settings

Figures 3 and 4 show the average responses of all participants, with t-tests indicating significant differences. The percentage of correct responses for each level was highest for Level 1, and scores dropped significantly between Level 1 and Level 2, and between Level 1 and Level 3. This indicates that participants found it increasingly difficult as the amount of information increased during vocabulary learning, confirming that the difficulty is properly increased through an increase in the amount of information.

17 participants (with TOEIC scores over 500 or EIKEN Grade Pre-2 or above) were considered advanced learners, and their responses to difficulty were analyzed. Their evaluation of "test difficulty" at Level 2 was lower compared to the overall mean at 3.5 (SD:0.9). Level 3 was rated significantly more difficult than Level 2. Advanced learners felt that Level 2 was of moderate difficulty.

An analysis of the difficulty responses from the other 16 participants showed that the "test difficulty" at Level 2 was rated as difficult, with an average of 4.0 (SD:0.9), and the difficulty rating significantly increased between Levels 1 and 2. The mean score for Level 3 was the same as Level 2, at 4.0 (SD:1.0). "Fatigue" showed an increasing trend from Level 1 to Level 3, with values higher than the overall mean. This suggests that non-advanced learners began to feel fatigue from Level 1 and reached their difficulty limit by Level 2, therefore not feeling a change in difficulty at Level 3.

4.2.2 Regarding Overall Motivation

According to Figure 4, the items "curiosity about words" and "desire to study more" received the highest scores at Level 2. Motivation significantly increased from Level 1 to Level 2 and decreased after completing Level 3. The etymology presented at Level 2 received high scores, with a mean of 4.1 (SD:1.0), while the related words and example sentences presented at Level 3 were rated lower, with means of 3.4 (SD:1.1) and 2.9 (SD:1.1) respectively. This indicates that providing the appropriate amount and effective information is crucial for positively influencing motivation in foreign language vocabulary learning.

4.2.3 Regarding Motivation of Advanced English Learners

The item "desire to study more" showed the same trends as the overall results, with motivation dropping from Level 2 to Level 3 but without significant differences. Despite perceiving an increase in difficulty from Level 2 to Level 3, motivation did not significantly decrease. Additionally, the challenge rate for advanced learners at Level 3 was high at 50%, suggesting that highly skilled language learners are relatively less affected by an increase in information volume. In addition, the subjective evaluation of motivation was the highest for Level 2, but subjects tended to tackle Level 3, which is more difficult and has a larger number of questions.



Figure 3. Comparison of Difficulty by Level (Subjective Evaluation)



4.2.4 Regarding Motivation of Non-Advanced English Learners

The item "curiosity about words" showed the same trend as the overall motivation, with no significant difference between the mean of 4.2 (SD:0.8) at Level 2 and 3.9 (SD:1.1) at Level 3. The trend for "desire to study more" was the same as the overall, with no significant differences observed, indicating little change in motivation. The retry rate was highest at Level 2, at 47%, where motivation increased, and lowest at Level 3, at 13%. This suggests that similar to the subjective ratings of difficulty, participants felt they had reached their limit by Level 2, and there was no significant change in difficulty or motivation between Level 2 and Level 3.

5 CONCLUSION AND FUTURE CHALLENGES

In this study, vocabulary learning applications for Chinese and English were developed, and their design specifications were verified while the motivation of the participants who used them was examined. The results showed differences in motivational aspects between experienced and inexperienced language learners, with inexperienced learners being more positively influenced by extrinsic motivation and rewards. Moreover, it was found that there is an appropriate amount of information that can enhance motivation depending on the user's abilities.

As future challenges, further improvements to the design of the rewards are to be considered. Additionally, methods to appropriately combine the type and amount of information according to the user's abilities are to be explored.

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FAMILIARITY-BASED CATEGORIZATION OF SOUND FIELD CONTEXT CONSTITUTING ATMOSPHERE

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ABSTRACT

In recent years, with the increasing prevalence of remote work alongside traditional office settings, the challenge of conveying the office atmosphere remotely has become apparent. This issue has raised concerns about diminished solidarity, a sense of belonging, and increased psychological stress among remote workers. People can imagine the atmosphere of a place through its sounds, but it is unclear which specific sounds contribute to this perception. Therefore, previous studies have focused on the sound field context information and categorized the sounds that make up the atmosphere by classifying them into context information and individuality information. However, this study was insufficient to examine the effects of differences in familiarity with the sounds heard. In this study, the sounds that compose the atmosphere were investigated for three groups with different familiarity. The results showed that groups with higher familiarity were more likely to perceive context and individuality when they heard the same sound.

Keywords: familiarity, atmosphere, context, individuality

1 INTRODUCTION

In recent years, with the spread of COVID-19, remote work, where people work from home, has been gaining ground in addition to traditional office work. In office work, people work in the

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same space as those around them, making it easier to "share the atmosphere." However, in remote work, it is difficult to "share the atmosphere" because each person works in a different isolated space. This problem causes a communication gap between office workers and remote workers (Rafael et al., 2021). Furthermore, there are concerns that it may cause increased psychological stress such as loneliness, in addition to a reduced sense of solidarity and belonging among remote workers (Nahil et al., 2021). Therefore, there is a need to develop methods for sharing the atmosphere of a place even remotely.

Methods for sharing the atmosphere of a place to remote locations have been studied. The temporary corridors (Ogawa et al., 2021) and Ultra and Meta-Realistic Telework Communication System (Sakurai et al., 2018) are expected to promote communication between remote workers, but they need to interrupt their work to operate their devices. In other words, the atmosphere of the place can be shared, but work efficiency is reduced. Naito et al. (2023) proposed a method to strengthen the sense of connection between remote workers using sound. In this method, the situation of a remote worker was estimated from the camera image and sounds corresponding to that situation were transmitted to other remote workers. This means that the sounds transmitted are not related to the sounds produced in the actual situation, which may not effectively convey the atmosphere.

Our group is currently conducting research on methods of transmitting atmosphere to remote locations using sound and images. In our previous research, we categorized the sound field context information that conveying the office atmosphere using a matrix consisting of two axes: "context", which represents places, environments, or actions, and "individuality", which represents individuals such as voices, and tried to evaluate the impact on remote work using sounds created based on the matrix (Konagaya et al., in press). However, this previous study only evaluated subjects with extremely high familiarity who work on site on a daily basis and lacked an evaluation of the impact of differences in familiarity. In remote work in particular, it has become clear that information in the daily work environment of others is important, such as who is around, what activities are taking place and who is talking to whom (Cho et al., 2020) (Dourish et al., 1992). Therefore, it is assumed that the familiarity of the person receiving the information is also an important factor when the atmosphere is conveyed.

Based on the above, the purpose of this study is to analyze and categorize the sound field context that constitutes an atmosphere considering differences in familiarity. We attempt to categorize the sound field context by investigating the sounds that compose the atmosphere of a group of subjects with different familiarity.

2 METHODS

The objective of this experiment was to categorize the sounds that constitute the atmosphere in terms of differences in familiarity. For this objective, we attempted to survey the sounds that constitute the atmosphere in subjects of different levels of familiarity using audio recorded in a simulated office environment.

2.1 Experimental Procedure

2.1.1 Preparation of Audio

Recordings were made in a laboratory simulating an office. An omni-directional condenser microphone (MM-MCU05BK, Sanwa Supply Co., Ltd.) was placed on the participant's desks and recorded for a day when they were working. From the audio recordings, a range of 1 minute containing a variety of sounds was selected as the audio used in the survey. In this experiment, the audio presentation was set to 1 minute to prevent lack of intuitive responses due to prolonged sound listening. This time, we chose one minute of audio, with two students in the laboratory talking about their research while the others were working on a computer.

2.1.2 Survey of Sounds Constituting Atmosphere

Respondents were asked to answer the questionnaire about the sounds that make up the atmosphere. The questionnaire was structured to proceed according to the following steps:

- 1. Input respondent information (name, affiliation, age, gender).
- 2. Play audio automatically.
- 3. Answer the questions in Table 1.

Acquired Information	Question Sentence
Situation Imagined by Audio	What did you think the situation was like?
Situation imagined by Addio	*Please answer "when, where, who and what" as far as you can tell.
Sound Elements	If you could name three sounds that led you to think this was the situation, what would they be?
Constituting the Situation	*If you can't think of three, please fill in the ones you can think of and write 'none' for the rest.
Amount of Information on Context	How much could you understand about where and what someone was doing based on the sound you listed?
Amount of Information on Individuality	How much could you determine who (gender, occupation, name) was present based on the sound you listed?

Table 1. Acquired Information and Questions Sentence on the Questionnaire

In this experiment, differences in Familiarity are categorized by the affiliation of the respondent. To this end, respondents were asked to choose their affiliation among "member of the laboratory where the audio was recorded", "member of other laboratory", and "member not affiliated with any laboratory". Each affiliation was labeled, in order, as High Familiarity Group, Medium Familiarity Group, and Low Familiarity Group. There were sixty-four respondents to this questionnaire, of whom twenty-three were in the High Familiarity Group, fourteen in the Medium Familiarity Group and twenty-seven in the Low Familiarity Group. About the questionnaire, "Situation Imagined by Audio" and "Sound Elements Constituting the Situation" in Table 1 were answered in a descriptive format, while "Amount of Information on Individuality" were answered using a sliding bar that could be moved in 0.01 increments, with a minimum value of 0 and a maximum value of 1. To

complete the questionnaire, respondents used their own devices. Since the volume may vary depending on the device held by the respondent when playing the audio, we played a volume adjustment audio before playback to standardize the volume.

2.2 Analytical Methods

In accordance with previous studies, this study categorized sound elements using sound field context categorization matrix consisting of two axes: context and individuality, shown in Figure 1 (Konagaya et al., in press).



Figure 1. Sound Field Context Categorization Matrix (Konagaya et al., in press)

The amount of context and individuality information for each sound element listed in Table 1 is used as a rating value and plotted in the range 0-1 on the matrix in Figure 1. Since Figure 1 does not specify specific values for the vertical and horizontal axes in, in the result of this study, the sound elements were considered "low" if they were less than or equal to 0.5 for both context and individuality, and "high" if they were greater than 0.5. However, sound elements marked as "none" by respondents who could not write three sound elements in the questionnaire were excluded from the analysis. To assess differences in Familiarity, Wilcoxon rank-sum test was applied to the context and individuality values between the groups.

3 RESULTS AND DISCUSSION

Figure 2 shows the results of mapping the sound elements answered by the questionnaire. Table 2 shows the total number of elements in each familiarity group and the number and percentage of elements in each quadrant in Figure 2. Table 3 shows the mean values and standard deviations of context and individuality for each familiarity group.



High Familiarity

- Medium Familiarity
- Low Familiarity

Figure 2. Mapping Results of Sound Elements

	High Familiarity	Medium Familiarity	Low Familiarity
Low Context Low Individuality	2 (3.6%)	4 (11.8%)	10 (15.4%)
High Context Low Individuality	20 (35.7%)	11 (32.4%)	20 (30.8%)
Low Context High Individuality	5 (8.9%)	4 (11.8%)	10 (15.4%)
High Context High Individuality	29 (51.8%)	15 (44.1%)	25 (38.5%)
Total	56 (100%)	34 (100%)	65 (100%)

Table2. The number and percentage of sound elements in each quadrant

Table3. The mean values and standard deviations of context and individuality for each group

	High Familiarity	Medium Familiarity	Low Familiarity		
Context	0.72 ± 0.25	0.64 ± 0.27	0.58 ± 0.25		
Individuality	0.60 ± 0.40	0.47 ± 0.34	0.50 ± 0.30		

Figure 2 and Table 2 show that sound elements are concentrated in the high context and high individuality areas for all groups. This result indicates that people tend to perceive atmosphere more readily with sounds that have more contextual and more individual information. This may

be because contextual and individual sounds are more memorable (Konagaya et al., in press) and thus respondents were more likely to imagine the atmosphere.

Regarding context, Table 2 shows that 87.5% of the sound elements for High Familiarity, 76.5% for Medium Familiarity, and 69.3% for Low Familiarity are distributed in the High Context region. Table 3 shows that the higher the familiarity group, the higher the context of the recognized sound. Wilcoxon rank-sum test revealed that High Familiarity is significantly different from Low Familiarity (p < 0.001). Wilcoxon rank-sum test also showed the possibility of the difference between High Familiarity and Medium Familiarity (p < 0.1). These results indicate that the group with higher familiarity may have acquired more contextual information. This may be because people in the higher familiarity could easily guess what the sound was and what the situation was like from the sounds they heard, based on their background of having worked in the same or similar space before. For those with Low Familiarity, it is considered that understanding the context became more difficult than High Familiarity group due to a completely different usual workspace. In Medium Familiarity, although working in a different laboratory, it is considered that people would obtain a high level of contextual information due to the presence of some common working environments, albeit lower than that of High Familiarity. Since one of the reasons for the lack of significant differences between High Familiarity and Medium Familiarity is the small amount of data for Medium Familiarity, there is a need to reexamine with more data in the future.

Next, regarding individuality, Table 2 shows 60.7% of the sound elements for High Familiarity, 55.9% for Medium Familiarity, and 53.9% for Low Familiarity are distributed in the High Individuality region. Table 3 shows that High Familiarity is more individualistic in its perceived sounds than the other two groups. Wilcoxon rank-sum test revealed that High Familiarity is significantly different from Medium Familiarity (p < 0.05) and Low Familiarity (p < 0.05). These results may indicate that groups with higher familiarity acquire more individual identification when hearing the same sound. This is thought to be because, for example, when hearing the same spoken voice, some people with high familiarity can even assign the person's name, while those with medium familiarity can only infer information about their gender and occupation, and those with low familiarity can only infer information about their gender.

4 CONCLUSION

The object of this study was to categorize the sound field context constituting atmosphere based on familiarity. As a result, it was revealed that people perceive the atmosphere through sounds with high levels of context and individuality, and that those with higher familiarity are more sensitive to acquiring context and individuality from the same sounds. However, there are still considerations remaining for this study. Regarding familiarity, this study categorizes it into three groups, but a more detailed examination of familiarity is possible by taking into account the respondents' usual work sites. It is also necessary to consider whether the sounds that make up the atmosphere entered by respondents are suitable as the sounds of actual work. Therefore,

in the future, we will evaluate the psychological state of remote workers when these sounds are played during actual remote work to clarify the appropriate sound for the work.

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CONSIDERATIONS FOR INTERFACE DESIGN IN MR WITH RESPECT TO SUBJECTIVE DISTANCE PERCEPTION

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ABSTRACT

In recent years, Mixed Reality (MR) has begun to be applied across various fields. One such application area is the medical field, where its use is anticipated in technically demanding tasks such as brain aneurysm surgery. However, in MR environments, it has been reported that there are individual differences in the ability to perceive distances and manipulate small objects, which require precise operations. This study investigated the ability to perceive distances in MR by recording the time and coordinates when a real cube and a virtual cube were aligned. It was found that in the MR space, the discrepancy in perception of the coordinates of virtual objects is affected by the angle on the x-axis and the distance on the z-axis.

Keywords: mixed reality, hololens2, spatial recognition, interface

1 INTRODUCTION

In recent years, Extended Reality (XR), which merges real and virtual spaces, has garnered attention and has been actively researched. Augmented Reality (AR), a part of XR, is a technology that enhances real spaces by adding digital information and is applied in various fields including medicine (Hirofumi et al, 2013). Further developed from AR is Mixed Reality (MR), which reflects the user's movements into digital information by recognizing the shapes and positional data of real-world spaces, enabling more intuitive operations.

In the current medical field, the demand for neurovascular treatments using catheters has surged (Yoshitaka, Shigeru, Takashi, & Tomotaka, 2020). In particular, it has become one of the

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standard treatment methods for unruptured cerebral aneurysms, where the catheter must be shaped to conform to the vascular path according to the position of the aneurysm and the shape of the blood vessels, a task requiring skilled manipulation. Therefore, research is being conducted on developing MR-based assistive technologies. In VR spaces, it has been reported that the ability to perceive distances is diminished compared to real spaces (Kenta, Keita, & Koichi, 2019), and when viewing virtual objects through a Head-Mounted Display (HMD), the inability to adjust the crystalline lens for distance perception and the loss of size constancy are thought to be the cause. Similar effects are anticipated in MR spaces, and it may become difficult to accurately perceive distances when performing detailed work on small objects.

This study records the discrepancies in coordinates and the time taken to align a real cube with a virtual cube, investigating the impact on the ability to perceive distances in MR spaces. The study aims to identify the appropriate operational range that minimizes the impact on distance perception and to propose an intuitive interface that accounts for individual differences.

2 EXPERIMENTAL ENVIRONMENT

The real cube, virtual cube, and respective conditions are as shown in Figure 1. The coordinates of the real cube were determined by calculating the midpoint between the coordinates of the thumb and index finger detected through hand tracking. Therefore, it was necessary to instruct the participants to pinch and hold the cube between these fingers. Consequently, to meet the goal of this study, which involves manipulating small objects and to limit variations in how they are held, the real cube was designed as a cube with each side measuring 0.01 meters. The conditions for the virtual cube were set at two levels: distance and angle. The distances were defined as within reach, at 0.3m, 0.35m, 0.4m, 0.45m, and 0.5m. The angles, derived from the following formula (1), positioned the virtual cube on the surface of a sphere centered on the participant, with the distance levels as the radius. This configuration ensured that the virtual cube remained sufficiently within the participant's field of vision, at nine levels (bottom right, top right, center right, bottom left, top left, center left, center bottom, center top, and center center). The 45 combinations of virtual cube positions (5 distance levels × 9 angle levels) are listed in Table 1. Additionally, the coordinates of the virtual objects were determined based on the participant's head coordinates.



Figure 1. Participant's posture, real cube and virtual cube, distance conditions, and angle conditions

$$x = \cos\left(\sin^{-1}\varphi\right) \times \cos\frac{\pi}{\theta} \times rad$$

$$y = \sin\left(\sin^{-1}\varphi\right) \times rad \tag{1}$$

$$z = \cos\left(\sin^{-1}\varphi\right) \times \sin\frac{\pi}{\theta} \times rad$$

		radius=0.3			radius=0.35		radius=0.4		radius=0.45			radius=0.5				
		Θ=1.65	Θ=2	Θ=2.55	Θ=1.63	Θ=2	Θ=2.6	Θ=1.61	Θ=2	Θ=2.64	Θ=1.6	Θ=2	Θ=2.68	Θ=1.59	Θ=2	Θ=2.7
φ =0.25	Х	-0.095	0.000	0.097	-0.118	0.000	0.120	-0.144	0.000	0.144	-0.167	0.000	0.169	-0.191	0.000	0.192
	у	0.075	0.075	0.075	0.088	0.088	0.088	0.100	0.100	0.100	0.113	0.113	0.113	0.125	0.125	0.125
	Ζ	0.274	0.290	0.274	0.318	0.339	0.317	0.360	0.387	0.360	0.403	0.436	0.402	0.445	0.484	0.445
φ =0	Х	-0.098	0.000	0.100	-0.122	0.000	0.124	-0.149	0.000	0.149	-0.172	0.000	0.175	-0.197	0.000	0.198
	у	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Ζ	0.284	0.300	0.283	0.328	0.350	0.327	0.371	0.400	0.371	0.416	0.450	0.415	0.460	0.500	0.459
φ =-0.25	х	-0.095	0.000	0.097	-0.118	0.000	0.120	-0.144	0.000	0.144	-0.167	0.000	0.169	-0.191	0.000	0.192
	у	-0.075	-0.075	-0.075	-0.085	-0.875	-0.875	-0.100	-0.100	-0.100	-0.113	-0.113	-0.113	-0.125	-0.125	-0.125
	Ζ	0.274	0.290	0.274	0.318	0.339	0.317	0.360	0.387	0.360	0.403	0.436	0.402	0.445	0.484	0.445

Table 1. Reference coordinates of the virtual cube

3 SUBJECTIVE EVALUATION EXPERIMENT ON DISTANCE PERCEPTION IN MR ENVIRONMENT

3.1 Method

The participants consisted of 16 males and females with normal visual acuity who were able to see the real and virtual cubes without problems. The experimental procedure is explained as follows:

1. Explain the purpose and method orally and obtain the participants' consent.

2. The participants are seated in a chair and wear a head-mounted display (Microsoft HoloLens 2). They are instructed to sit with their back against the wall facing forward, arms down, and holding the real cube in the right hand (see Figure 1).

3. Optimize the image using the interpupillary distance and gaze input from the head-mounted display.

4. The participants are to align the real cube with the coordinates of the virtual cube displayed on the head-mounted display where they believe it is perfectly overlapped and signal the experimenter.

5. Record the coordinates of the real and virtual cubes and then hide the virtual cube.

6. Participants reset by sitting with their back against the wall, arms down, facing forward.

7. Steps 4 to 6 are repeated as one trial, and a total of 45 trials are conducted, covering 45 combinations of distances and angles of the virtual cube.

3.2 Results



Figure 2. Average deviations for left, right, and center positions



Figure 3. Average deviations of y-coordinates at each distance

The computer mounted on the head-mounted display recorded the time and the coordinates of the virtual cube at one frame degree. A frame is the time between a process and the next process, so one frame is less than one second. In addition, when the participants signaled that the real cube was overlapped with the virtual cube, the coordinates of the real cube, calculated from the coordinates of the thumb and index finger, were recorded and the distance between the virtual cube and the real cube was calculated. To elucidate the effects of distance and angle on deviations in the x, y, and z coordinates, a two-way analysis of variance was conducted. The results revealed a significant difference in the deviations of the x-coordinate with respect to angle (F[8,711]=1.951, p=0). A t-test, dividing the angles into left, right, and center, followed by Bonferroni's multiple comparison test, indicated significant differences between the center and left (p<.001), and the center and right (p<.001) (see Figure 2). It was found that the deviations of the x-coordinate are smallest when the virtual cube is in the center position. No significant differences were noted between the right and left sides (p=0.471); however, deviations were larger on the left side compared to the right. Significant differences were also observed in the deviations of the z-coordinate with distance (F[4,715]=2.384, p=0.002). Following a t-test and corrections using Bonferroni's multiple comparison test, significant differences were noted between 0.3m and 0.5m (p=0.019), 0.35m and 0.5m (p=0.001), and 0.4m and 0.5m (p=0.008) (see Figure 3). Regarding the z-coordinate, 0.35m showed the smallest deviation, and deviations increased with distance. Although no significant difference was found at 0.3m compared to 0.35m, an increase in deviation was observed. Table 2 shows the percentages calculated by dividing the absolute deviations of the x-coordinates on the left, right, and center by the absolute deviation of the x-coordinate in the center, multiplied by 100. Table 3 shows percentages calculated by dividing the absolute deviations of the z-coordinate at each distance by the absolute deviation at 0.35m and multiplying by 100. Applying these ratios to the collision detection range of virtual objects suggests that deviations can be reduced to similar levels as in the x-coordinates in the center and the z-coordinates at 0.35m.

Table 2. Ratios of deviations at each angle relative to the x-coordinate deviation in the center

Left	Center	Right
280.9%	100.0%	220.8%

Table 3. Ratios of deviations at each distance relative to the z-coordinate deviation at 0.35

0.3m	0.35m	0.4m	0.45m	0.5m
102.8%	100.0%	110.0%	121.2%	149.5%

4 OBJECTIVE EVALUATION EXPERIMENT ON DISTANCE PERCEPTION IN MR ENVIRONMENT

4.1 Method

The participants consisted of 19 males and females with normal visual acuity who were able to see the real and virtual cubes without problems. The experimental procedure is explained as follows:

1. Explain the purpose and method orally and obtain the participants' consent.

2. The participants are seated in a chair and wear a head-mounted display (Microsoft HoloLens 2). They are instructed to sit with their back against the wall facing forward, arms down, and holding the real cube in the right hand (see Figure 1).

3. Optimize the image using the interpupillary distance and gaze input from the head-mounted display.

4. The participants approach the real cube to the virtual cube displayed on the head-mounted display, attempting to perfectly align the coordinates.

5. A successful alignment is considered when the distance between the real and virtual cubes is less than 5mm (measured from the center coordinates). The time taken from the participant finding the virtual cube to successfully aligning the real cube is recorded, and the virtual cube is then hidden.

6. Participants reset by sitting with their back against the wall, arms down, facing forward.

7. Steps 4 to 6 are repeated as one trial, and a total of 45 trials are conducted, covering 45 combinations of distances and angles of the virtual cube.
4.2 Results



Figure 4. Average task completion times at each distance

The computer mounted on the head-mounted display recorded the time and the coordinates of the virtual cube at one frame degree. At the same time, the coordinates of the real cube calculated from the coordinates of the thumb and index finger were recorded, and the distance between the real and virtual cubes was calculated. In order to accurately measure task completion time, it is necessary to minimize the effect of the time spent searching for the virtual cube. Furthermore, the farther the virtual cube is from the participant, the longer the time used to approach the real cube to the virtual cube, so this effect must be minimized. Therefore, measurements were started when the distance between virtual cube and real cube was less than 0.2 m. The distance of 0.2 m was determined by investigating the distances with the fewest malfunctions. Furthermore, it is shorter than 0.3 m, the shortest distance among the five distance levels of conditions. To elucidate the effects of distance and angle on task completion time, a two-way analysis of variance was conducted. Although no significant main effects were observed, the mean task completion times at each distance revealed that 0.35m had the shortest duration (see Figure 4). As the distance increases from 0.35m, there is a trend toward longer task completion times, with smaller changes occurring after 0.45m. It was found that the shortest distance of 0.3m resulted in the longest task completion times.

5 DISCUSSION

In MR environments, it was found that the discrepancy in the perception of the coordinates of virtual objects is smallest when the x-coordinates are centered. Virtual objects that appear in front are easier to capture with both eyes, which is thought to contribute to minimizing the discrepancy. Furthermore, a larger discrepancy was observed on the left side compared to the right. Many of the participants in this experiment were right-handed, and they held the real cube in their right hand, which likely caused a greater movement distance of the real cube when aligning it with virtual cubes that appeared on the left. However, the objective evaluation experiment revealed that the angle has a minimal impact on task completion time. The influence of the discrepancy in x-coordinate perception on operational efficiency needs further investigation. For the z-coordinate, it became clear that the discrepancy increases as the distance from 0.35m increases. No significant difference was found in the objective evaluation experiment, but a similar trend was observed. In VR spaces, it is understood that virtual objects

positioned far away are perceived to be closer due to the fixed adjustment of the lens and the change in eye convergence (Kenta, Keita, & Koichi, 2019). Since MR spaces are similar to VR environments, it is considered that as the display position of the virtual object becomes more distant, the perception of its coordinates is increasingly affected.

In constructing interfaces using MR technology, maintaining the position of virtual objects at 0.35m directly in front of the user, or adapting the ratios shown in Tables 1 and 2 to the collision detection range of virtual objects can minimize the impact on operability in MR spaces by compensating for the discrepancies in coordinate perception.

6 CONCLUSION

In this study, using real and virtual cubes, we recorded the discrepancies in coordinates when they were aligned and measured the time taken to align them, to investigate the ability to perceive distances in MR environments. It was found that in MR spaces, the perception of the coordinates of virtual objects is influenced by the angle for the x-axis coordinate and the distance for the z-axis coordinate. Operational ranges and interfaces that minimize these effects and take into account discrepancies in perception were proposed.

In this experiment, the effects of distance and angle on the discrepancies in the x, y, and z coordinates were investigated, but no clear trends have been identified. Future studies are planned to further refine the criteria to clearly define the thresholds for effective operational ranges that allow for efficient handling, and to investigate methods for training that minimize the discrepancies in coordinate perception.

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USING BREATHING MOTIONS OF VR AVATARS TO INDUCE USER SENSATIONS

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ABSTRACT

This study aims to explore the technique to induce specific sensations in users through the discrepancy between the user's actual movements and VR avatar's breathing motions and its effects. The results of the experiment shows that the avatar's breathing motions were able to influence subjective sensations and heart rate, despite a small impact on comfortableness and user attention. Additionally, it was found that the effect of breathing motions were not compromised even in the presence of other stimuli. Therefore, it is believed that the breathing motions of VR avatars can alter user sensations depending on the intensity and are effective when combined with existing content.

Keywords: avatar, breathing motions, sense of body ownership, VR, heart rate

1 INTRODUCTION

With the widespread adoption of virtual reality (VR) among the general public, new communities for interacting with others as avatars (representations of oneself) have emerged. To manipulate avatars as desired in VR spaces, it is necessary to obtain two senses: the sense of body ownership, feeling that the observed body is part of oneself, and the sense of agency, feeling that oneself is moving the body (Gallagher, 2000). Therefore, accurately representing one's movements in VR was crucial (Tsakiris & Haggard, 2005). However, it has been reported that creating a discrepancy between actual movements and visuals can alter perceptions such as hardness, weight, and shape of objects and the resistance felt by users (Yee & Bailenson, 2007). By applying this technique to avatars, it is believed to positively change emotions in VR spaces and be effective in rehabilitation using VR in the medical field.

Therefore, this study focuses on breathing motions and aims to investigate how VR avatar's breathing motions influence user perceptions though the discrepancy between actual movements and virtual visuals.

2 EXPERIMENT 1: THE EFFECTS OF AVATAR BREATHING MOTIONS

2.1 Experiment Overview

Experiment 1 aimed to investigate the influence of avatar breathing motions on subjective and objective evaluations. Participants experienced avatar breathing motions and evaluated

their impressions and perceptions. Brain waves and heart rate of the participants were measured during the experiment. The subjects included 20 males and females in their 20s who consented to participate in the experiment. The experiment was conducted in a soundproof room to minimize the effects of noise on brainwaves.

2.2 Stimuli

The breathing motion involved a slight up-and-down movement of the viewpoint and body (Figure 1). In Experiment 1, avatar breathing motions were created in five intensity levels (None, Slow, Normal, Fast, Very fast) (Table 1). Here, for the up-and-down viewpoint oscillation intensity, Normal was determined based on the average respiratory rate at rest for adults, and Very fast was determined based on the average respiratory rate during intense exercise.



Figure 1. The avatar that users operated

Pattern	Breathing cycles
None	0 Times/min
Slow	6 Times/min
Normal	15 Times/min
Fast	24 Times/min
Very fast	40 Times/min

Table 1. Avatar breathing cycles

2.3 Experimental Procedures

The equipment used in Experiment 1 included the VR headset "Meta Quest 2," the heart rate monitor "Fitbit inspire 2," and the brainwave monitor "Muse 2." Heart rate data were recorded using the "Fitbit" app, and brainwave data were recorded using the "Mind Monitor" app. During the experiment, considering the height difference with the avatar, participants were instructed to perform the experiment while seated. Furthermore, to minimize external influences on heart rate and brainwaves, participants were instructed not to move or speak except for controller operation.

In Experiment 1, participants wore the equipment and experienced five patterns of avatar breathing motions randomly. Heart rate and brainwaves were measured for two minutes each. After experiencing each stimulus, step 1 and step 2 were taken; after experiencing all stimuli, step 3 was taken.

1. Multiple-choice questions

"Please select all that apply to what you felt you (the avatar) were doing." Exercising with slight stretching / Feeling dizzy / Breathing / Floating / Doing nothing

2. SD scale evaluation

Rate on a 1 to 5 scale for pairs of adjectives such as "hard to breathe / easy to breathe," "disordered / calm," "energetic / fatigued," "uncomfortable / comfortable," "awakening / drowsy," "relaxed / tense."

3. Evaluation of self-body recognition

Rate on a 1 to 5 scale (1: no such feeling - 5: have such feeling) for the following questions: "did you feel as if the avatar's body was your own body," "did you feel that you were moving the avatar's body," and "did you experience VR sickness."

3 RESULTS AND DISCUSSION OF EXPERIMENT 1

3.1 Evaluation through Multiple-Choice Questions

From the results of Slow and Normal (red text), there was a tendency for participants to perceive the sensation of breathing more easily as the avatar's breathing motions approached the average respiratory rate of 15 breaths per minute (Table 2). Additionally, when the respiratory rate exceeded 24 breaths per minute at rest, participants gradually began to feel a discrepancy with their own movements and likely judged the movements on the video side.

Terms	Light exercise	Dizziness	Breathing	Floating	Nothing
None	0.0%	0.0%	17.4%	4.3%	78.3%
Slow	4.8%	0.0%	38.1%	0.0%	57.1%
Normal	12.0%	0.0%	48.0%	32.0%	8.0%
Fast	29.2%	8.3%	29.2%	29.2%	4.1%
Very fast	48.2%	11.1%	11.1%	25.9%	3.7%

 Table 2. Proportions of Responses Per Stimulation Condition

3.2 Evaluation through SD Method

The mean values were calculated for the results, and one-way analysis of variance (ANOVA) was conducted for the factors of avatar breathing motions, corrected by the Bonferroni method (Figure 2). The blue density of the bar line indicates None to Very fast.

For "ease of breathing," "calmness," "comfort," and "drowsiness," there was a tendency for ratings to decrease as the breathing cycle became faster. However, in the Normal condition, the ratings were higher, indicating that the avatar's breathing motions matched those of the participants.

Regarding "tension," the rating for Very fast was significantly higher than for conditions other than Slow. This suggests that by shortening the avatar's breathing cycle more than the participant's state, subjective tension in the participants was influenced.



Figure 2. Average evaluations by SD method and ANOVA of results

3.3 Evaluation of Self-Body Recognition

For "Did you feel that the avatar's body was part of your own body?", the mean was 3.35 (SD: 1.01) with a median of 4. For "Did you feel that you were moving the avatar's body?", the mean was 3.65 (SD: 1.01) with a median of 4. Additionally, for "Did you experience VR sickness?", the mean was 1.70 (SD: 1.05) with a median of 1.

From the results, it was confirmed that self-body recognition was obtained and VR sickness did not occur.

3.4 Influence on Heart Rate and Brainwaves

Regarding heart rate, t-tests corrected by the Bonferroni method were conducted for differences between each participant and stimulus condition (Table 3). Yellow indicates a significant difference. Significant differences were obtained between stimulus conditions overall, indicating that the intensity of the avatar's breathing motions affected heart rate.

Regarding brainwaves, observation of the power spectrum fluctuation of alpha and beta waves for each stimulus showed no overall trend for alpha waves. Beta waves exhibited variability with weaker intensity stimuli, indicating that discomfort and attention were minimally affected within the range of intensity of the avatar's breathing motions provided in this study.

 Table 3. Results of t-tests for Heart Rate Differences between Stimulus Conditions (p-values)

sub	none / slow	none / normal	none / fast	none / veryfast	slow / normal	slow / fast	slow / veryfast	normal / fast	normal / veryfast	fast / veryfast
1	0.001	0.001	0.001	0.001	0.023	0.001	0.001	0.001	0.001	0.001
2	0.001	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.827	0.094
3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	0.001	0.001	0.001	0.981	0.001	0.001	0.001	0.001	0.001	0.001
5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.021	0.001
6	0.001	0.001	0.961	0.001	0.001	0.001	0.001	0.021	0.001	0.001
7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	0.002	0.019	0.001	0.001	0.489	0.755	0.001	0.459	0.001	0.001
9	0.001	0.256	0.016	0.910	0.001	0.001	0.001	0.835	0.059	0.036
10	0.001	0.001	0.001	0.289	0.217	0.005	0.001	0.002	0.001	0.001
11	0.001	0.001	0.135	0.001	0.001	0.001	0.001	0.001	0.340	0.001
12	0.001	0.001	0.001	0.001	0.979	0.507	0.001	0.564	0.002	0.001
13	0.001	0.004	0.522	0.004	0.001	0.001	0.001	0.001	0.887	0.001
14	0.001	0.001	0.936	0.060	0.001	0.001	0.001	0.001	0.001	0.397
15	0.001	0.002	0.001	0.001	0.001	0.717	0.090	0.001	0.001	0.139
16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
17	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.131	0.001
18	0.001	0.647	0.001	0.178	0.001	0.055	0.001	0.001	0.640	0.001
19	0.001	0.277	0.016	0.007	0.001	0.001	0.001	0.011	0.001	0.462
20	0.001	0.001	0.033	0.087	0.628	0.001	0.001	0.001	0.001	0.001
										Yellow : *p<0.05

4 EXPERIMENT 2: EFFECTIVENESS OF BREATHING MOTION PRESENTATION WHEN COMBINED WITH OTHER STIMULI

4.1 Experiment Overview

Experiment 2 aimed to subdivide the intensity of breathing motion presentation and examine the threshold at which users' perceptions change. Additionally, it aimed to investigate the effectiveness of breathing motion presentation when combined with other stimuli.

Participants were instructed to manipulate the avatar and observe scenes where balls flew at random intervals as a combined stimulus factor. Impressions of the breathing motion presentation were evaluated during the experiment, and participants' heart rates were measured. The participants included 20 males and females in their 20s who consented to participate in the experiment.

4.2 Stimuli

Based on the results of Experiment 1, it was found that participants were more likely to perceive breathing sensations as the intensity approached 15 breaths per minute, and they began to feel a discrepancy with actual movements when the intensity exceeded 24 breaths per minute. To further refine the stimulus intensity, Experiment 2 set the breathing cycle of the breathing motion presentation to five levels ranging from 15 to 27 breaths per minute (Table 4).

Pattern	Breathing cycles
1	15 Times/min
2	18 Times/min
3	21 Times/min
4	24 Times/min
5	27 Times/min

Table 4.	Avatar	breathing	cycles
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As for stimuli to be combined with breathing motion presentation, scenes where balls flew at random intervals were selected due to their ability to induce tension and simplicity. The random interval was set between 1 and 10 seconds to sustain the participants' attention, with balls

randomly appearing within this interval. The direction of the balls was directly in front of the user's initial position, and the size of the balls was set to a radius of 0.5m for visibility. Additionally, the speed of the balls was set within the range of speeds at which humans can throw, with two options provided: Slow (40 km/h) and Fast (140 km/h).

4.3 Experimental Procedures

The equipment used in Experiment 2 was the VR headset "Meta Quest 2" and the heart rate monitor "Apple Watch Series 8." A compact watch-type heart rate monitor was chosen to minimize interference with other devices. Heart rate measurements were taken to examine the relationship between breathing motion presentation intensity and participant state. Heart rate data were recorded using the real-time observation app "HypeRate" on the watch. In Experiment 2, after participants wore the equipment, the following button operation explanation was provided (Figure 3).



Figure 3. Overview of the experiment stimulation

In the VR space, participants could click buttons using the avatar's right hand. The left-side [START] button initiated the scene where balls flew, disappearing along with the UI when pressed. Each trial of the experiment lasted from pressing [START] to pressing the [NEXT] button, located on the right side (90 degrees clockwise), to proceed to the next stimulus.

The experiment consisted of a total of 10 trials, comprising five patterns of avatar breathing motions (1-5) combined with two patterns of ball speeds (Slow, Fast), presented in random order. Heart rate was measured for two minutes in each trial, and after each trial, a 7-point evaluation using the SD method was conducted orally (Table 5). The adjective pairs selected for the SD method were related to breathing and consisted of three evaluative factors, three activity factors, and three force factors. Additionally, after completing all trials, participants provided free-form feedback.



Evaluative factors	Activity factors	Force factors
"Good/bad"	"Unnatural/natural"	"Hard-to-breath/easy-to-breath"
"Boring/interesting"	"Showy/subdued"	"Tense/relaxed"
"Unpleasant/pleasant"	"Lively/comfortable"	"Heavy/light"

5 RESULTS AND DISCUSSION OF EXPERIMENT 2

5.1 Evaluation by SD Method

A two-way analysis of variance was conducted on the evaluation using the SD method. Significant differences were found in both the ball speed factor and the avatar's breathing motion factor for "flashy/plain," "energetic/calm," and "unpleasant/pleasant" (Table 6). Orange indicates significant difference. Additionally, significant differences were only observed in the avatar's breathing motion factor for "difficult to breathe/easy to breathe," "bad/good," "tense/relaxed," and "unnatural/natural." There was a significant difference between breathing motion presentations of 15-21 breaths per minute and those of either 24 or 27 breaths per minute. Furthermore, although there was no significant interaction between the ball speed factor and the avatar's breathing motion factor for all adjective pairs, there was a tendency for a more positive perception as the breathing motion presentation approached 15 breaths per minute (Figure 4).

		hard to breath / easy to breath	bad / good	tense / relaxed	heavy / light	unnatural / natural	boring / interesting	showy / subdued	lively / comfortable	unpleasant / pleasant
	Ball speed	2.12	4.94 *	7.17 *	6.14 *	7.04 *	0.82	8.34 **	11.43 **	10.42 **
Significant difference (F)	Breathing motion	9.77 **	4.03 **	3.97 **	0.77	3.66 **	1.36	5.85 **	9.12 **	4.28 **
.,	Reciprocal action	2.74 *	2.01	1.43	1.26	0.31	1.14	1.55	2.84 *	0.33
								Orange :	**p<.01, *p	0<.05

Table 6. SD Method Evaluations Variance Analysis Results



Figure 4. Average Ratings of Adjective Pairs

From the results of the analysis of variance, it was found that the avatar's breathing motion acted as an independent factor and was effective even when expressed simultaneously with other stimuli. Additionally, based on the significant difference results between the intensities of breathing motion presentation, the optimal range of breathing motion presentation to induce subjective perceptions was considered to be 15-21 breaths per minute.

5.2 Influence on Heart Rate

A two-way analysis of variance was conducted on the heart rate of each participant. Significant differences were found in many cases for the avatar's breathing motion factor, the ball speed factor, and the interaction between them (Table 7). From the results, it was revealed that the avatar's breathing motion and ball speed had a significant impact on heart rate. Additionally, since the avatar's breathing motion influenced physiological indicators even when combined with other stimuli, its application to existing VR content is anticipated.

		1	2	3	4	5	6	7	8	9	10
	Ball speed	63.25 **	23.66 **	328.71 **	28.18 **	485.97 **	40.67 **	8.60 **	76.21 **	78.48 **	152.07 **
Significant difference	Breathing motion	196.21 **	98.70 **	118.53 **	83.63 **	25.98 **	550.0 **	48.60 **	32.79 **	108.39 **	6.84 **
(F)	Reciprocal action	641.67 **	89.91 **	193.65 **	112.78 **	70.66 **	176.99 **	62.77 **	19.11 *	306.78 **	36.09 **
										**p<.01	
		11	12	13	14	15	16	17	18	19	20
	Ball speed	13.29 **	637.76 **	84.59 **	4.41 **	23.88 **	290.74 **	61.37 **	542.52 **	714.02 **	32.10 **
Significant difference	Breathing motion	9.33 **	248.84 **	272.57 **	47.92 **	50.94 **	23.09 **	169.80 **	444.88 **	140.02 **	24.48 **
(F)	Reciprocal action	31.68 **	198.51 **	71.46 **	95.45 **	102.19 **	40.11 **	75.25 **	224.57 **	56.64 **	59.76 **
										**n< 01	

Table 7. Heart Rate Variance Analysis Results

6 CONCLUSION

In this study, we examined the impact of VR avatar breathing motion on users' perceptions by utilizing the discrepancy between actual movements and digital visuals. Avatar breathing motion did not significantly affect comfort level or user attention, but did influence subjective perceptions and heart rate. This revealed that users' perceptions could be altered by the intensity of the presentation.

Furthermore, the effectiveness of avatar breathing motion even when combined with other stimuli suggests potential applications in positively influencing users' emotions in VR environments.

Moving forward, further investigation into the effects during exercise and cross-modal influences is necessary.

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INVESTIGATION OF MARKER PLACEMENT METHODS FOR AN AR APPLICATION IN THE SURGICAL FIELD

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ABSTRACT

The current medical field, especially surgery, is making use of 3D-printed models to collate 3D data of injured sites that have complex structures with specific positions in the site. To simplify this process, we developed an assisted application to identify positions in an injured site more easily by using AR and a tablet for use in surgeries of the head. We investigated three new marker and 3D model placement methods to increase alignment precision the object placed on the screen with the affected area in the real-world site and conducted evaluation tests on the application. The results showed that the method of placing a marker at the reference point by using a button while aligning it with the indicator on the center of the screen had smaller error than the method of directly tapping the reference point. Since there was no significant difference in the placement position by users, this method is considered to be effective in confirming the location of the affected area du surgery.

Keywords: augmented reality, AR kit, marker placement

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1 BACKGROUND AND OBJECTIVE

Augmented Reality (AR), the projection of a virtual space into the real world, has found a wide range of applications in the entertainment field and everyday life helped by the ready availability of smartphones and is now receiving attention from the education and medical fields in Japan as well as globally. In the medical field, AR is mainly used in education and for assistance during surgery, and AR is said to be especially compatible with surgery support.

Nakaguchi et al. used a variety of specialized equipment like projectors and optical position sensors to project AR-generated models of blood vessels, internal organs, or tumors at specific positions in the head or abdomen of patients and used this technique in surgery simulations. However, the alignment of the virtual space to the real world is still a large problem when applying AR in surgery.

The current medical field, especially surgery, is making use of 3D-printed models to collate 3D data of injured sites that have complex structures with specific positions in the site (Fig. 1), but this approach is quite labor- and time-intensive since the models need to be printed with a 3D printer. AR enables a visual three-dimensional representation, so shapes and positions can be visualized simply by superimposing these three-dimensional representations on images. Since overlay with areas inside the body is easier with AR than with physical models, using AR as a support tool before and during surgery would bring great advantages. On the other hand, the high cost of installation due to the purchase of specialized equipment and development costs is one reason why AR is not yet as widely used in medical care as VR, which is why AR applications using cheap or already existing equipment need to be developed. Therefore, the goal of our research was to investigate AR-based methods to generate coordinates to more easily identify positions in an injured site (our research focused on the head) using a tablet and to develop an AR-assisted application that can be used before and during surgery.



Figure 1. 3D-printed model

2 DEVELOPMENT OF AN AR APPLICATION TO VISUALIZE THE SHAPE OF THE INJURED SITE

2.1 Development environment

In order to position 3D models of blood vessels and tumors located in a patient's head in a virtual space, we developed an application that generates coordinates from placed markers.

Assuming use of the application with iOS devices, we used Xcode (ver: 14.2) and Unity (ver: 2021.3.12f1.), both integrated development environments for iOS devices. For the AR functions, we used the AR functionality ARKit (ver: 4.2.7), a feature included in the dedicated AR development framework ARFoundation (ver: 4.2.7) provided by Unity. The execution environment of Unity and Xcode was MacBook Pro (ver: 12.6.7) and the application was executed on the iPhone 12 (ver: 16.3.1) and the 5th generation iPad Pro (ver: 16.5.1).

2.2 Marker and 3D model placement methods

The application we developed places and aligns three markers in the head area and then displays 3D models of the injured site onto the head. The marker positions (hereafter called reference points) are aligned to characteristic anatomical points on the body surface, and the three reference points are positioned in the center of the infraorbital rim and at the left and right ear canal opening (Fig. 2). These points are based on the Reid's base line, which is used in CT scanning of the head, and using the same reference plane that is used to obtain the 3D data of a patient's head should reduce misalignment between the virtual space and the real-world object when projecting the 3D data.



Figure 2. Marker placement based on the German horizontal plane

To increase the ease of use and real-world alignment precision of the application, we investigated new marker and 3D model placement methods to develop our application. Tab. 1 shows the model placement methods that were assessed. For marker recognition, we investigated methods to automatically position 3D models using facial recognition or image recognition with image markers.

	Method 1	Method 2	Method 3	Method 4
Number of markers	3	5	0	1
Reference points	Ear canal opening + The center of the infraorbital rim	Ear canal opening + The center of the infraorbital rim	Face	Image markers
Reference objects	Feature points	Feature points	Feature points	Image makers

Table 1. Model placement methods used in the application

In another 3D model placement method, we increased the number of reference points from three to five. The reference point positions are shown in Fig. 3. We added two points (2, 3) below the left and right eye sockets to the three existing reference points (1, 4, 5). By calculating the average of the midpoint of the existing three points and the midpoint of the four points below the left and right eye sockets and at the left and right ear canal opening (average value is indicated with \star in Fig. 3), we determined 3D model coordinates and aimed to increase precision.



Figure 3. Positions of the five reference points

2.3 Application functions

The newly created functions of our application are listed below.

- 1. Function to manually position 3D models.
- 2. Function to place head at desired angle.

3. Function to place markers by tapping the desired position directly on the screen.

- 4. Function to display 3D model coordinates on the screen.
- 5. Addition of operation manual screen.
- 6. Function to hide feature points and placed markers after 3D model positioning.
 - 7. Function to change 3D model appearance.

- 8. Improvement of 3D model and marker transparency and colors.
- 9. Function to link the plane displayed when positioning the 3D model with the reference points.

Screenshots from the application in use are shown in Fig. 4. In screenshot 1, reference points were increased to five points, and screenshot 2 shows the hear oriented so that the horizontal place is parallel to the ground.



Figure 4. Screenshots from the application in use

3 EVALUATION TESTS

To compare the three marker placement methods and evaluate the ease of use and user-dependent error of marker placement, we developed six variations of the application with different operation modes. As test subjects, 26 university students (men and women) between 20 and 29 years old were asked to use the applications and evaluate the ease of use of the respective operation mode. After explaining how to use the application and a demonstration by the researchers, the test subjects used the application and the operation was completed when the target was successfully placed in the intended position. We obtained the object coordinates and evaluated the positioning error from the distribution of the results from all test subjects. The tested applications are shown in Tab. 2. In experiment 1 and experiment 2, test subjects performed the operation while sitting and with the head model arranged in a vertical position. Experiment 1 evaluated the three marker placement methods of reference point placement by tapping on the screen and placement of three or five reference points with buttons and alignment to an indicator in order to examine the precision of each placement method and the user-dependent error. Experiment 2 tested application 4, which included a function to change the transparency of the 3D model, to evaluate the ease of visualization. In experiment 3, test subjects performed the operation while standing to evaluate the ease of use and precision at different angles of the head model.

The objective of comparing the three marker placement methods (placement of three reference point by tapping on the screen, and placement of three or five reference points with buttons and alignment to an indicator) was to investigate the ease of use and the

user-dependent positioning error. Another goal was to evaluate which of two 3D model appearances was easier to see. Test subjects were asked to use the six variations of the application with the different placement methods and we evaluated the ease of use of each operation method.

		EX1			I	EX3
	App1	App2	Арр3	App4	App5	Арр6
Number of markers	3	3	5	3	3	3
Marker placement methods	Tap reference point	button and alignment to an indicator	button and alignment to an indicator	button and alignment to an indicator	Tap reference point	button and alignment to an indicator
Angles of the head model	vertical	vertical vertical		vertical	horizontal	horizontal
Posture	sitting	sitting	sitting	sitting	standing	standing

Table 2. List of developed applications

4 TEST RESULTS AND DISCUSSION

4.1 Model positioning depending on user skill

Fig. 3 shows the averages and distribution of the coordinate axis values generated by skilled users (the researchers) and the test subjects. A t-test with a p-value of 5% was performed for each experiment and showed that there was no significant difference between the coordinates generated by skilled users and test subjects.

The distribution of the 15 axis values in total that were calculated from the five experiments (excluding experiment 2 evaluating the model display options) performed by the test subjects and skilled users was smaller when generated by skilled users than by test subjects, with the exception of the y-axis in experiments 1-1, 1-2, and 3-2 (see the blue boxes in Tab. 3). The sums of the distributions of test subjects show that the error was smaller for placement with button on the actual area than for placement by tapping on the screen (see the red dotted boxes in Tab. 3).

While no significant difference was found between the results generated by test subjects, the largest distribution was seen for the x-axis in all experiments. The reason for this large error on the x-axis is likely because vertical movement along the x-axis is the main part of marker placement. Also, the method with the smallest difference between coordinates generated by the test subjects and the reference values generated by skilled users was experiment 3-1 (tapping), and the method with the largest difference was experiment 3-2 (button). When focusing only on the coordinates, placement by tapping seems to result in a smaller error. Since

experiment 3 was performed while standing, the users could move their body more freely and this contributes to larger errors for results from both test subjects and skilled users. Based on these results, using equipment like a tablet stand to fix the device in place and limiting the degree of body movement of the user can be expected to reduce this error.

In addition, the sum of the distributions of test subjects was the smallest in experiment 3-2 which was performed while standing (indicated in yellow in Tab. 3). Experiment 3-2 was the fifth time a user performed the operation, and so it is assumed that this is because the users had become used to the operation. For this reason, practicing the operation before using the application in an actual task will likely result in smaller user-dependent errors.

Test subject		EX1-1			EX1-2			EX1-3	
Axis	x	у	z	х	у	z	х	у	z
Average	1029.188	561.335	-964.382	1029.305	561.317	-964.301	1029.360	561.364	-964.240
Distribution	0.110	0.004	0.051	0.103	0.006	0.023	0.096	0.028	0.026
Sum of the distributions			0.164			0.131			0.150
Test subject		EX3-1			EX3-2				
Axis	x	у	z	х	у	z			
Average	1029.122	561.148	-964.413	1029.175	561.126	-964.355			
Distribution	0.048	0.015	0.033	0.047	0.003	0.021			
Sum of the distributions			0.096			0.071			
Skilled users		EX1-1			EX1-2			EX1-3	
Axis	x	у	z	х	у	z	x	у	z
Average	1029.027	561.424	-964.289	1029.000	561.454	-964.199	1029.134	561.454	-964.221
Distribution	0.010	0.006	0.032	0.007	0.007	0.013	0.009	0.004	0.002
Sum of the distributions			0.048			0.027			0.015
Skilled users		EX3-1			EX3-2				
Axis	x	у	z	x	у	z			
Average	1028.974	561.154	-964.568	1028.923	561.704	-964.461			
Distribution	0.003	0.003	0.002	0.004	0.063	0.006			
Sum of the distributions			0.007			0.073			

 Table 3. Averages and distributions of coordinate axis values (pixel)

4.2 Marker placement methods

In a questionnaire on the marker placement methods, 73% (19 of 26 test subjects) of the users answered that placement with button and alignment to the center of the screen was the best method. The averages of the subjective evaluation were calculated for all evaluation items, and a t-test with a p-value of 5% was performed. The Bonferroni correction was used to adjust for the multiple comparisons between the three applications used in experiment 1. The results are shown in Tab. 4.

For the evaluation item "Were you able to place the marker as intended?", the placement method with button was rated higher than placement by tapping in both experiments 1 and 3, and the difference was significant in experiment 1. For the evaluation item "Ease of use of the application," the method with five reference points was rated higher than that with three reference points in experiment 1 even though the difference was not significant (see blue box in Tab. 5). In experiment 3, application 2 was rated higher and the difference was significant (t = 2.06, p<.05). Based on the above results of the evaluation by the test subjects, we think the ease of use is better for placement of with button than for placement by tapping on the screen and that using five reference points is also better.

The ease of use as well as the other evaluation items were rated lower in experiment 3 than in experiment 1. Since experiment 3 was performed while standing, this is probably because the user's body is moving around more and this makes the operation more difficult.

1-1(tap)	1-2(button)	1-3(button,5)
4.54	4.77	4.77
3.96	4.46	4.42
77%	91%	90%
1.08	0.23	0.28
0.23	0.15	0.04
4.04	4.31	4.50
	1-1(tap) 4.54 3.96 77% 1.08 0.23 4.04	1-1(tap) 1-2(button) 4.54 4.77 3.96 4.46 77% 91% 1.08 0.23 0.23 0.15 4.04 4.31

Table 4	. The averages	of the sub	jective	evaluation
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EX3(standing)	3-1(tap)	3-2(button)
Ease of use	4.31	4.62
Were you able to place the marker as intended?	3.96	4.31
How many markers did you place as desired?	(85%) 2.54	(87%) 2.62
Redo Count	0.54	0.31
Reset Count	0.19	0.23
The ease of use	3.73	4.23

4.3 Marker placement methods

In the evaluation results of the appearance of the 3D models of the injured site in experiment 2, 65% of users answered the question "Which appearance is best for confirming object structure and details?" with "normal appearance", and 85% of users answered the question "Which appearance is best for overlay with the injured site assuming the application is used during surgery?" with "semi-transparent appearance." This suggests that the normal appearance is good for confirming the object structure and details, and the semi-transparent appearance is good for overlay with the injured site during surgery. A function to change the transparency and color with a slider would be a good future addition.

5 CONCLUSION AND POINTS FOR IMPROVEMENT

In this research, we investigated marker placement methods for development of an AR application that can be used to assist in surgery, and aimed to increase alignment precision. Testing of the improved application showed that all methods had a small user-dependent positioning error, and that the method using marker placement to reference points with button and alignment to an indicator in the center of the screen also had a small error. The method using five reference points was easier to use than that with three reference points. Experience with other AR applications or degree of skill most likely do not have an effect on the placement positions. Fixating the device and practicing beforehand can reduce the error in positioning. In terms of model appearance, the normal appearance is better for confirming the object structure and details, and the semi-transparent appearance is better for overlaying the model with the injured site during surgery. It is known that when observing the injured site from

multiple directions, model emulation can be affected by special features or the surrounding environment. For this reason, position deviations caused by changes in the real world cannot be corrected and alignment precision deteriorates depending on the surroundings during use. We plan to work on minimizing deviations and increasing precision by investigating methods using image markers to obtain coordinates. We also intend to further improve the application by testing it in environments that are similar to the actual clinical use and incorporating feedback from users.

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DESIGNING FOR CHANGE: INFLUENCING CONSUMER BEHAVIOR THROUGH USER-CENTERED AND EMOTIONAL DESIGN

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ABSTRACT

This paper explores drivers behind the evolution of consumer goods, focusing on economic, environmental, technological, societal, and regulatory factors. Investigating user behavior and the adoption of innovative technologies, the study aims to provide insights into strategies for integrating novel products into the consumer landscape. It presents psychological fundamentals of behavior change, including the Transtheoretical Model of Behavior Change and the Theory of Planned Behavior, and examines tools such as nudging, the Kano model, and Kansei Engineering. Through one case study, the paper illustrates the influence of user-centered design, emotional design, and surprise features on user behavior. Ultimately, it emphasizes the importance of prioritizing user-centered design and emotional design principles in product development, offering implications for enhancing customer acceptance and delight.

Keywords: User-Centered Design, Behavior Change, Emotional Design, Kansei Engineering, Nudging

1 INTRODUCTION

In the ever-evolving landscape of consumer goods, the introduction of novel products marks a pivotal moment characterized by distinct appearances and innovative functionalities. The rationale behind these transformations is multifaceted, encompassing a convergence of factors that drive the evolution of market offerings. This paper delves into the intricacies of this phenomenon, identifying five primary drivers that underpin the transition from older to newer products.

The first driver, rooted in economic imperatives, revolves around the pursuit of enhanced profitability. Companies endeavor to replace outdated products with modern counterparts, imbued with contemporary aesthetics and advanced features, thereby bolstering their competitive edge in the market.

Environmental considerations emerge as another compelling force propelling product innovation. As society increasingly prioritizes sustainability, there is a palpable shift towards eco-friendly alternatives. However, these replacements may entail compromises in performance, necessitating adjustments in user behavior, whether through adapting to smaller car engines or acclimating to the nuances of electric vehicles.

Technical progress constitutes a third impetus, wherein the proliferation of cutting-edge technologies, such as those integrated into the Internet of Things (IoT), permeates everyday products. This technological push introduces users to novel functionalities, often requiring a learning curve to fully harness their potential.

Societal dynamics, encompassing shifts in cultural norms and values, exert a profound influence on product innovation. As societal perceptions evolve, symbols of status and power undergo redefinition, prompting the emergence of products that reflect egalitarian ideals and inclusive values.

Furthermore, legislative mandates wield significant sway over product design, as regulations governing safety, environmental protection, and industry standards necessitate adaptation and compliance.

While the advent of new products is generally met with enthusiasm by consumers, the assimilation of novel features can pose challenges, particularly in adjusting behaviour to align with product functionalities. Notably, technology companies observe a trend wherein younger demographics, typically early adopters, exhibit reticence towards complex products, highlighting the importance of user-friendliness in driving adoption.

Speculatively, the learning curve associated with mastering a product's features, coupled with the perceived lack of tangible benefits to personal life, may deter users from fully engaging with innovative offerings. Additionally, the extent of behavioural modification required to optimize product performance may outweigh perceived benefits, thereby undermining adoption efforts.

In elucidating the multifaceted dynamics of product innovation adoption, this study aims to offer insights into the complex interplay between market forces, technological advancements, societal shifts, and user behaviour, thereby informing strategies to facilitate seamless integration of novel products into the consumer landscape.

2 AIM

The purpose is this paper is to point out ways for product designers to consider customer behavior in their early design phases that allow users to easier adapt and embrace novel products.

Research Questions

1. What are key drivers for customers to change their behavior?

2. What tools are available to achieve customer behavioral change towards products?

3. How can these thinking be integrated into product designer's work?

3 MATERIALS

3.1 Psychological grounds for change

Behaviour change is a complex and multifaceted process influenced by a mulitude of internal and external factors. In this chapter, we dive into the psychological fundamentals that underpin why and in what situations people modify their behaviour. Furthermore, we explore the role of external support mechanisms in facilitating and sustaining behavioural change, offering insights into effective strategies for intervention and empowerment.

At the heart of behavioural change lie cognitive, affective, and motivational processes that shape our decisions and actions. One prominent theory that elucidates these dynamics is the **Transtheoretical Model of Behaviour Change** (TTM), which posits that individuals progress through distinct stages—precontemplation, contemplation, preparation, action, and maintenance—on their journey towards behaviour change (Marshall & Biddle, 2001). Crucially, this model underscores the importance of readiness to change, highlighting how individuals' attitudes, beliefs, and perceived self-efficacy influence their likelihood of initiating and sustaining behavioural change.

Additionally, the **Theory of Planned Behaviour** (TPB) offers valuable insights into the determinants of behaviour, suggesting that attitudes, subjective norms, and perceived behavioural control predict behavioural intentions and subsequent action (Ajzen, 1991). By considering the interplay between attitudes, subjective norms, and perceived control, this theory provides a nuanced understanding of the cognitive processes that underlie behaviour change.

Behavioural change is often catalysed by specific situational factors that prompt individuals to reassess their habits and routines (Busch, 2018). Life transitions, such as marriage, parenthood, career changes, or health crises, can serve as potent triggers for behaviour change, prompting individuals to reevaluate their priorities and adopt new habits aligned with their evolving circumstances.

Moreover, environmental cues and contextual factors play a pivotal role in shaping behaviour. Nudging interventions, which leverage subtle alterations in choice architecture to steer individuals towards desirable behaviours, exemplify how environmental design can influence decision-making and facilitate behaviour change without relying solely on conscious effort or willpower (Nilsson, 2020).

While internal motivations and cognitive processes play a central role in driving behaviour change, external support mechanisms can provide crucial scaffolding and reinforcement for individuals striving to enact lasting change (Busch, 2018). Social support networks, encompassing family, friends, peers, and community groups, offer emotional encouragement, accountability, and practical assistance, thereby bolstering individuals' resilience and commitment to their goals (Busch, 2018).

Technological innovations also hold immense potential as tools for external support in behaviour change efforts. Mobile applications, wearable devices, and online platforms can provide real-time feedback, goal tracking, and personalized interventions, empowering individuals to monitor their progress, overcome barriers, and cultivate sustainable habits (Van Den Ende & Dolfsma, 2005).

Furthermore, behavioural interventions grounded in **behavioural economics**, such as incentives, rewards, and gamification, capitalize on psychological principles to incentivize desired behaviours and foster engagement (Young, 2017). By tapping into individuals' intrinsic motivations and leveraging extrinsic rewards, these interventions create a supportive environment conducive to behaviour change.

3.2 Tools for changing behavior

3.2.1 Nudging

Nudging is a concept rooted in behavioural economics and psychology that involves subtly influencing people's decisions and behaviours without restricting their freedom of choice (Thaler & Sunstein, 2008; Wilkinson, 2013). It operates on the principle that small, strategically designed interventions in the decision-making environment can lead individuals to make choices that are in line with their long-term goals or societal welfare.

These interventions typically take the form of subtle changes in the presentation or framing of options, known as choice architecture, which can influence individuals' perceptions, preferences, and ultimately, their decisions. For example, placing healthier food options at eye level in a cafeteria or grocery store nudges individuals towards making healthier dietary choices without mandating specific dietary restrictions (Wilkinson, 2013).

Nudging can change user behaviour by leveraging various cognitive biases and heuristics that influence decision-making processes. For instance, the default effect capitalizes on people's tendency to stick with preselected options by making desirable choices the default option, thereby increasing the likelihood of adoption. Similarly, social proof leverages the herd mentality, prompting individuals to emulate the behaviour of others in a given context (Cohen, 2013; Wilkinson, 2013). It seems that a key for a nudge to be effective is that is not perceived as manipulative (Gråd et al., 2021). Increasing transparency of a nudge is one way to decrease the likelihood of feeling manipulated and it is debatable if transparency decrease the willing to act pro-socially or if the effect is negligible (Gråd et al., 2021).

A helpful distinction is between so-called pro-self and pro-social nudges (Hagman et al., 2015). Pro-self nudges are by Hagman et al. described as nudges that help individuals steer away from irrational behavior that decreases their long-term wellbeing. Pro-social nudges are in contrast described as nudges that nudge individuals to act in accordance with the best interest of the common good and not foremost to their personal best interest. Hagman et al.s study indicates that people are more likely to prefer pro-self nudges but there are also evidence that nudges are positive for pro-social behavior if people do not feel that they are being manipulated and

that people that feel that they are being manipulated are unaffected by the nudge in their decision-making (Gråd et al., 2021).

3.2.2 Kano- model

The Kano model (Kano et al., 1984) is a framework used in product development and customer satisfaction management to understand and categorize customer preferences and needs. Named after its creator, Dr. Noriaki Kano, the model suggests that customer satisfaction with a product or service is influenced by various features or attributes in different ways.

The Kano model categorizes product features into three main types:

1. Basic or Threshold Features: These are essential attributes that customers expect a product or service to have. Their absence leads to dissatisfaction, but their presence does not necessarily generate satisfaction; rather, they are taken for granted. For example, in a smartphone, basic features might include making calls, sending texts, and accessing the internet (Kano et al., 1984).

2. Performance Features: These are attributes that directly correlate with satisfaction. The more of these features a product possesses, the more satisfied customers become. Performance features are directly proportional to satisfaction but not having them doesn't necessarily lead to dissatisfaction. An example in a smartphone could be a high-resolution camera or long battery life (Kano et al., 1984).

3. Excitement or Delight Features: These are unexpected or innovative features that surprise and delight customers, often exceeding their initial expectations. While their absence does not cause dissatisfaction, their presence can significantly enhance customer satisfaction and loyalty. These features often differentiate a product from its competitors. For instance, in a smartphone, a facial recognition unlock feature or augmented reality capabilities might be considered excitement features (Kano et al., 1984).



Figure 1. Kano model (adapted from Kano et al., 1984)

The Kano model can be used to change user behaviour by strategically incorporating features based on their categorization. By identifying and prioritizing which features fall into each category, businesses can tailor their product development efforts to focus on enhancing performance and incorporating excitement features that drive customer satisfaction and loyalty. Additionally, understanding customers' expectations regarding basic features can help prevent dissatisfaction by ensuring these features meet or exceed minimum requirements. Ultimately, by leveraging the insights provided by the Kano model, businesses can design products and services that not only meet but exceed customer expectations, leading to improved user behaviour such as increased engagement, loyalty, and advocacy (Hartono & Chuan, 2011).

3.2.3 Kansei Engineering

Kansei Engineering is a methodology used in product design and development to incorporate users' emotional and psychological responses, known as "Kansei," into the design process. Originating from Japan, "Kansei" refers to the intuitive and emotional aspects of human perception and experience. Kansei Engineering aims to understand and quantify these subjective feelings and preferences to create products that resonate with users on a deeper, emotional level (Schütte, 2005).

The process typically involves several steps:

1. **Identification of Kansei Factors**: Researchers gather data through surveys, interviews, or observational studies to identify the emotional attributes or qualities that users associate with a product or experience. These attributes could include feelings like comfort, excitement, security, or aesthetics.

2. **Translation into Design Elements**: The identified Kansei factors are then translated into tangible design elements or features that can be incorporated into the product. For example, if users associate comfort with a car seat, design elements such as cushioning material, seat contour, and lumbar support may be adjusted to evoke that feeling.

3. **Experimental Design and Evaluation**: Prototypes or product variations are developed based on the identified Kansei factors, and user evaluations are conducted to assess emotional responses and preferences. These evaluations can range from subjective surveys to physiological measurements like heart rate or facial expressions.

4. **Iterative Refinement**: Based on the feedback received, design iterations are made to further refine the product to better match users' emotional needs and preferences. This iterative process continues until a satisfactory design that elicits the desired emotional response is achieved.

Kansei Engineering can influence user behaviour by creating products that evoke specific emotional responses, leading to increased user engagement, satisfaction, and brand loyalty. By understanding and addressing users' emotional needs and preferences, products can establish stronger emotional connections with users, motivating them to choose and continue using the product over alternatives (Schütte, S., Mohd-Lokman, A., Coleman, S., Marco-Almagro, 2023, Hartono & Chuan, 2011). Additionally, products designed using Kansei Engineering principles are more likely to elicit positive word-of-mouth recommendations and foster a sense of attachment or affinity among users, further influencing their behaviour towards the product.

3.3 Strategies for Creating Customer Acceptance and Delight

User-Centered Design: Central to fostering customer acceptance and delight is the principle of user-centered design, which emphasizes the importance of empathizing with users, understanding their needs, and involving them throughout the design process. By conducting user research, gathering feedback, and iteratively refining prototypes based on user input, engineers can ensure that products are aligned with users' preferences, behaviours, and aspirations, thereby enhancing acceptance and satisfaction (Norman, 1998).

Emotional Design: Incorporating emotional design principles into product development can evoke positive emotions and foster delight among users. Elements such as aesthetics, sensory appeal, and storytelling can imbue products with personality and charm, eliciting emotional responses that deepen user engagement and attachment. By considering the emotional impact of design choices, engineers can create products that resonate with users on a profound level, cultivating lasting connections and driving brand loyalty (Eyal, 2014).

Surprise and Delight Features: Introducing unexpected or innovative features that go beyond users' expectations can spark delight and intrigue, setting products apart from competitors and enhancing user satisfaction. Whether it's hidden Easter eggs, personalized touches, or whimsical interactions, surprise and delight features create memorable experiences that leave a lasting impression on users, fostering a sense of delight and excitement (compare Eyal, 2014).

4 PRODUCT EXAMPLE

The redesign of a warehouse truck serves as an illustrative case study showcasing how product design can influence user behaviour:



New design of the control console

Figure 2. Image of the example fork lift truck (Schütte, 2002).

Forklift trucks, ubiquitous in warehouse settings, historically posed significant safety risks, leading to injuries and fatalities. Collaborative research between Linköping University and a major forklift manufacturer aimed to understand drivers' subjective attitudes towards these vehicles, utilizing visual analogue scales and Kansei Engineering methodology (Nolimo & Eklund, 1999; Schütte, 2002). Drivers' perceptions of safety and speed were measured, revealing a discrepancy between their internal sense of safety and external reality.

The study found that drivers perceived significantly higher levels of safety and lower speeds while operating the vehicle compared to observers outside (Nolimo & Eklund, 1999). This misperception contributed to accidents, exacerbated by time pressures and collaborative work environments. In terms of the theory of planned behavior the drivers seemed to lack perceived behavioral control due to that they seemed to deem the behavior of driving safer out of their control. Attempts to mitigate risks through electronic speed limiters were also met with resistance and were seen as intrusive (Nolimo & Eklund, 1999). However, it seemed that drivers still were aware, and hence had the attitude, of that their driving behavior was risky partly through their subjective norm influenced by the observers statements of them driving too fast.

Subsequently, researchers and engineers sought alternative methods to encourage safer driving behaviours. Leveraging Kansei Engineering, features within the driver's cabin were identified as influencing subjective perceptions of safety and speed. Modifications were made to the cabin design, including lowering the overall height of cabin walls, streamlining the driving console for a sleeker appearance, and incorporating brighter interior colours to enhance how much of the external environment could be seen from the driver's seats (Schütte, 2002).

The changes made to enhance external visibility can be understood as nudges to increase the pro-social behavior of driving safer. Results showed a 10% reduction in average driving speed on test tracks, while drivers maintained a similar perception of speediness and efficiency (Schütte, 2002). Since drivers maintained their perception of speediness and efficiency the nudges for the behavioral change can therefore be understood increasing the behavioral control of driving slower while at same time being non-manipulative and non-intrusive. By addressing subjective

perceptions through design modifications, the redesign successfully influenced driver behaviour towards safer practices, highlighting the potential of Kansei Engineering and using psychological constructs of behavioral change in enhancing user safety and experience.

5 DISCUSSION AND CONCLUSION

By examining the interplay between user behaviour, product design strategies, and the adoption of novel technologies, this section aims to offer insights into fostering customer acceptance and delight in the landscape of consumer goods.

One of the central themes that emerged from this study is the paramount importance of the user-centered design paradigm in shaping user behaviour towards products. By prioritizing empathy, understanding, and collaboration with end-users throughout the design process, product designers can create offerings that resonate with user needs, preferences, and aspirations. The findings underscore the effectiveness of user-centered design in enhancing customer acceptance and satisfaction, thereby driving adoption and loyalty.

Building on the foundation of user-centered design, emotional design principles emerged as a key strategy for eliciting positive user responses and fostering delight. Incorporating elements such as aesthetics, sensory appeal, and storytelling into product design can evoke emotional connections with users, deepening engagement and loyalty. The study highlights the transformative potential of emotional design in creating memorable experiences that leave lasting impressions on users, ultimately influencing their behaviour towards products.

Furthermore, the study underscores the significance of surprise and delight features in differentiating products and enhancing user satisfaction. By introducing unexpected or innovative features that exceed user expectations, product designers can create unique value propositions that resonate with users on a profound level. These features not only enhance user experiences but also cultivate brand loyalty by fostering positive associations and memorable interactions.

The case study examining the redesign of a warehouse truck provides tangible insights into the application of these design principles in real-world contexts. By leveraging Kansei Engineering methodology, researchers were able to identify features within the driver's cabin that influenced subjective perceptions of safety and speed. The subsequent design modifications aimed to encourage safer driving behaviours without compromising efficiency, resulting in a tangible reduction in average driving speed on test tracks. This case study serves as a compelling example of how user-centered design strategies together with psychological constructs of nudging and the theory of planned behavior can be effectively employed to shape user behaviour towards safer practices.

In light of these findings, several implications and recommendations emerge for product designers, manufacturers, and researchers. Firstly, there is a clear imperative to prioritize user-centered design principles in the early stages of product development, ensuring that products are aligned with user needs and preferences. Additionally, the integration of

emotional design elements and surprise and delight features can significantly enhance user experiences and drive customer acceptance and loyalty. Furthermore, the case study highlights the potential of Kansei Engineering methodology in identifying design features that influence user behaviour, offering a promising avenue for future research and application in product design.

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ABSENCE PORTAL

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ABSTRACT

Absence may not be an emotion, but it precipitates emotion. Absence and presence are transcendent philosophical themes. It is easier to argue for presence, given that we maintain presence in the world. As for absence, debate has been more varied. In this paper, we acknowledge presence, but we also present some standing arguments which recognize substantiality of absence as an operant or a force in the world. To that, we add an argument of a transactional relationship between absence and presence, where absence plays a *completing* role in noumenal transaction between person and world. In that role, absence (through suspension or emptying of self) enables passage into a space of presence that is revealing.

Keywords: absence, presence, emotion, Δ^+

1 INTRODUCTION

You cannot shave a man's head in his absence.¹⁰

This keen figuration sets the absence-presence question into a combustible dialectic. In it, absence and presence are locked in an accusative altercation, where the latter seems to direct provocation at the former. Yet, the confrontation is mixed. Eminent thinkers such as Henri Bergson defy the idea of nothingness ("positive nature of reality preempts nothingness" [see Sorensen. 2022]; experience of annihilation of some particular thing does not legitimize annihilation of everything [Richmond, 2007]) while others such as Jean-Paul Sartre attempt to challenge the Bergsonian position--despite challenges to Sartre's own arguments (there is reality to the idea of nothingness; experience of seeing that Pierre is not in restaurant is not the

⁹ The saying belongs to a West African ethnic group. It has been reproduced here true to its native, gendered formulation. Obviously, it speaks to the woman just as well. (Thanks to the translator.).

same as seeing all these other people in the restaurant--even though Pierre is not there [Richmond, 2007]). For Kitaro Nishida, there is an "'absolute nothing'...upon which all being is predicated" (Krummel, 2018, p. 240) (nothing is not utter nothingness; it is a space of emplacement--room for determinate, mutually distinct beings and causal interactions between things with form [Krummel, 2018]; there must exist a space of encompassment, in which something lies [Abe, 1995]). "To great dreamers of...holes," wrote Bachelard (1994), "nothing is ever empty" (p. 140). As for John Dewey, some form of caution sets in (formal laws are "applicable to formal or non-existential subject matter;" when universal and particular propositions are in play, "the latter alone are existential in import [while] the former [are] hypothetical") (Garrison, 1999, p. 353).

In this paper, we will ultimately turn our attention to negotiating absence. In particular, due to the nature of her work, a designer should be aware that she will likely confront some form of absence (of information) and she ought to be prepared to navigate her way though it. Many design problems present as a *wicked problem*. Each represents an open system and the designer is "caught up in the ambiguity of [its] causal webs" (Rittel & Weber, 1973, p. 167) Parameters of the problem are uncertain. So, an absence is established.

Although absence is not an emotion, it could be argued that it shares some characteristics with emotions. For instance, absence is something experienced, as is emotion (American Psychological Association [APA], n.d..). Also, as emotion has "an overt or implicit engagement with the world," (APA), so, it can be argued, does absence. Roberts and Krueger (2021) observed that an emotion can be directed at "a perceptual or quasi-perceptual state" (p. 186).

Moreover, absence of an object or feature can trigger certain emotions. Roberts and Krueger (2021) argued that some emotions are responses to absence--e.g. surprise at lack of good books in the library. Emotions respondent to absence could include yearning, nostalgia, hope, and anticipation. Absence of information creates an information gap, observed Golman and Loewenstein (2018). They added: "When a person is aware of a specific unknown, it often attracts attention and evokes emotions" (p. 143). In the case of designing, anxiety/frustration might result from absence of information. The pattern of emotion is often complex, however, with one experience leading to another (APA, n.d.; Roberts & Kruger, 2021). So, for instance, the frustrated designer mentioned above might resort to an evaluative judgement about potential failure of the project and might become increasingly anxious.

Absence of information can be sourced in many different things. In this paper, we frame it around a client--a protagonist--about whom the designer seeks information to complete a design task. First of all, however, we will briefly examine the two ideas, absence and presence.

2 ABSENCE

2.1 Conceptions of absence: Perceptual, cognitive, affective

A commonly-held point of view is that absence can be experienced. Farennikova (2013) argued that we are able to *see* absence--as happens when one expects to find an object in a

place and it is "seen" not to be there. In that case, experience of absence could be argued as *perceptual*. A perceptual absence is known directly through experience (Mumford, 2021). Gow (2020) took issue with the perceptual view, arguing that experience of absence is a particular type of *cognitive* experience which is effectively described as more than just sensory experience. Mumford (2021) described cases involving an expectation as cognitive cases. One cannot perceive what is not there, he explained, but one can make an inference or deduction from what is seen (i.e. that what could be *is* absent). Gow argued that the particular cognitive type is an *intellectual seeming*.

Another view of absence is as follows: The case of not finding an object where it is expected to be found is one where surprise is evoked. Insomuch as the experience is one of surprise, then it is not perceptual, but *affective*. This is the view proposed by Martin and Dokic (2013). They presented it as a *metacognitive* account. Each of the foregoing positions has had arguments presented against it. Here is not the place to probe into those.

After exploring the perceptual and affective positions, Abath (2019) also introduced a type of absence--which he characterised as a *frustrating* absence. The frustrating absence is indicative of a case where a desire is thwarted by absence of a thing in the world. For instance, an actor desires to find a *pain au chocolat* which she had already eaten (and knew it) in a bowl--just wishing it might be there again to be enjoyed--but on opening the vessel, finds it empty. It is a case of non-surprise, but frustration nonetheless. It is a frustrating absence. It can be argued that Abath's might be a special case of one of the types already discussed.

2.2 Absence: Fit within a mathematical paradigm

An analogue of nothingness is the number zero (0). Zero can be seen as exhibiting a dual nature: it is a legitimate cardinal number (which one can use meaningfully for computation), but it can also be understood as representing nothingness (Barton, 2020). The latter, a phenomenological accounting, according to Barton, is supported by such an algebraic structure as one which yields that, for quantity, x, then x + 0 = x. It is evident, noted Barton, that this phenomenological account of zero is cast in tension with the other account mentioned earlier, which places zero on an ontological par with other finite cardinal numbers. That conception of zero can be supported with the argument that mathematics can be conceived as a structure. Zero, then, is a position on/within that structure (e.g. of natural numbers), much as are the other numbers in the structure. A phenomenological account is, however, Barton argued, still able to stand without contradicting the ontological. Drawing on Sorensen, Barton noted that some absences have determinate sensible qualities (e.g. gaps, shadow, holes) while others do not (e.g. silence: "there is no concrete positive sensation accompanying a token of silence, as there is with seeing darkness or feeling cold" [p. 3840]). Yet, in the latter case (e.g. silence) zero is locatable ("I can...hear silence in the cockpit of an unconscious pilot who has left [her] microphone on" just as I can "have an experience of zero sandwiches in the hamper" [p. 3841]). It is also detectable (I can install a device on a box such that it emits a sound when the box is empty. In that case, I can "detect an instance of zero [nothing in the box]" [p. 3841]). Barton noted the foregoing as akin to Farennikova's model of absence perception (see Farennikova, already discussed above)--which he described as absence perception where absence is

understood through a *mismatch* (e.g. I go to pick up my keys in their usual location. In my working memory, I draw upon a rough visual template of my keys in their physical context. I project that vision onto my current surroundings. The template does not "project accurately onto my [visual] surroundings" because, this time, the keys are not there. I become aware of a mismatch between the expectation drawn up through my working memory and the current world around me.) Thus, both the ontological account and phenomenological account of zero can coexist. Barton wrote:

Farennikova's Mismatch Model can be adapted to the current case to provide an elegant interpretation of perception of instances of zero. In a situation of numerosity perception we are projecting possible numbers of objects to be (possibly approximately) matched. In perception of a token occurrence of zero...[we] recognise an instantiation of zero and distinguish it from instantiations of the positive finite cardinals. Thus, in addition to understanding zero as a property which can be experienced via number cognition we can also understand...via perception of absence. (p 3841)

In the foregoing, Barton wished to make the claim that "cognition of zero can be understood as a species of absence perception" (p. 3825). He went on to address (and offer a counter to) objections which might be raised concerning his proposition. The interested reader is invited to explore those at the source.

2.3 Absence: Fit within an artistic paradigm

Walsh (1992) made an eloquent case for a "something 'more missing'" (p. 69). This is not about the perceptual absence case, where a thing identified is missing (e.g. as noted above, an object not in a place). Neither is it about affective absence--which also turns on an identified thing which is not there and thus surprises the protagonist. It is, yet, not of the frustrating absence type, where, once again, a thing--which is missing--has been defined. The "something more missing" transcends the identified; it rests on our capacity to wrestle with the "incomprehensible"--depicted as so because we are not certain what it could have been. It is as, Walsh quoting Theseus, granting habitation and a name to an "airy nothing" (p. 70).

Walsh (1992) employed a phrase--which he did not pursue aggressively, but which should be perceived as illuminating: "the esthetic generation of uncertainty" (p. 69). In this, the arts, given to creative enterprise, can thrive. Take a visual art such as sculpture, for instance. Using the *Venus de Milo* as an example, Walsh argued that "the statue has not only ceased to be a stone but has, in part, ceased to be anything at all" (p. 72) as a result of the incomprehensibility of what her missing arms (and left foot) as well as "unprecedented spiralling twist of the torso" (p. 72) would have made the statue depict if we had seen them and understood them. Its omissions have "[granted] emptiness a home" (p. 73). The statue, with its incomprehensible parts, is no longer "defined by compass and measuring wand;" it has transitioned "from that which is representable to the senses [to] that which is not" (p. 72). This, he added, is an instance of "nothing-made-visible" (p. 72) or, if one might re-arrange it, a *lending appearance* to what is not comprehensible (absent to mind, at least).

In literature, another creative art form, written words are "islands of coherence rising out of" a vast, unintelligible background (Walsh, 1992, p. 79). Writers add to the mystery. They use words to create suspense; they capture (and inspire about) what cannot be said with "inked scratches on a page;" narratives fade into shadows (p. 81). In music, absence may also be described. The composer places sound in the vast unknown of silence and then strategically utilizes silences to punctuate flows of sound as states "pregnant with unrevealed significance" (p. 83).

We are born into uncertainty, wrote Walsh (1992). The human condition is fundamentally liminal in nature, "a suspended state of 'radical incompleteness' where we are 'always on the borderland of a something more'" (quoting Wheelwright, p. 77). Art is a powerful mode of expression by which we embody that incomprehensible state and space "where potential is never arrested and never completely fulfilled" (p. 77). Omissions and suppressions found in artwork, these "obscurities [which are] inseparable from esthetic effort, are not simply stock effects injected into a work, but arise from within as inexorable byproducts of creative endeavor" (p. 78). Once that absence has been made conspicuous, we are "forced to accommodate some degree of uncertainty in our interactions with [the] larger entity of which the absence is a part" (p. 79).

2.4 Absence and cause

It is easy to conceive of an object as having effects associated with it-- i.e. an object being a cause. Can absences be causes? Tiehen (2015) described an "ontological problem for the view that absences can be causes" (p. 507), a challenge by some philosophers, against the view that absences could be causes (or effects). Causation, they argue, is "a relation between actual events" (p. 507). Actual events can be described as things which happen. Absences, on the other hand, can be described as things which do not happen. In that case, absences are not actual events. Since causation, as expressed above, is a relation between actual events, then it is not possible for absences, which are not actual events, to be causes. It should be quickly noted (which Tiehen does) that this is just one position and it is controversial in its own way. For sake of argument, however, we can use it to question production of a thing, an outcome, absent its "cause." It is the problem we are exploring in the current paper--that absence of a protagonist might just likely result in an effect which we will ascribe to that absence-of-protagonist and which, we suppose, will be different from effect caused by presence-of-protagonist. In effect, in designing, what we say we have designed for an actor--which we claim is to fulfil her desire--in absence of that actor could be different from what would have resulted as a solution in presence of the actor.

3 PRESENCE

3.1 Presence and cause

Henri Bergson, recalled Sorensen (2022), "maintained that the positive nature of reality pre-empts nothingness" (n.p.). It is existence of a fact of something (e,g, Trees have roots.) which makes absence of roots on trees conceivable. Otherwise, there would not be need to think about roots on trees. The fact allows the negative to be derivable. In anticipation of
our project in this paper, if one took hold of the foregoing line of argument, one could argue that the possibility that a human (our client-to-be) exists first is a reasonable proposition.

Sorensen (2022) also recollected for the reader an argument by van Inwagen that we are interested in concrete things--e.g. a speck of dust. Such things, continued Sorensen, are part of the causal order. Abstract entities, by this line of reasoning, "do not cause anything" (n.p.).

We would like to extend that thought to some non-concrete things--in particular, human desire. As a person with a desire is bounded naturally (and we would add, *uniquely*, to herself--since the boundary is "caused" by existence of the person), so desire of that person, unique to her, is bounded by the person who has "caused" that desire. Given that--with an eye towards our eventual turn in this paper--it becomes ill-advised to ignore, diffuse or diminish the import of that particular desire when considering the case of that individual as an actant in the world.

3.2 Body as *axis* of orientation

Philosopher/phenomenologist Edmund Husserl described body as the zero point of orientation for pure ego (Sawicki, n.d.; Sheets-Johnstone, 2019). The body is to be seen as a "spatially anchored relation of consciousness to its surrounding world" (Sheets-Johnstone, 2019, p. 33). Speaking allegorically, we present that surrounding world--proximate space--as representing a first level of presence -- the one which is essential for giving location to or containing what is present and thus makes that thing identifiable--sensorily or intellectually. That space is unique in its configuration to the thing it exists to reveal and, to the extent that it can be defined, can be seen as a representation of the thing. A second level of presence is, of course, the subject of interest itself--a person, an object, an idea, and so on. We invite the reader to consider here that, for our current project, the more critical dimension is consciousness over physical body; it is the mind-being-realized which is the engine of lived experience. It is to that to which we would like to draw attention: While a body signifies physical presence, it is the mind which it contains which extends presence beyond a moment of a thing (the object in space; the germ of idea) to an energetic conception of (lived) experience with its desires/goals/aspirations.

3.3 The mediated environment: non-corporeal presence in the 20th and 21st centuries

3.3.1 Agent affirming its own presence

Today, we recognise varying discourses surrounding capability to live trans-corporeally--whether those involve investigations into consciousness, reflection, virtual reality or other discourses. We can, as it were, project some of our own abilities onto some other agent which we have chosen to play out those abilities. In terms of characterising that other body, especially in discourses within the cybernetic domain, we often employ the concept of embodiment.

Embodiment, wrote Krieger (2005) is a multilevel phenomenon which "entails the interplay between bodies, components of bodies, and the world(s) in which the bodies live" (p. 351). Blanke and Metzinger (2009) described embodiment (at least, as used in cognitive science and

philosophy of mind) in terms of "the relevance of sensorimotor skills for general intelligence, the situatedness of cognition and the role that the body has in shaping the mind, plus the subjective experience of using and 'having' a body" (p. 7). These insights help to frame Kilteni et al.'s (2012) description of a sense of embodiment by person, A, towards a body, B (or as perceived in the environment provided as/by B), as "the sense that emerges when B's properties are processed as if they were the properties of one's [i.e. here, person, A] own biological body" (p. 375). For us, in all of these, a significant note is that a person's engagement of B is mediated by a foundational knowledge, which is a reality: "I know I own a body." Doubting that is not an option.

3.3.2 Agent affirming its own body

From an experimental study which attempted to understand the relationship between a person's virtual embodiment within a visually-framed virtual reality (VR) environment¹¹ and that person's perception of body (through a sense of control of own body and experience of bodily interaction with objects within that VR space), Cho (2022) drew some conclusions. Here are two:

1. When subjects were provided with a virtual hand with which to grab an object, they felt less difficulty than when they were not provided with a virtual hand. Presence of a hand, though just an image, made a difference.

2. While both sense of body ownership and sense of agency were important for effective personal engagement with objects in a visually-framed virtual world, sense of body ownership [an acting owned body] was a more powerful embodiment factor.

Gall et al. (2021) found out in a study that, in a condition where embodiment is perceived as high (i.e. participants mentally strongly connect the virtual body with their own real body), participants experienced higher arousal, dominance and more intense valence than they did in the low embodiment condition. The authors indicated that the illusion of virtual embodiment had impact on human cognitive processes. One could re--interpret the foregoing as follows: Perception of a body which we take to be our own has impact on how we become engaged with the environment around us. They wrote that "presence of a body in a particular environment might increase the relevance of that environment to one's goals" (p. 7).

4 INCORPORATION OF ABSENCE AND PRESENCE

4.1 Absence as object of desire

Philosopher Simone Weil's dialogues on absence offer some points of reflection on a teleological implication of absence. They open up a conversation about functional roles which can be served by absence.

¹¹ Other relevant terms, when it comes to computer usage, are presence, synthetic presence, virtual presence, social presence, ego presence, telepresence: they implicate "an experience that appears to involve displacement of the user's self-perception into a computer-mediated environment" (Draper et al., 1998, p. 354).

In a comparative paper, Pirruccello (1995) provided analysis of Weil's meditations on absence. First to note here is Weil's initiation of the idea of *attention* into her ruminations. Attention is "the activity of waiting [or] of expecting" (p. 61). As will be revealed in a moment, Weil conceived of this waiting or expectation in a way which embodies self-diminishment. In Weil's conception (and she approached it from a spiritual sense), the object of faith or object of desire itself--the one to which one directs attention--has to be a nonbeing, a "nonexistent." She also added that "the subject and object of attention must be identical" (p. 63). Thus, the action of attention is congruent with the action of faith (or desire)--which is the guiding of the individual to itself (i.e. the teleological object). For our purposes, then, we recognize that there is a desire to which a protagonist aspires. The end of that desire is absence and the path to that desire involves manifestations of absence (waiting, expecting, self-diminishment).

Moving towards [true] desire has to be a journey through absence. The reason, for Weil, is very clear: the journey towards purity at the end (i.e. faith itself, which is object and action which leads to it) cannot be encumbered by diversions or protagonist's self-referentiality--if agent is to arrive at purity that lies at the end. Distractions of the world surrounding the protagonist, and even self of the protagonist, cannot get in the way. Absence (or nonexistence) of the object of attention or faith or desire means it "cannot be possessed or in any way supportive of the ego-self's illusory being" (p. 63). Other compromising constitutives of the self and the world around cannot be allowed to interfere when focus should be on purity of object of attention or desire. This clarifies the matter of diminishment of self to which we made allusion earlier.

Here, we will provide a relevant twist--an apparent twist which, in end, is not about substance but just articulation. Weil's argument for absence might appear to contradict our own argument for presence, which we have made in this paper. We invite the reader to consider it, however, in this way: Things such as normative goals and standards, generated by context within which a person exists, are constraints which, with a hold on a protagonist's thinking, either yoke her desires to what is dictated by those norms and standards or limit those desires. The protagonist who, through awareness of a self and its competing, dueling contextual constraints (which work to limit self to only certain "normative acquirable goods"), empties herself of those constraints is able to be liberated to arrive at an extra-normative space and dwell (revel, marvel, bask) in the "richness" of that "good" to which the *unique* self is attuned or with which it is aligned. So, absence is anteceded by recognition of a presence here (which has both unique and normative characteristics) and a pure (ideal) presence beyond (which has been freed of encumbrances of normative characteristics). Moving from the former to the latter involves an emptying. For the protagonist, emptying could be of two forms: either an emptying which involves shedding normative limitations or an emptying which involves complete evacuation of self so as to allow self to be a vessel ready to receive self afresh. For a designer who is ministering to the protagonist, only the self which taps the post-emptied self (of the client) leads towards solution-as-ideal. How does it work?

4.2 A theory of evanescent absence: Δ^+ and absence that sees beyond

The designer passes through a portal (or, aptly, a designer's unique insight is threaded

through a portal). The threshold is but a fleeting moment, yet it is requisite. That portal is *absence--*a "space" where the designer does not possess (is missing) vital knowledge and, herself, must suspend self in order to unify with the purity of narrative of the client's desire on the other side.

At this point, it is necessary to deploy an illuminating mathematical abstraction. Imagine time itself as a variable which tends to zero, so itself being subject of the derivative based on itself. Absence is as $t \rightarrow 0$ (i.e. t tends to zero).

A designer's transactions with a client in setting the design problem takes place in time. It matters here not if transactions take place over an hour or weeks. There comes a "space" which is beginning of cognizance (apprehension, discernment, understanding) of the client's uniqueness (or unique desires). That is the portal. Time is essential as a construct insomuch as there is movement from non-knowledge of desire to knowledge of desire. It requires time to translocate.

In that threshold, absence, itself, manifests in a space of *almost-absence*, a space where time (and absence) tend to zero. It is too fleeting, too imperceptible, for the human to delineate it, but we are able to represent it by means of the derivative concept--where time does not quite stand still (because it does not), where there is hardly enough "space" to contain anything and which serves as a form of explicans. In a way, it is as Heidegger's bridge which gathers the earth as banks of the river and thus renders the banks intelligible.

For a designer in our station, absence is transitory. Absence is a gate to beyond. For a designer, absence is as Δ^+ . In passing through it, the designer tips into the client-obtained, absence-sublimed singularity which is what is on the other side--the space of desire which is consequence of the client's own purification act. Beyond the portal, then, there is another presence--this time, presence which is instantiation of desire--the client's desire which the designer wishes to access.

Absence is a cause in designing to fulfil desire (i.e. absence is an essential ingredient). Absence completes delivery of desire. It is a completion because, in designing, while it is possible for the designer to correctly speculate on some of the desires of the protagonist/client, there is absence of the unknown-unique. So, some of desire could be fulfilled without need of presence of the protagonist. It is not possible, however, to have foreknowledge of all a protagonist's desires. If it were possible to do so, then the idea of uniqueness would be rendered mute. Uniqueness exists because an agent's characteristics are inherent, tied up in the agent, and because only the agent is capable of delivering all of them.

There is an absence which is essential, revelatory, but transitory. On both sides of it, there is presence--presence which is durable and is therefore pragmatic. In that, we assert the essentialness of presence--presence which is a cause, which, on one side, is a zero point of orientation while, on the other side, is unique identification--presence which is enactment of affirmation and is vital for realizing solution to a design problem that is sourced in human desire.

5 CONCLUSION

In this paper, we have assumed the position that presence is not repudiable. We have also argued, however, for a revealing and completing role of absence. Presence is elucidated and illuminated by absence. Critically, we have provided articulation for an elusive concept--an imperceptible, fleeting moment (the *portal*) through which a successful designer passes.

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PERCEPTUAL CLAIM ABOUT PERFORMANCE ON READING A GRAPH, BASED ON A SIMPLE ASSESSMENT: PILOT STUDY

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ABSTRACT

We wanted to examine the verity or falsity of a perception: a claim of improvement in ability to read a graph. This was a specific narrative graph we had created. In this paper, we use the term, narrative graph, to represent a multivariate, composite graph that illustrates a phenomenon or phenomena across a historical time line. It is not a new form, as can be seen in Minard's well-known 1869 illustration of Napoleon's military campaign to Russia in 1812. We used four participants as models who scored their perceived ability to read a graph pre- and post-intervention. The intervention was a brief tutorial over the graph. We built their data into an agent-based model. Our results were mixed. Perceived qualities such as self-efficacy and self-confidence are relevant constructs when considering performance of mathematics tasks.

Keywords: perception of ability to interpret graph, narrative graph, self-confidence

1 INTRODUCTION

In an earlier project aimed at illustrating stories with graphs in order to expand the orbit of graph literacy, we created an integrated narrative graph to depict a well-known fable by the celebrated Greek writer of fables, Aesop. The tale we chose was "The fox and the crow" (Library of Congress, n.d.). We extracted quantities from the tale and used those as multiple bases for constructing our graph. The idea of such a narrative graph (or graph system) is not new, as can be seen in Charles Joseph Minard's well-known illustration of Napoleon's military campaign to Russia in 1812 (Jones, 2019). For this paper, we presented our narrative graph to a small group of subjects, described it, asked them to re-describe it. We observed if they were

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able to read the parts correctly and observed on a simple self-assessment scale if the simple intervention had any effect on their perception of their ability to read a graph.

2 PERCEPTION OF PEFORMANCE

First, we will briefly examine two constructs that contribute to explaining self-evaluation of performance: self-confidence and self-efficacy.

In a review of literature, Oney and Oksuzoglu-Guven (2015) identified various definitions of self-confidence. We reproduce several of them here.

Self-confidence is:

- "an individual's certainty about his or her abilities" (after Vealey, 1986).
- "a feeling of assuredness and lack of anxiety" (after Compte & Postlewaite, 2004).

• "a favourable opinion an individual holds about the estimation he makes under uncertainty" (after Guennif, 2002).

Oney and Oksuzoglu-Guven (2015) also presented a conceptualisation of confidence which describes it as a projection of hope, self-efficacy, optimism and resilience (after Stajkovic, 2006).

Since graphing is associated with mathematics, self-confidence in mathematics may be defined. Schuh et al. (2023) defined self-confidence in mathematics as an expression of how well an individual believes she/he might perform on a mathematics task. Confidence, broadly, in the context of studying mathematics may be seen as a general concept of an estimate of how well an individual expects to be able to learn and perform mathematics tasks (Morony et al. & Kiwanuka et al. in Schuh et al.).

In terms of confidence, an interesting view is that it is possible that self-assessment of one's own capabilities are inflated. Johnson and Fowler (2011) not only recognised presence of overconfidence, they argued for an evolutionary basis of it among humans. Fundamentally, they argued that, under plausible conditions, overconfidence could be advantageous in that it can increase resolve, ambition and even persistence (because it could become a self-fulfilling prophecy). The authors were not extolling overconfidence, though. They cautioned that it bears bore risk and could lead to hazardous decisions.

Another useful and related concept is self-efficacy. Self-efficacy is "confidence in one's ability to successfully complete a specific task" (Jameson et al., 2022, n.p.). According to Bandura (2001), perceived self-efficacy forms a partial basis of decision on challenge one chooses to face, how much effort one will expend on the challenge and also perseverance in tackling the challenge. In mathematics, for those who experience mathematics anxiety, a specific type of self-efficacy, called emotional self-efficacy, might mediate mathematics anxiety and mathematics performance (Jameson et al., 2022).

3 GRAPHING AND COMMUNICATION

Spatialization is a form of information visualization where information is depicted in a spatially-extended way (Montello et al., 2004). Graphs are a form of spatialization. Data, which are abstractions, are organized in terms of their interrelationships and then they are "graphically...rendered for visual examination and exploration" (p. 317).

Graphs are inscriptions--i.e. "representations which exist in material form (e.g., paper, computer screen") and can therefore be shared by several agents...[as opposed to] mental representations, which are not accessible" (Roth & McGinn, 1998, p. 35). An inscription, wrote Roth and McGinn, is a constructed semiotic object which has a relationship with a referent for which the former stands as a sign. It is essential to make that relationship one that is understandable to the reader.

According to Kosslyn (1989), graphs are developed at different levels: syntactic, semantic and pragmatic. At the syntactic level, attributes afforded by the graph element (a symbol) are used to effect (e.g. lines can be given different colours). The semantic level is used to communicate information about what the element is supposed to represent (e.g. multiple lines can represent multiple variables). At the pragmatic level, symbols communicate information beyond their semantic representation (e.g. non-parallel or crossing lines of a factorial design graph signal an interaction between variables).

Healy (2019) observed that graphing is a visual representation of data and not a mechanism that magically transmits pure understanding of what it means to a viewer. Graph makers should consider effective ways for image to transport the viewer back to the data (p. 23). Healy portrayed a viewer's encounter with a graph as a decoding operation that the viewer performs in order to understand content embedded in the graph (p. 25).

4 SAMPLE PARTS OF OUR NARRATIVE GRAPH

In *The fox and the crow*, fox, hungry, roams across the landscape in search of food. In all likelihood, fox, across time, experiences some ups and downs. We depict two of those in figure 1--hope as a positive thing, despite its rise and fall, and hunger pang as a painful, negative thing (also rising and falling).



Figure 1. (a) Across time, fox's hope of finding (or acquiring) food rises and falls. (b) Equivalently across time, fox's hunger pangs grow and ebb.

When fox finds crow, fox approaches and begins to adulate crow. After some time, crow is flattered enough to attempt to sing--with subsequent costly consequence and ensuing silence. Their vocalizations are depicted in figure 2--fox and crow, respectively.



Figure 2. (a) Fox speaks. (b) Crow responds.

5 OUR MODEL

5.1 Introduction

Four participants were individually asked to perform a graph description task. The narrative graph was created by the author and depicts the fable, *The fox and the crow* (Library of Congress, n.d.). To begin, on a simple scale (0 = "I do not understand graphs at all" and 10 = "I can absolutely, fully well understand a basic graph") each participant scored self in terms of perception of ability to describe/interpret graphs. One score was done pre-intervention (intervention = evaluator's description of narrative graph). Then the evaluator described the graph and its parts. The evaluator allowed for questions to be asked. Then the subject was asked to perform a simple distraction task which lasted between four and twelve minutes (e.g. rounds of tic-tac-toe with an accomplice; building a structure with Lego bricks). Note that this distraction is not so much to create cognitive contrast on the task than it is a simple memory rupture to attempt to destabilise recency.

narrative graph. During this time, the evaluator used a measure which included features of the graph which had earlier been described by the evaluator to assess how many features the participant described/interpreted correctly. There were eleven items. Finally, each participant was asked to score self again on a fresh copy of the same perception scale used pre-intervention.

Using data collected, a model was built (Netlogo, 2020). It contained four human agents representing our four participants. It also contained the eleven features/questions on the evaluator's measure. In the model, human agents encountered graph features and a score of correctness on interpretation, based on data observed earlier, was recorded for each encounter. The model was run 30 times, each run lasting 30,000 time-steps. That yielded nearly one million (actual = 900,000 data points per HM on every PV, or 9,900,000 data points per HM in all). (See section 5.2.1 for definition of HM or PV.) With all four HMs, 39,600,000 data points were used in the analysis. Details of the model and usage are provided below. A final assessment was made to determine if the model output supported each participant's claim of perception of improvement or not in interpretation of the graph.



Figure 3. Model environment

5.2 Model rules

5.2.1 Definitions

Human model (HM): For this pilot study, four participants were used. Each participant completed roles described above.

Graph: The graph used in this pilot study was a "narrative graph." It attempted to re-create a well-known fable by Greek writer, Aesop, as a graphical narrative by extracting quantities from the fable to generate simple plots. The chosen fable was *The Fox and the Crow* (Library of Congress, n.d.).

Evaluator measure: The evaluator used a tool with eleven (11) items to assess HMs' description/interpretation of the graph. Each item was a graph feature that was explained to HM during intervention and which HM attempted to describe/interpret correctly post-intervention.

Provocateur (PV): For the model, provocateur described an item on the evaluator's measure. (They are to be considered "good" provokers of thinking/interpretation.) Each item was a description of a component of the graph that was to be interpreted. There were eleven (11) PVs in all.

Human model (HM) self-assessment of graph description/interpretation ability: A simple scale (0 - 10; 0 = "I do not understand graphs at all" and 10 = "I can absolutely, fully well understand a basic graph") was completed by each participant prior to intervention. After evaluator's intervention measure had been completed, the HM scored the same scale again. We observed if self-assessment score remained the same or not. Results were as follows:

Participant change on score from pre-intervention to post-intervention:

HM-1: 7 -> 10 HM-2: 10 -> 10 HM-3: 5 -> 7 HM-4: 6 -> 7

5.2.2 Base parameters

HUMAN MODEL CONVERSION FACTOR

- 1. Number of items on evaluator measure = 11
- 2. If number of items HM-1 scored on evaluator measure = 8.5
- HM-1 value on evaluator measure (HM-1_VEM) = 8.5/11 = 0.77
- 3. HM's score change from pre-self-assessment to post-self-assessment:

If HM-1's perceived self-score on graph knowledge improvement (HM-1_PSGKI) = 3

4. HM-1's conversion factor (HM-1_CF):
(?) x HM-1_VEM = HM-1_PSGKI
(?) = HM-1_PSGKIS / HM-1_VEM
(?) = 3 / 0.77
HM-1 CF = 3.90

Table 1. HM's conversion factors

(*If model runs yield a VEM score of greater than 0.64, then model indicates out-performance of participant's perception of improvement. If model runs yield a VEM score of less than 0.64, then model indicates under-performance of participant's perception of improvement.)

НМ	HM value on evaluator's measure (HM-x_VEM)	HM's perceived score of improvement in graph interpretation	Conversion factor (CF) = HM-1_PSGKI / HM-1_VEM
----	--------------------------------------------------	----------------------------------------------------------------------	---------------------------------------------------------

		(HM-x_PSGKI)	
HM-1	8.5 / 11 = 0.77	3	3 / 0.77 = 3.90
HM-2	7 / 11 = 0.64	0	no change⁺
HM-3	6.5 / 11 = 0.59	2	2 / 0.59 = 3.39
HM-4	5.5 / 11 = 0.50	1	1 / 0.50 = 2.00

PROVOCATEUR PARAMETER (PV_ptr)

We use a random selection of spreads based on the four scores each time the PVs are encountered.^{13,14} Use of the spread does homogenize scores across HMs somewhat, but variance is going to be limited in a shallow scale anyway. Conversion factors (described above) should help with some discrimination.

PV	Score range	re range Score median (HM / 4		PV_ptr	
 Continuous, sinuous line as base of travel 	0.50 - 1.00	0.50	(1.00 + 0.50 + 0.50+ 0.50) / 4	PV_ptr_1	0.63
Time increases along x-axis	0.50 - 1.00	0.75	(0.50 + 1.00 + 1.00 + 0.50) / 4	PV_ptr_2	0.75
 Increased distance from origin = increased scale [height] of bars along positive y-axis 	0.00 - 1.00	0.00	(1.00 + 0.00 + 0.00 + 0.00) / 4	PV_ptr_3	0.25
 Fluctuation of grouped bar heights along positive y-axis = fluctuation of hope 	0.50 - 1.00	0.75	(1.00 + 0.50 + 1.00 + 0.50) / 4	PV_ptr_4	0.75
 Effect of lack of food (hunger pangs) = bar heights along negative y-axis 	0.00 - 1.00	1.00	(1.00 + 1.00 + 1.00 + 0.00) / 4	PV_ptr_5	0.75

Table 2. Provocateur parameters for model

e.g. Scores on PV_1 for HM-1, HM-2, HM-3 and HM-4 are, respectively:

1, 0.5, 0.5, 0.5

Therefore, PV_ptr_1 = 2.5/4 = 0.63

¹³ One alternative would be to use a universal value, where each PV has an expected value based on averaging of the scores. That value per item [PV] would embody complexity of the item's interpretation across all individuals [HMs] rather than an idiosyncratic value. That universal value would be a criterion value that, hopefully, would be more stable. We would need a much larger "n" to be able to use that sensibly.

¹⁴ Another alternative would be to use a floating random number across the range of observed values (which we tried). Because the range is so short (0.00 - 1.00), however, discrimination across PVs was reduced. That might happen with the averaging alternative above as well, but, at least, that would be representative of a large number of respondents.)

 Width of grouped bars = relative length of stay at specific location/station 	0.00 - 1.00	0.50	(1.00 + 1.00 + 0.00 + 0.00) / 4	PV_ptr_6	0.50
 Space between bar groups = distance between stations 	0.00 - 1.00	0.50	(0.00 + 0.00 + 1.00 + 1.00) / 4	PV_ptr_7	0.50
 Fox speaks = yellow spectrogram 	0.00 - 1.00	1.00	(1.00 + 1.00 + 0.00 + 1.00) / 4	PV_ptr_8	0.75
 Crow speaks = maroon spectrogram 	0.00 - 1.00	0.50	(1.00 + 1.00 + 0.00 + 0.00) / 4	PV_ptr_9	0.50
10. Crow silence = maroon spectrogram flatlined		1.00	(1.00 + 1.00 + 1.00 + 1.00) / 4	PV_ptr_10	1.00
11. Fox silence = yellow spectrogram flatlined	0.00 - 1.00	0.50	(0.00 + 0.00 + 1.00 + 1.00) / 4	PV_ptr_11	0.50

5.2.3 Sample items (PVs)

- 1. Time increases along x-axis
- 2. Increased distance from origin = increased scale [height] of bars along positive
- y- axis
 - 3. Fluctuation of grouped bar heights along positive y-axis = fluctuation of hope
 - 4. Effect of lack of food (hunger pangs) = bar heights along negative y-axis
 - 5. Width of grouped bars = relative length of stay at specific location/station

5.2.4 Runs (in present tense)

1. Multiple model runs are done with human-agents encountering provocateurs. (Multiple model runs are carried out so that each run is a proxy for a different human model of the same capacity/category (e.g. HM-1). Multiple model runs create variation within the category.

2. To score each encounter, we use a random selection from spreads (see 2nd column of table 2 or 4th column for actual values) based on the discrete four HM scores per PV each time the PVs are encountered.

3. If HM-1 does a run, call score on PV_1: HM-1_PV_1_run-1.

(a) **HM-1_PV_1_run-1** = (sum of all PV_1 scored during the model run) / (timesteps during that model run).

(b) Add all eleven PV scores in run 1 and divide by 11 (# of PVs) to get HM's modelled score on evaluator's measure for run 1 only:

(HM-1_PV_1_run-1 + HM-1_PV_2_run-1 + ... + HM-1_PV_3_run-1) / 11

This is the model_{run_1} equivalent of **HM-1_VEM** (see table 1) for the first model run. Call it **HM-1_VEM_modelrun-1**.

4. Carry out step #3 above for all four HMs to derive HM-1_VEM_modelrun-1, HM-2_VEM_modelrun-1, HM-3_VEM_modelrun-1,

 $\mathsf{HM}\text{-}4_\mathsf{VEM}_modelrun\text{-}1$

5.2.5 Final assessment: What we did (starting from #2 below, using HM-1 as example)

 We completed all model runs (30) to derive HM-1_VEM_modelrun-x, HM-2_VEM_modelrun-x, HM-3_VEM_modelrun-x, HM-4_VEM_modelrun-x (see section 5.2.4 [3] above) for every run.

2. There were 30 runs (at 30,000 time-steps each). We recorded for HM-1: HM-1_VEM_modelrun-1, HM-1_VEM_modelrun-2...HM-1_VEM_modelrun-30.

3. We added all items in #2 and divided by number of runs to get final *modelled* score on evaluator's measure for HM-1. We called it **HM-1_VEM_model_final**.

4. We multiplied HM-1_VEM_model_final by HM-1_CF (see table 1 above) to

derive HM-1's graph knowledge improvement according to the *model*. We called it **HM-1_PSGKI_BYmodel**.

- 5. We compared HM-1_PSGKI_BYmodel with HM-1_PSGKI (see table 1 above).
- 6. (Interpretation standard:

If HM-1_PSGKI_BYmodel is equal to or greater than HM-1_PSGKI, then HM-1's perceived self-score on graph knowledge improvement scale is

supported. (Model shows it could be as good as HM perceived, or better.)

If HM-1_PSGKI_BYmodel is less than HM-1_PSGKI, then HM-1's

perceived self-score on graph knowledge improvement scale is not supported. (Model shows it is not as good as HM perceived.)

7. For HM-1, the following observations were made:

HM-1's perceived score of improvement in graph interpretation

(HM-x_PSGKI) = 3.00

HM-1's graph interpretation improvement according to the *model* (HM-1_PSGKI_BYmodel) = 2.42

8. HM-1_PSGKI_BYmodel is less than HM-x_PSGKI. Therefore HM-1's

perceived self-score on graph knowledge improvement scale is not supported. It would appear as if HM-1 slightly inflated own improvement.

9. Results for all HMs are presented in table 3 below.

 Table 3. Final assessment:
 Perceived vs. modelled improvement in graph

 knowledge/interpretation
 Perceived vs. modelled improvement in graph

(*If model runs yield a VEM score of greater than 0.64, then model indicates outperformance of participant's perception of improvement. If model runs yield a VEM score of less than 0.64, then model indicates underperformance of participant's perception of improvement.)

нм	HMs' perceived score of knowledge/ improvement in graph interpretation (HM-x_PSGKI)	HMs' graph knowledge/ interpretation improvement according to the <i>model</i> (HM-1_PSGKI_BYm odel)	Assessment
HM-1	3	2.42	Model does not support HM's perception

HM-2	zero	(VEM score = 0.62) ◆	Model does not support HM's perception *
HM-3	2	1.96	Model does not support HM perception (could be within error limits)
HM-4	1	1.24	Model supports HM's perception

6 CONCLUSION

Our basic results were mixed. Several things could be taken into consideration in a future study. A larger number of participants is a first consideration. That would help capture variability more effectively. The graph system was described to the participants and they had to re-narrate it in a short space of time. Perhaps giving more mental incubation time might increase richness and resilience of improved knowledge (if there was) as a result of mental networking--and suggest better retention. That might better reflect efficacy of the intervention. (On the other hand, it would eviscerate benefit of immediate recall--but it should be noted that immediacy could be spurious, anyway.) Our model used randomness to account for variation in participant scores and evaluator's assessment (via a large "n"--provided by number of model runs). This was based on an assumption of a corrected-to-normal-distribution in terms of performance. It is possible that the distribution, in reality, might not be so. A large "n" base data may be needed to first determine nature of that distribution.

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SMALL GROUP AND ITS SIZE: AN EXPLORATORY STUDY

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ABSTRACT

Use of a small group of people to complete a task is commonplace. Size of the group depends on different factors. Given a particular task, however, where salient conditions are held constant, what is an optimal small group size? In this exploration, we engage that problem. We created a model into which groups that ranged in size from two to seven members were placed. Each group encountered, at random, group traits supportive of team success or unfavourable for team success. A numerical scorecard of gains and losses, respectively on those encounters, was kept for each team. The model was run three thousand times. At end, despite different outcome scores, we did not find a statistically-significant difference between groups, based on size.

Keywords: teamwork, social conflict, task conflict, public space (of collaboration)

1 INTRODUCTION

At some point or another, many educators or organizations will have made the decision to assign a task to be completed by members set out as an array of teams. Whether labelled or structured as teamwork, group work, collaboration or cooperative learning/problem solving, the theme of teamwork manifests actively in design education, practice and research (Alaoutinen, 2012; Bene & McNeilly, 2020; Goduscheit & Knudsen, 2015; Hultén et al., 2018; Park, 2020).

Output of a team project could be conceptualized as one form of reification of proximity. The product of teamwork is materialization of a system of which proximity is its innate matrix. In teamwork, proximity could be physical, where team members work side-by-side, but it does not have to be. Common purpose is essentialised in proximity. Team output is successful

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only to the extent that there is convergence of purpose. Even when inceptive disposition of ideas is divergent, implicit exertion of a collective goal gradually re-orients frames of mind towards a common and constrained space of unified purpose. Here, proximity in teamwork can be understood both as a figurative quale and an integral ingredient of performative structure.

What is an optimal size of a team? The question could be interpreted/pursued in multiple ways. For one, obviously, an appropriate answer will depend on the project at hand. Another interesting way to ask the question, however, is this: How much does a composite of relevant factors, intentionally supposed as independent, benefit a team, based on team size? The supposition of independence is based on the logic that humans are intended to assign a value score to given factors (see method section below), but the human mind works with its own schemata. Schema shapes how an individual *perceives* the value of *each* factor included, but might not effectively manage the question of interaction(s) among factors. A person, for instance, thinking about social loafing might not consider that it could contribute to loss of motivation. So, the former is scored, in effect, independently of the latter. It might be valuable to consider the question of schemata because they might affect perception and, possibly, consequent action. So, the outcome we hope to explore is not about telling us which team size is "best," but which team size might benefit most, given a set of factors as indicated by a set of subjects.

2 GROUP CHARACTERISTICS

As is to be expected, there are benefits and disbenefits to be found in team work. Benefits, for instance, would include diversity of ideas and reduced workload while disbenefits include concerns over such things as social loafing and schedule conflict (Schultz et al., 2010). In this section, we explore some themes of benefit and disbenefit which pertain to teamwork.

2.1 Diversity of knowledge and perspectives

One condition of teamwork is a broader range of perspectives brought by team members--broader range than a person working solo. Van der Vegt and Bunderson (2005) noted that "exposure to individuals with different expertise, knowledge, and experience is a key source of individual and collective learning" (p. 534). Through interaction with dissimilar others, new paradigms and perspectives are introduced. Diversity in conception fosters cross-fertilization of ideas (Van der Vegt & Bunderson, 2005). There is an enriched resource space from within which to begin thinking about solutions. Divergent thinking, with its elements of fluency (multiple ideas), originality (novelty as relative to extant solutions) and elaboration (richness of exploration of ideas) (see Paletz & Schunn, 2009), is rendered plausible in a teamwork context. "Finding good solutions requires considering many alternatives" (Paletz & Schunn, 2009, p. 82) and there is an implicit understanding that "the diversity of ideas offered through a team-based assignment could not be replicated by each individual working alone" (Schultz et al., 2010. p. 18).

2.2 Transactive memory/processes

Transactive memory system is a knowledge management system whose dynamics/forces apply to both in-classroom and outside-classroom projects. According to Wegner (1986), transactive memory examines the manner in which groups process and structure information. A premise is that, for every individual, other people can be locations of external storage of information. This interdependence sets up a knowledge-holding system which is larger and more complex than the memory system owned by each individual (Wegner, 1986; Wegner et al., 1991). A device is that individual members of a team are relied upon (through expertise, delegation or both) to be the leading resource for a different aspect of a project. Functionally, it benefits the team through division of labor, assignment of task to person with expertise (inherent or temporarily acquired) in the specific subject and, in an ideal situation, collaborative cohesion gained through trust (in persons with delegated responsibilities). Transactive memory system also fosters efficient communication and, in a percipient sense, an intersubjective awareness of how knowledge or expertise is distributed within the group. In addition to the foregoing, transactive memory system enables individual members, once each person's task has been delimited, to direct extra focus and energy on specific tasks, thereby generating potential for effective outcomes (see Ali et al., 2019; Leo et al., 2018; Lewis, 2003; Marques-Quinteiro et al., 2019).

2.3 Knowledge hiding

Up until now, we have talked about knowledge as a shared vital resource for task completion. It is not always the case, however, that knowledge is shared readily. Sometimes, an individual might attempt to "hide" knowledge. Knowledge hiding has been defined by Connelly et al. (2012) as "an intentional attempt by an individual to withhold or conceal knowledge that has been requested by another person" (p. 65). One reason to hide knowledge might be distrust of colleagues. Another reason is perception of knowledge as owned by self and as something to be protected or safeguarded (Chatterjee et al., 2021). It is obvious that hiding knowledge presents a challenge to team success.

2.4 Task conflict, process conflict, relationship conflict

As there is mutual support in a team context, conflict also occurs. Jehn (1997) identified three types of conflict which occur in a task-oriented organisational setting: task conflict, process conflict and social conflict. Task domain is about understanding and definition of a problem to be solved (adapted from Paletz & Schunn, 2009). Task conflict is conflict "involving different ideas, perspectives, and viewpoints regarding the work itself" (O'Neill et al., 2013, p. 236). Process is about actions that will need to be performed in order to accomplish the task (adapted from Paletz & Schunn, 2009). Process conflict is "conflict about how task accomplishment should proceed" (Jehn, 1997, p. 540). Relationship deals with in-group matters concerning behavior and regard towards one another (adapted from Paletz & Schunn, 2009). Relationship conflict is conflict which involves "interpersonal tensions, frictions, and resentment" (O'Neill et al., 2013, p. 236).

At a time, it was customary to reason that conflict interfered with team performance, distracting team members from performance of their tasks (De Dreu & Weingart, 2003).

Research has shown, however, that the picture is more complicated. For instance, as noted by Jehn (1997) below, given the right managerial environment, task conflict can yield a positive outcome--through compelling dialogue, accommodation of multiple points of view, and so on.

Effect of task conflict on performance depends on conditions present in each situation, wrote Jehn (1997). For instance, "task-related...team conflict can improve organizational performance and growth" when allowance is made for enhanced understanding of various viewpoints and creative options are allowed (p. 530). Task conflict can also be beneficial when working on non-routine tasks. As De Dreu and Weingart (2003) explained, "nonroutine tasks are typically complex tasks without standard solutions, therefore requiring some consideration by the team." In a case as such, task conflict "increases group members' tendency to scrutinize task issues and to engage in deep and deliberate processing" (p. 742). The issue might not be the same with routine tasks, they continued. Routine tasks "typically have highly developed and effective standard operating procedures" and it is the case that task conflict is "more likely to interfere with those procedures than improve on them" (p. 742).

Process conflict involves "incompatibilities regarding how to carry out the work, such as logistical issues and the distribution of task responsibilities" (O' Neill et al., 2013, p. 240). Performance instances include such typifications as "responsibility disagreements," "disagreeing about utilizing people" and "disagreements about assignments [or distribution] of duties or resources" (Jehn, 1995, p. 540). Process conflict can exact its own toll on resources (such as time), vision (through, for instance, non-clarity about roles) and emotion.

Relationship conflict often manifests as a threat. It tends to bring about "interpersonal incompatibility" (Paletz & Schunn, 2009, p. 82). Relationship conflict "creates anxiety, fear, and remorse" (Carnevale & Probst in O'Neill et al., 2013, p. 240). Information processing ability of the group is curbed, noted De Dreu and Weingart (2003), "because group members spend their time and energy focusing on each other rather than on the group's task-related problems" (p. 742).

2.5 Social loafing

Social loafing describes "tendency for individual effort to decrease when people work in groups rather than individually" (George, 1992, p. 191). There are extrinsic and intrinsic explanations for social loafing. Extrinsic explanation, wrote George (1992) is that, sometimes with group outputs, individual contribution becomes unidentifiable. That might reduce motivation to participate. Also, if a team member perceives that her efforts might be seen by others as dispensable, she might engage in social loafing (Gabelica et al., 2021). As for intrinsic explanation, George (1992) argued that if an individual perceives that task visibility is low (e.g. supervisor will not notice degree of my participation), then that individual might believe she or he can "reap the benefits of overall group performance at little personal cost in terms of effort expended" (p. 193). Indeed, George's study supported the view that intrinsic involvement moderated relationship between task visibility and social loafing. There are negative consequences of social loafing--including such things as loss of team observed, loading might

even "trigger a negative performance spiral among peers," leading to decreased motivation on the part of others (p. 713).

3 METHODS

We chose to use an agent-based model for our exploration. First, we identified factors which represent dynamics of team activity. Some of these factors have already been described above. We integrated those with personal experience of observing and participating in teamwork. For this exploration, we identified nine factors in domains of knowledge sharing, distributed effort, logistical issues and social issues.

A questionnaire was created with nine items (Sample item: "If someone on our team has answer to a problem, she or he can fill in gap of knowledge for another member who does not know the answer. How much will that help or harm us?" (See results section below for identification of all nine factors employed.) Response to each item was recorded on an eleven-point scale: five levels in the negative direction from "low harmful" to "extremely harmful" and, as a mirror, five levels in the opposite direction, indicating "helpful" from low to extreme. Levels were indicated with numbers increasing or decreasing systematically by one, each step. There was a neutral level (scale value of zero).

Thirty-one undergraduate students completed the questionnaire. Two respondents were dropped due to excessive arbitrariness in responses. Also, one of the nine questionnaire items was dropped due to apparent misconstrual (see results section). Distributions on questionnaire item responses were generally skewed. Therefore, median values were used for parameterization (see table 1).

A model was created in Netlogo (2020). Seven levels of team were created (from a one-person "team" to a seven-person team). Teams were named by number of members. We began with up to a team of five. After initial runs and observing what appeared to be effect of team size on final outcome (which would later turn out to be spurious, given our final study reported here) we re-started the project with up to a team of six--with intent of affirming the effect of team size. At the end of that set of runs, we saw no team size effect. For re-affirmation, we re-started the project with up to a team of seven. That last design is what is reported in this study.

Factors identified in the questionnaire were inserted in the model as unique agents and, at initiation of each model run, were deployed randomly. *Run* here describes life of a team project, represented as time from its initiation to its end, It is further described two paragraphs below. During model run, agents of each team moved about and, on encounter with a factor agent, recorded occurrence of that factor as an accompanying score for the team. The team with highest positive (or least negative) net score at end of a run represented the most optimal case. The model was run 3,000 times.

We termed encounter between factor agent and team agent--i.e. an instantiation of the factor--an *incident*. Each incident (e.g. one instantiation of *conflict of personalities*) is recorded

as a *fragment* of the model-value of that factor. Factor model-value is specified as median score of that factor from our field data. During each run, registration of a factor fragment score can keep occurring (and is continually summated), as induced by different dynamic agents representing team members, until the factor model-value is reached.

We approached length of each model run as follows. We allowed the model to determine length of run so as to provide for a range of possibilities. We allowed for team projects that last between one day and two weeks (fourteen days). We took each time step of the model to represent one minute. The model was allowed to choose a duration between 1,440 and 20,160 minutes. It was hoped that our large number of runs would yield a reasonable distribution of project duration. Figure 2 shows a model run with 15,365 steps.

4 **RESULTS**

Table 1 presents means and medians of items (factors of teamwork) from our collected data. The nine factors used are as follows: fill(ing) in knowledge gap (v1), correction of misinformation (v2), disagreement upon ideas (v3), sharing burden of work (v4), conflict of schedules (v5), diverse perspectives (v6), conflict of personalities (v7), social loafing (v8), buddy motivation (buddy system) (v9). Eventually, v3 was dropped. It was intended to represent cases of unresolved disagreement leading to process or solution decay. It was construed as an adverse factor. It appeared, however, that respondents interpreted it as they interpreted v6 and so v3 was scored notably positively by over sixty percent of respondents. We assumed, wrongly, that respondents would see *diversity* of ideas (positive) as different from *disagreement* on ideas (negative).

	v1	v4	v6	v9	v2	v5	v7	v8
Mean	3.79	3.206	4.069	4.034	3.464	1.653	1.360	2.227
	31	9	0	5	3	8	0	3
Median	4.00	3.000	4.000	5.000	4.000	1.000	1.000	2.500
	00	0	0	0	0	0	0	0

Table 1. Medians of questionnaire items

As has been noted, we carried out 3,000 runs of the design. Outcome scores summated at end of all 3000 runs were recorded for all teams (see table 2). Our original summated-3000-run-outcome data presented a leptokurtic distribution for every team. Histograms clearly displayed a surfeit of run outcome score of zero for all teams. That means either non-occurrence of *incidents* (i.e. non-occurrence of teamwork factors) was common or outcome scores (both positive and negative) were more effectively neutralizing one another. We performed a check of normality. For all team data, skewness coefficient was within ± 1.0 (range of -.327 to .586). All kurtosis coefficients were extreme. Shapiro-Wilk test of normality showed, not unexpectedly, significance in every case. When zero scores were removed (first test described below), we had the following descriptives. Summated-3000-run-outcome scores stayed the same. For all team data, skewness coefficient was within ± 1.0 (range of -.079 to .064). Kurtosis coefficients also all fell under 1.0 (largest = .654). A check of q-q plots showed no appreciable deviation from normality. Shapiro-Wilk test did show three teams presenting significance at .05 level (teams 2, 3 and 5). We chose not to perform transformation of our data. We also chose to proceed with a Kruskal-Wallis test.

	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7
Outcome score (zeros kept)	0.00	-137.00	232.00	-111.00	-147.00	495.00
Median (zeros kept)	0.00	0.00	0.00	0.00	0.00	0.00
Outcome score (zeros removed)	0.00	-137.00	232.00	-111.00	-147.00	495.00
Median (zeros removed)	1.00	-1.00	1.00	-1.00	-1.00	2.00

Table 2. Per-team summated score and median--all 3000 runs

We carried out two tests, based on three arguments. We describe them as follows.

Scores of zero--whether as result of non-incidents or as countervailed (i.e. resulting from opposing signs)--provided no reckonable indicator. Besides, effect of a very large number of zero scores on the distribution was significant--as noted above about resulting leptokurtic distributions. We decided to neutralize effect of zero scores across teams. We specified a zero score as a missing value. A result of specifying zero as missing value was that our output-scores-per-team became unequal in size (count), ranging from 428 (team 7) to 1,325 (team 2).

Using SPSS, we performed the Kruskal-Wallis test. The test indicated significance at the .05 level, suggesting difference between, at least, a pair of teams: χ^2 (5) = 11.428; p = .044. Post hoc pairwise comparisons indicated significance between team 7 and team 6; team 7 and team 5; team 7 and team 3; and team 7 and team 2. Adjusted significance by Bonferroni correction, however, resulted in no statistical significance between pairs listed above.

A second argument is that scores of zero are as much part of the outcome as other scores. Therefore, we carried out a test of all scores--without specifying zero scores as missing values. In this case, we included all zeros. First, all teams failed test of normality (skewness coefficients were extreme and Shapiro-Wilk test, as expected, indicated significance in all cases). Outcome of a Kruskal-Wallis test indicated no statistical significance at .05 level: χ^2 (5) = 5.227; p = .389.

A third argument extends the former. It is that scores of zero represent a mix of non-*incidents* and neutralized scores (i.e. result of non-zero scores being first recorded and then neutralized in course of model run). This argument is plausible. We used evidence. We

carefully examined step-by-step scores (i.e. fragment scores recorded for each incident) across 100 selected/sampled runs. In cases where model run outcome scores were zero, per team, it was most often due to non-incidence. Of 600 columns of data in sample we examined, only 3.34% (16 out of 479) of zero outcome scores represented cases of neutralization of scores. The rest were non-incidents. Figure 1 below is a plot of the 100 runs we examined. The thick



"line" of symbols on zero score is not really a line, but an indication of concentration of non-incidents (including the small proportion of neutralized scores) across all teams. Figure 2 illustrates a case (just one run) where, across four teams, positive and negative scores per team can be observed in a transactional relationship while two teams remained flat, with non-incidents. We did not expect analysis to yield any result different from the two above.





Figure 2. Progressive score transactions (within team) and presence of non-incidents: A Sample

In tests performed, we found no statistical significance. When we removed zero scores, we inched closer to finding significance. Looking at summated outcome scores per team (table 2), however, increase (or decrease) in team size did not seem to systematically predict optimal outcome. We can argue that with or without zero scores factored in, there is no association between team size and optimal outcome.

5 CONCLUSION

In this exploration, the optimal team is represented by an outcome score which is more positive or less negative than score of other small groups with which it has been compared. Of the six team sizes we compared, analyses did not indicate that any size was preferred over another. There is always risk of type II error (in our particular case)--that we missed a

should-be statistically-significant result. We speculate on some circumstances which surround that possibility--and, hence, are potential matters for future model design.

(a) One conjecture is that if we went beyond a team of seven, we might discover difference. By then, though, team size would be tending beyond small. That might be a concern. Also, we did already walk some steps down this path when we began with the largest team size at five, then grew it to six and finally to seven. (b) Another matter is regarding possibility of sampling error. It is possible that participants we sampled--especially, given a small sample--did not bear true representation of opinions (and scores) across the population. (c) Next, it is possible that there are other team factors that could have been included in the model. It is possible, though, that effect of adding other factors would merely be change in positive-negative contour of the observed (i.e. from participants) factor score landscape. That Observing our field (modelled) data, we saw that factors which change might not matter. favoured team success seemed to have been given stronger scores in their direction than disfavouring factors were scored in their own direction. Another curious observation was that most respondents seemed to have treated conflict issues (in particular, schedule conflict and social [personality] conflict) rather trivially. (Our past experience is that these tend to be real, problematic issues which generate soreness in group relationship and impair group effectiveness.) Despite all that, an imbalance of positive-negative scores has not delivered any systematic favour-per-team-size (as can be seen in table 2). (d) Model specification could be another issue. We parameterized ceiling of factor optimality at median value of each factor. Perhaps a different core or boundary condition would be more ideal. (e) Our weighting of factors is only partial. When we used mean factor scores to weight, it hyper-inflated factors with larger scores. We do, however, recognize an in-built team effect (by team size--an important criterion for us) based on larger teams having more encounters with each factor, but the effect simply not "exaggerated." This is an area of re-design for future work. (f) Future work could consider parameterization of interactions (either soft ones based on simple connections of factors by subjects or more established ones based on past studies). (g) Size of our world (area within which agents ran) was the equivalent--by comparison to size of each agent--of about thirty (\approx 30) people standing side-by-side, if each agent represented one person. It seems within a sensible range of space of direct interaction. In the end, however, a better way to determine effect of world size would be to test the condition through model design. (h) One might consider duration of the task to be completed by each team. We believe we have made a viable choice on this question. Our model included a duration range of one day to two weeks, with the model allowed to select length randomly. (i) Finally, the possibility cannot be ignored that there is indeed no significant difference between team sizes we have explored. We recognize that model results can be contingent. As such, there is more work to do in future studies to continue re-interrogation through modification of the types of conditions and design parameters mentioned above.

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EFFECTS OF BALCONY DECK HEIGHT ON

SUBJECTIVE EVALUATION OF LIVING SPACE: COMPARATIVE STUDY BETWEEN MINIATURE MODEL AND VIRTUAL MODEL

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ABSTRACT

In modern housing, to identify design methods that make living spaces appear more comfortable and spacious, even slightly, it is important to enhancing the quality of life (QoL) of residents. This study explored the possibility whether it is effective to utilize the outdoor balcony space adjacent to the room in order to make living spaces appear larger. Generally, the floor level of balconies is lower than that of the living spaces, but in this experiment, we investigated whether changing its level by adding a deck to the balcony would affect the perceived spaciousness of the living spaces.

Participants were asked to evaluate their impressions of the space, by the Semantic Differential method (SD) and the Magnitude Estimation method (ME) for the miniature model and virtual model.

Eleven participants provided subjective evaluations of the space using fourteen pairs of adjectives, and factor analysis was performed on these evaluations. The results of the SD method revealed that higher deck levels significantly increased the subjective evaluation of the space. Similarly, the ME method results showed that higher deck levels increased the sense of depth and spaciousness. The findings of this study demonstrated that the deck level of the balcony affects the sense of depth and spaciousness of the living space, suggesting it is an effective design method to make living spaces appear larger. The comparison between the two spaces showed that there were no significant differences for most factors, indicating that it is possible to estimate the perceived spaciousness and depth with the virtual model.

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Keywords: Living space, Balcony, Continuity with the outdoors, Virtual reality

1 INTRODUCTION

In modern housing, many architects have attempted to make spaces appear as spacious as possible. Recently, from a sustainability perspective, there is a growing belief that compact and energy-efficient homes are more suitable for contemporary living than large residences. In fact, the average total floor area of owner-occupied homes has decreased by about 14% over the past 20 years, reaching 115.8 square meters in 2022. The average floor area of rental homes, on the other hand, is approximately 40% smaller compared with owner-occupied homes. Given these trends, it is important to make living spaces appear larger and more comfortable for enhancing the quality of life (QoL). Therefore, the final goal of this study aims to identify design methods that make spaces feel more spacious by effectively utilizing external spaces, rather than physically increasing the internal space.

Originally, windows in Japan, known as "mado," were sliding window fitted between wooden pillars, which differ from the windows in Western masonry or two-by-four constructions derived from the term "wind eye." One distinctive feature of Japanese housing is the frequent use of "sliding window" (hakidashi-mado) that extend directly from the indoor floor level upwards. If the external space can be considered the continuous space, the interior space may be perceived as more spacious.

Previous studies, such as Yoshizawa et al.¹⁾, have validated the reproducibility of real spaces using VR systems and found that the virtual model tended to appear narrower in terms of depth perception compared with actual spaces. However, they also suggested that judging depth is more difficult than judging height or width. Yoon et al.²⁾ suggested that the continuity between indoor and outdoor spaces is influenced by the indoor illuminance and color temperature. Kondo et al.³⁾ indicated that the direction of the floor's wood grain pattern affects depth perception. Sugano et al.⁴⁾ demonstrated the psychological effects of indoor spaces with windows and potted plants through participant experiments. Chiba et al.⁵⁾ reported on the impact of intermediate areas (engawa) on the connection between indoor and outdoor spaces. They suggested that differences in the depth of intermediate areas influence impression evaluations.—

Therefore, this study that effectively utilizing external balcony spaces adjacent to living rooms can enhance the sense of spaciousness and comfort in the living rooms. To verify this hypothesis, we conducted experiments with subjects to identify effective design methods.

2 METHODS

2.1 Experiment Overview

An experimental miniature model with variable deck floor height was constructed. It assumed in a room of a residence with a sliding glass door. A virtual model of the same feature was also created. Participants were asked to observe each model and evaluated them.

2.2 Experimental Environment

Figure 1 shows the schematic diagram, as well as photos, of the experimental miniature model. The model is designed to represent a 20 square meter room at a 1/6 scale. The height of the balcony was set to three adjustable levels. The floor finish inside the model was made by attaching a thin veneer of natural wood (light brown oak) on top of styrene board, while the walls and ceiling were covered with commercially available wallpaper (white). To facilitate understanding of the space's size, 1/6 scale models of finely crafted chairs and table were placed inside. An opening was cut in the front wall to simulate a sliding window, although no window frame or glass was installed. A balcony and railing were placed outside the window. The railing was designed as a wall to block the view, rather than as a lattice. The balcony floor was covered with the same natural wood veneer as the interior flooring. Since the experiment was intended to simulate daytime, no ceiling lights were installed. The floor illuminance was set at 80 lx in the center of the room and 150 lx in the center of the balcony. In the virtual model experiment, participants wore a VIVE Pro Eye (HTC Corp.) head-mounted display (hereinafter referred to as HMD) to freely observe the virtual model. This model was created using 3D graphic software (Blender) and the illumination settings and HMD output were managed using a game engine (Unity). Unlike the scaled model, the Virtual model was created at the actual size of the real space (width: 3.6m, depth: 5.4m, height:2.4m). The shape was made identical to the miniature model. The finishes of the floor, walls, ceiling, and balcony floor were close to the materials used in the miniature model. Participants sat in a chair, wore the HMD, and placed their heads on a chin rest to fix the height.



Figure 1. The schematic diagram

2.3 Participants

A total of 11 students (6 males, 5 females) from Yamagata University participated in the experiment. Their age ranged from 20 to 24. All participants had normal or corrected-to-normal vision.

2.4 Experimental Conditions

The experimental conditions are shown in the figure 2 and 3. The eye level heights were set at FL+1150mmfor sitting and FL+1550mm for standing. Additionally, assuming the balcony was covered with a wood deck, the deck levels were set as follows: lower = FL-480mm, middle =

FL-240mm, upper = FL±0mm. Additionally, two eye levels were set, corresponding to seated and standing positions. The experiment was conducted in six combinations of these eye level heights and deck levels in both the miniature model and the virtual model, totaling 12 patterns for comparison.





Figure 2. The experimental conditions patterns

Figure 3. The experimental conditions

2.5 Experimental Procedure

The experimental procedure is shown in the figure 4. Participants were required to participate in experiments in both the miniature and the virtual model. The order of which space to conduct first was randomized to counteract order effects. Similarly, the presentation order of eye level heights and deck heights was also randomized.



Figure 4. The experimental procedure

2.6 Subjective Evaluation

2.6.1 Semantic Differential (SD) method

The impression of the space was evaluated using the Semantic Differential (SD) method. Seven-point scale rating based on 14 pairs of adjectives was conducted. For comparing psychological reports via the SD method across experimental conditions, Welch's test was used for comparisons between two groups, a parametric test. For comparisons among three groups, ANOVA (analysis of variance) was conducted followed by multiple comparisons using Tukey's test. The two-group experimental conditions involved changes in eye level and model (miniature vs virtual). The three-group experimental conditions were based on deck levels.

2.6.2 Magnitude Estimation (ME) method

The differences in the perception of spatial depth (psychological measure) across each experimental condition were assessed using the Magnitude Estimation (ME) method. The depth perception of the space when the deck level was at the low-level was taken as the standard, with a value of 100, and rated the perceived depth of spaces at middle- and high-level deck levels.

3 RESULTS

3.1 Subjective Evaluation

Figure 6 presents the impressions of the miniature model and the virtual model obtained via SD method, shown as average scores on a seven-point scale. Among the adjective pairs shown in the figure, except for 'easy to concentrate \Leftrightarrow hard to concentrate,' 'big \Leftrightarrow small,' and 'high \Leftrightarrow low,' it is considered that higher ratings correlate with increasing deck heights. In the virtual model, a similar trend is observed where higher deck heights correlate with higher evaluations, though brightness and warmth receive higher ratings compared with the miniature model.



Figure 6. Miniature model impression evaluation (left: Miniature model; right: Virtual model)

3.2 Factor Analysis

Factor analysis was conducted to elucidate the impression evaluation structure of participants for the 12 experimental conditions. The maximum likelihood method was employed for factor extraction, and varimax rotation (orthogonal rotation) was adopted. Based on the results of the scree plot, four factors were extracted using the Kaiser criterion and scree test. The results of the factor loadings are presented in the table 1.

Factor 1 correlated with items such as comfort, a sense of security, and favorability, and was interpreted as reflecting mental comfort, thus named "Psychological Comfort." Factor 2 correlated with brightness, warmth, and a sense of openness, and was interpreted as reflecting the visual and sensory expansiveness and warmth of the space, thus named " spatial attractiveness " Factor 3 correlated with continuity with the outside and a sense of depth, thus named "External Continuity." Factor 4 correlated with the impressions of size and height of the space, thus named "Spatial Scale."

	Factor 1 (Psychological Comfort)	Factor 2 (Spatial Attractiveness)	Factor 3 (External Continuity)	Factor 4 (Spatial Scale)
Cozy - Not cozy	0.79	0.35	0.3	-0.04
Calm - Not calm	0.75	0.28	0.22	-0.04
Feel relieved - Feel an xiou s	0.7	0.28	0.17	0.05
Easy to concentrate - Hard to concentrate	0.69	-0.02	0.06	0.09
Preferable - Unpreferable	0.53	0.44	0.44	0.11
Bright - Dark	0.18	0.87	0.24	0.02
Warm - Cold	0.17	0.8	0.29	0.01
Spacious - Cramped	0.37	0.55	0.38	0.02
Openness - Closed	0.33	0.54	0.39	-0.05
Continuous with the outside - Not continuous	0.24	0.34	0.89	-0.06
Oneness with the outside - Not oneness	0.2	0.34	0.82	0.08
Sense of depth - Not Sense of depth	0.24	0.43	0.44	0.08
Large - Sm all	0.13	0.16	0.07	0.74
High - Low	-0.05	-0.12	-0.03	0.76

 Table 1. Summary of factor analysis of the space impression (n=132)

Figure 7 shows the average factor scores for each condition. The scores for the Factor 1 and Factor 3 indicate that, regardless of whether it is in the miniature model or the virtual model, higher deck levels correspond to higher scores, while lower deck levels correspond to lower scores. Additionally, the scores for Factor 2 are generally higher in the virtual model.



Figure 7. The average factor scores (left: Miniature model; right: Virtual model)

3.3 SD Method

The subjective evaluations were classified into four factors and tested, revealing that the difference in deck levels strongly influences the evaluations. Higher deck level was rated significantly higher. The difference between models (miniature vs virtual) and the difference between eye levels, on the other hand, were not significant. The test results for Factor 1 and Factor 3 in the analysis are shown in Figures 8 and 9, respectively.



Figure 8. Boxplot of Factor1 (left: Space; right: Deck level)



Figure 9. Boxplot of Factor3(left: Space; right: Deck level)

3.4 ME Method

The values of the perceived depth (psychological quantities) reported by the subjects under each condition are shown in Figure 10, with their median values listed in Table 2. Regardless of the eye level (sitting or standing), the psychological ratings tend to be higher for higher deck levels.


Figure 10. Boxplot of Psychological quantity

(Eye level)		SIT		STAND						
(Deck level)	Low	Middle	High	Low	Middle	High				
Miniature Model	100	110	140	100	120	140				
Virtual Model	100	120	150	100	130	140				

 Table 2. Psychological quantity
 (Median)

4 DISCUSSION

Higher balcony deck levels were rated significantly higher in almost all the impression evaluation items. The ME method results also showed that as the deck level increased, the sense of depth in space increased, indicating that deck level is crucial for spatial evaluation.

Comparison between the SD evaluations of the miniature model and those of the virtual model revealed no significant differences in most items, suggesting that the virtual model is effective for evaluating spatial impressions.

For evaluating the sense of depth in space, the physical quantities were defined based on the visible angle, as in Figure 11, with results shown in Table 3. Based on the psychological magnitudes reported by the subjects (Table 2), we calculated the power exponent using $R=k \cdot S^n$, where R and S denote psychological and physical quantity, respectively. The physical quantities were defined using the indoor floor in front of the deck (up to 1800 mm from the opening) as the standard stimulus(d), with its vertical visible angle (θ) as the standard physical quantity. The comparison stimulus was the standard visible angle plus the deck's visible angle ($\Delta \theta$). Figure 12 shows the power function graph for the physical and psychological magnitudes. The trends in psychological magnitudes suggest that the virtual model alone can effectively evaluate the sense of depth, as the power exponent values are similar for both the miniature and virtual models.



Figure 11. Definition of total visible angle

Table 3. Total visible angle

(Eye level)	Sľ	T(degree	es)	STAND(degrees)					
(Deck level)	Low	Middle	High	Low	Middle	High			
Miniature Model	5.7	6.7	8.7	7.3	9.4	11.1			
Virtual Model	5.7	6.7	8.7	7.3	9.4	11.1			



Figure 12. Power function graph (left: Miniature model; right: Virtual model)

5 CONCLUSION

In this study, we explored the possibility of making residential living spaces perceived more spacious by incorporating outdoor spaces such as balconies into the design. Simultaneously, we aimed to clarify the differences in impression evaluations between virtual spaces and real spaces. It was found that the deck level of the balcony significantly influences the impression of the living space. Differences in deck levels resulted in varying impression evaluations, with higher levels significantly increasing the perceived depth, equivalent to a sense of continuity or unity with the outdoors. These trends suggest that outdoor spaces can be incorporated into the living area. Furthermore, higher deck levels were also significantly associated with higher evaluations of "psychological comfort" and "spatial attractiveness." Thus, adjusting the deck level of balconies in future residential designs can be an effective method to make living spaces feel more spacious. Additionally, since there were no significant differences observed in four impression factors between the model space and the virtual space, we demonstrated that it is useful to use virtual space for impression evaluations.

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DATABASE CONSTRUCTION OF FACIAL EXPRESSIONS OF ELDERLY JAPANESE AND EVALUATION BASED ON **FACS**

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ABSTRACT

In this study, a database of facial expressions of elderly Japanese people was constructed, and their characteristics were analyzed by an expression analysis system. Facial expressions are important indicators for evaluating users' internal states and are essential for improving the accuracy of human emotion estimation systems. While facial expression databases exist for a wide range of ages in Europe and the USA and for young Japanese, there are very few available facial expression databases for elderly Japanese people. It has been suggested that the Japanese have unique facial expression features and that wrinkles and facial muscle deterioration may affect facial expression features in the elderly. We constructed a database of facial expressions for 111 elderly Japanese subjects, containing facial expressions corresponding to eight emotions (happiness, sadness, fear, surprise, anger, disgust, excitement, relaxation) and neutral facial expressions. An analysis based on Action Units (AUs) using OpenFace showed that the magnitude of AU values comprising emotional facial expressions was lower in the elderly than in younger Japanese. The database will be made publicly available in the Informatics Research Data Repository (IDR) of the National Institute of Informatics (NII).

Keywords: Facial expression database, Japanese elderly facial expressions, facial expression recognition, OpenFace, Action Unit analysis.

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1 INTRODUCTION

Japan's society is ageing rapidly, and facial expressions are often used to support elderly people with dementia. For example, facial expressions are used as pain indicators for elderly people with dementia who have difficulty self-reporting subjective pain (Kunz, Scharmann, Hemmeter, Schepelmann & Lautenbacher, 2007; Hadjistavropoulos et. al, 2014). Facial expressions are one of the universal indicators for evaluating users' internal state (Takayanagi, Kirita & Shibata, 2014). The burden on the nursing and medical fields is great, and automated systems are required in these fields to evaluate user states by learning from facial expression data.

There have been various studies on the collection of facial expression images, which are essential for emotion research. However, a large database of facial expressions on elderly Japanese could not be identified. There are concerns about using expression databases from other countries to train emotion recognizers for Japanese people (Sato, Hyniewska, Minemoto, & Yoshikawa, 2019). This is because the facial expressions of the Japanese may have different characteristics from those in other regions, such as Europe or the USA. Furthermore, the elderly may be affected by age-related wrinkles and deterioration of facial muscles. Although a database of facial expressions of younger Japanese exists, the facial expressions of the elderly may have different characteristics.

The most important contribution of this study was the construction of a database of facial expressions of elderly Japanese. In addition, the collected facial expressions of the elderly were compared with those of younger Japanese in existing databases. To construct the database of facial expressions, 111 elderly Japanese subjects (mean \pm SD age 73.2 \pm 4.6 years; 56 males and 55 females) were photographed with facial expressions corresponding to eight emotions (happiness, sadness, fear, surprise, anger, disgust, excitement, relaxation) and neutral expressions. The collected database of facial expressions of elderly Japanese people and the existing database of facial expressions of younger Japanese people were compared by extracting the facial expression features, Action Units (AUs) (Ekman & Friesen, 1978), using OpenFace (Baltrušaitis, Robinson, & Morency, 2016).

2 RELATED REASERCH

Ekman and Friesen (1987) suggest that there are universal, archetypal facial expressions that are specific to basic emotions. The Facial Action Coding System (FACS) (Ekman & Friesen, 1978) classifies facial expressions according to facial movements. The FACS uses a mechanism to encode the activity of facial muscles, called the AU, to represent facial expressions. However, Ekman's theory may not be sufficiently applicable to the facial expressions of Japanese people. Sato et al (2019) examined the facial expressions of 65 Japanese subjects based on six basic emotion scenarios (happiness, sadness, fear, surprise, anger and disgust). The results supported the existence of specific facial expressions for the basic emotions, although the facial expressions for emotions other than happiness and surprise may not correspond to those indicated by Ekman's theory. Observational studies have long noted the differences in the production of emotional facial expressions across cultures, particularly in the Eastern and Western worlds (Eibl-Eibesfeldt, 2017). Differences in the structure of the muscles that make up facial expressions may also influence the production of facial expressions (Jeong, Lemke, Dortzbach & Park, 1999; Shimada & Gasser, 2005; Choi et al, 2014). Furthermore, it has been reported that facial movements during facial expressions are smaller in Asian than in Westerners (Tzou, Giovanoli, Ploner & Frey, 2005). In addition, large individual differences between anatomical features of facial muscles (Pessa et al, 1998; D'Andrea & Barbaix, 2006; Waller, Cray & Burrows, 2008) suggest that more data are needed to train expression analysis systems.

In theory, facial expression databases would be effective in verifying these differences in a wide range of age groups, but no facial expression databases have been identified for elderly Japanese people. The FACES database takes into account generational differences (Ebner, Riediger, & Lindenberger, 2010). It comprises 171 young (n = 58), middle-aged (n = 56) and elderly (n = 57) female and male facial images showing six expressions: neutrality, sadness, disgust, fear, anger and happiness. However, this database does not include Japanese. The AIST facial expression database (Fujimura & Umemura, 2018) and the ATR facial expression database (Advanced Telecommunications Research Institute International [ATR], 2006) include Japanese people, but these databases target people in their 20s and 30s and do not include elderly people. These databases were used to compare young people's facial expression images with those of the elderly in this study.

In this study, the analysis of facial expression features was based on FACS AUs. An automatic analysis system, OpenFace (Baltrušaitis et al, 2016) was used to detect AUs; OpenFace is an open-source application for facial expression analysis developed by Baltrušaitis et al (2016). While manual annotation of AU values by trained human FACS coders is highly reliable, there are reports of comparable performance by computer-based analysis (Bartlett, Hager, Ekman & Sejnowski, 1999). Namba, Sato, Osumi and Shimokawa (2021) compared the performance of FaceReader (Skiendziel, Rösch & Schultheiss, 2019), AFARtoolbox (Ertugrul et al, 2019) and OpenFace as trained facial expression analysis systems in three contexts. The results showed that OpenFace's predictions were the closest to human-based annotation in Aff-Wild2 (Kollias et al, 2019), which recorded in-the-wild videos collected from YouTube, and in GFT (Girard, Chu, Jeni, Cohn, 2017), which recorded facial expressions during a conversation between a group of people. The AFAR toolbox performed similarly, whereas it is argued that OpenFace has an advantage in analyzing facial expressions due to the large number of corresponding AUs. It uses a pretrained model to estimate 68 facial landmarks, from which 17 AUs, facial orientations and direction of gaze can be estimated from arbitrary video images.

3 DATABASE SPECIFICATIONS

3.2 Overview of the database

Facial expressions were recorded from 111 Japanese elderly participants. The facial expression database contained facial expressions corresponding to eight emotions (happiness, sadness, fear, surprise, anger, disgust, excitement, relaxation) and neutral expressions.

Participants were instructed to create facial expressions in three ways: scenario-based expression, male photo imitation and female photo imitation, and videos were simultaneously recorded from five directions (diagonally left, front, diagonally up, diagonally down and diagonally right). In scenario-based expression, the elderly were expected to spontaneously express their facial expressions based on scenarios that evoked each emotion. In photographic imitation, sample images of facial expressions for each emotion were imitated, which can be used to evaluate the influence of gender on the function of facial muscles and the ability to imitate.

Emotions	Scenarios							
Happiness	You received a present that you had wanted for a long time.							
(mouth open)	You feel a happy, grateful emotion.							
Happiness	The teacher of the class you are attending praised you.							
(mouth closed)	You feel a happy, grateful emotion.							
Sadness	Your best friend is moving away to another town.							
Sauriess	You feel a sad, grieving emotion.							
	Imagine that you do not like being alone in the dark. One night you are							
Fear	alone in the house and all the lights suddenly go off.							
	You feel a fearful, frightened emotion.							
Surprice	You opened a box, expecting it to be empty, but a kitten jumped out of it.							
Surprise	You feel a surprised, startled emotion.							
Anger	A person did something to you that you strongly dislike.							
(mouth open)	You feel an angry, irritating emotion.							
Anger	Someone has stolen something you value very much.							
(mouth closed)	You feel an angry, irritating emotion.							
Disgust	I had an apple that looked good, but it was rotten.							
(mouth open)	You feel a disgusted, revolted emotion.							
Disgust	Kitchen garbage smells bad.							
(mouth closed)	You feel a disgusted, revolted emotion.							
Excitomont	The team you have been rooting for all your life has won an upset.							
excitement	You feel excited.							
Delevation	You are on holiday, sitting in a chair by a lake with a beautiful view.							
Relaxation	You feel relaxed, a good emotion.							
Emotionlass	You are not thinking about anything right now.							
Emotionless	You feel neither good nor bad moods.							

Table 1. Scenarios for each emotion

3.3 Participants

One hundred eleven elderly Japanese (56 males and 55 females, mean \pm SD age 73.2 \pm 4.6 years) participated in the study. The participants were men and women in their 60s to 80s, recruited regardless of theatre experience. They had eyesight, hearing, walking and language abilities that did not interfere with daily life and were native Japanese speakers. No participants were observed to have significant difficulty in expressing facial emotions during the recording process, and none reported any medical conditions that could affect facial expression. The purpose of the study was explained to the participants, and they consented to the management and disclosure of facial expression data. It was explained that the collected facial expression data would only be provided to third parties for research and development purposes based on applications from universities and research institutions and that the release of facial expression data by third parties would be prohibited. The case was approved by the Ethics Committee of

the Nagoya University Organisation for the Creation of Future Society (approval number 2021-32).

3.4 Equipment

Video cameras were set up directly in front of the participant's face as well as above, below, to the left, to the right, and at a 45-degree angle, and the distance between the face and the camera was 600 mm. The resolution was 1920×1080 and the frame rate was 60 fps. A 13.3-inch mobile monitor (M133K01, cdisplay) was placed in front of the participants and presented the scenario text and facial expression images for imitation. Instruction

Following previous studies (Sato et al, 2019; Fujimura et al, 2018; ATR, 2006), instructions were given for three methods: scenario-based expression, male photo imitation and female photo imitation. In the scenario-based representation, a scenario corresponding to each emotion was presented on the monitor, and the participants recreated the facial expressions they recalled from the scene. The scenarios (see Table 1) were created based on previous research (Sato et al, 2019). In the photo imitation, images of a man and a woman were presented and the participants were instructed to imitate the facial expressions of the images. The presented facial images were averages generated from images of the target emotion in the AIST facial expression database (Fujimura et al, 2018) and the ATR facial expression database (ATR, 2006), which contain young Japanese. In those databases, some emotions had a mouth-closed and mouth-open option, so those emotions were also recorded separately in this study. Therefore, 12 facial expressions were captured: happiness (open-mouth and closed-mouth), excitement, relaxation and neutral.

3.5 Procedure

Participants were recorded individually in the studio. Glasses were removed. They were seated with good posture, looking at the camera in front of them, with no facial expression. The participants were instructed not to speak specific words during the filming, although they were allowed to make emotional noises. The camera height was adjusted to the participant's eye level, and the distance between the camera and face was adjusted. Scenario-based expressive conditions were initially performed to prevent the influence of facial expression imitation. Before recording, the participants practiced with feelings of regret, which were not included in the emotion set. They practiced repeatedly to ensure that the facial expressions could be expressed in response to the instructor's cues. The call was given after the recording was started, and the recording was stopped 2 seconds after the change in facial expression was completed. Twelve scenarios were prepared in varying orders of presentation and adjusted to avoid bias according to gender and age. After a five-minute break, participants performed a condition in which they mimicked the facial expression pictures of others. Participants imitated a male or female photo first, and after another break, photos of them imitating the remaining gender were taken. After telling the participants the type of emotion to be imitated, the image was presented. As in the scenario-based condition, the order of presentation was counterbalanced.

3.6 Post-processing

Video data taken from five directions were time synchronized and trimmed. Time synchronization was based on the audio waveform. Fourteen videos were missing due to human error. In detail, one male participant's scenario-based expression, anger (mouth closed), was missing in all directions. Additionally, one female participant's female photo imitations of sadness, fear and disgust (mouth open/closed) and male photo imitations of happiness (mouth open/closed), sadness and anger (mouth closed) were missing in the upper direction. These data were included in the database with notes. Still images were extracted from the video. Using "FeatureExtraction" in OpenFace, the frame with the largest sum of AU values based on FACS was extracted as the frame with the largest expression and saved as an image.



Figure 1. Installation of recording equipment

AUs	01	02	04	05	06	07	09	10	12	14	15	17	20	23	25	26	45
Happiness (mouth open)	0	0	0	0	•		0	0	•		0	0	0	0	•	0	
Happiness (mouth closed)	0	0	0	0	•		0		•	٠	0	0	0	0		0	0
Sadness		0	•	•	0	0	0			0		0		0			0
Fear			0	•	0	0	0	0		0		0		0	٠		0
Surprise	•	•	0	•	0	0	0	0	0	0		0	0	0	٠		0
Anger (mouth open)	0	0			0					0		0		0	٠	0	0
Anger (mouth closed)	0	0			0	0			0	0					0	0	0
Disgust (mouth open)	0	0		0			•			0				0		0	0
Disgust (mouth closed)	0	0			•	•	•	•		0	•	•		0	0	0	0

Table 2. Results of comparison of AU values between elderly and younger age groups ($\bigcirc \& \bullet p < .05$)

Excitement					•		0	•	•		0	0		0	•		0
Relax	0	0	0	0	•	•	0	•			0						
Emotionless	0	0	0		0	0	0			0	0		0	0	0	0	0

4 COMPARISON WITH THE YOUNG JAPANESE FACIAL EXPRESSION DATABASE

The facial expressions of younger and elderly Japanese were compared. Twenty images (11 males and 9 females) from the AIST facial expression database and the ATR facial expression database were used for the facial expression images of the younger age group. For the facial expression images of the elderly, 110 images (55 males and 55 females) taken from the front in the scenario-based expression condition were used. OpenFace was used to analyze the 17 AUs, each of which was output on a scale of 500 (0.00 to 5.00). The output values were standardized and compared by Welch's t-test (significance level $\alpha = .05$) for each AU in each emotion. Figure 1 shows box plots of the AUs of the young and the elderly for various emotions. Of the pairs with significant differences at p < .05 in Table 2, those with significantly higher AU values for the elderly are indicated by open circles (\bigcirc). The AU cells that Ekman defines as universal expressions for each emotion are colored grey.

First, overall, the AU values of the elderly were significantly higher in many areas, which may be partially due to the effects of differences in the recording environment and instruction compared to existing databases. It is also possible that wrinkles and other effects associated with ageing may have an influence, but it is difficult to isolate the cause. In fact, in neutral expressions, the AU values of young people were not significantly higher than those of older people. On the other hand, with regard to the AUs defined in Ekman's theory, the elderly significantly exceeded the young or there was no significant difference in most cases, and there were the fewest cases in which the young exceeded the elderly. Specifically, for happiness (open mouth, closed mouth), AU6 and AU12 greater in the youth than the elderly. In surprise, young people were found to outperform older people in AU1, AU2 and AU5 as defined by Ekman, and in disgust (mouth closed), young people were found to outperform older people in all AUs. Despite the fact that older people have higher AU values than young people in many AUs, young people often outperform older people in AU movements that are strongly related to the expression of emotions. This means that AU movements characteristic of emotion may be reduced in the elderly, raising the possibility that the ability to express facial expressions is reduced due to a decline in the facial muscles. Although AU25 is not specified as a universal facial expression trait AU, it shows that for some emotions, AU values are lower for the elderly than those of young people. AU25 is the lip-opening movement, and it is possible that this movement is smaller in the elderly than in the young.

5 DISCUSSION

Comparisons using the existing database of young people's facial expressions showed that the intensity of expression of the AUs that contribute to the expression of emotions may be reduced in elderly people. Compared with younger people, older people have reduced movement in areas that should change significantly with the expression of certain emotions, particularly due to the weakening of facial muscles. This means that older people may express fewer facial expressions in response to intense emotion compared to younger people. In addition, elderly people's AUs related to mouth movements, such as AU10, AU12 and AU25, showed smaller values than those of young people, suggesting that the movements around the mouth may be decreasing.

The causes of the overall higher AU values in the elderly need to be investigated. One possibility is the influence of wrinkles; Fedok (1996) states that wrinkles start around the eyes, followed by the mouth and neck, starting in the late 40s. The average age of the elderly was 73, which may have affected the detection of AUs. These effects need to be taken into account for the estimation of emotions according to facial expressions among the elderly. Namba et al. (2021) also mention the effects of wrinkles and tension, stating that, in addition to RGB analysis, the use of depth information to represent facial features in three dimensions and rendering techniques to encode blood flow are useful. Future work should incorporate these techniques to conduct a more detailed analysis of facial expressions in the elderly.

It should be noted that the facial expressions in the constructed elderly facial expression database are not completely natural. The scenario-based facial expressions include acting by the participants, and it is possible that they do not adequately represent the emotions that actually occur. In this study, the existing database of facial expressions of young people in their 20s and 30s was used for comparison with the elderly, but as the recording environment and instruction differed from those of the database in this paper, it is necessary to be aware of these influences.

6 CONCLUSION

In this study, we recorded videos of eight emotions (happiness, sadness, fear, surprise, anger, disgust, excitement, relaxation) and neutral facial expressions of 111 elderly Japanese people and extracted still images to construct a facial expression database of elderly Japanese people. The facial expression analysis system was used to compare the database with the existing database of facial expressions of younger Japanese. The results showed that the values of AUs that move significantly in response to facial expressions were lower in the elderly than in the young. This result suggests that the intensity of facial expressions declines with age. This study also emphasizes the need to consider the effects of wrinkles and decline of facial muscles in the estimation of emotions by facial expressions in the elderly.

The database will be made available to universities and research institutions. We expect that the database will be useful for the development of globally robust support systems for the elderly that take into account changes in emotions to improve the accuracy of emotion estimation in Japanese elderly people and enable comparative studies of facial expressions in different regions. The database constructed in this study, titled the 'Japanese Elderly Facial Expression Database,' will be made publicly available in the Informatics Research Data Repository (IDR) of the National Institute of Informatics (NII), Japan (doi: 10.32130/rdata.9.1).

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DIFFERENCES BETWEEN EXPERTS AND NOVICES ON COGNITIVE BEHAVIORS FOR CIRCUIT DESIGN REVIEW

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ABSTRACT

Differences of cognitive activity between talented experts and novices are very important features to understand skills and to train novices efficiently. We examine the difference of them when they are doing a very specific technical task: review of semiconductor circuit designs. We employ a functional Near-Infrared Spectroscopy (fNIRS) and an eye-tracking system to observe brain and eye activities. In the experiment, we found that the experts focus showed distinct brain and eye movement patterns: the experts intensely focused on crucial points concerning logical and functional quality, so that they performed efficient and well-ordered review.

Keywords: expertise, proficiency, circuit design, layout diagram, fNIRS, eye-tracking

1 INTRODUCTION

This study conducts a preliminary investigation to evaluate how expertise in design and long-term professional experience influences subjective evaluations, eye movements, and brain

activity during the assessment of design impressions. By using physiological indicators such as eye movements and brain activity recordings, in addition to evaluating the designs themselves, the study aims to clarify the differences in proficiency, particularly among highly skilled design professionals.

In this study, the focus is on analog semiconductor circuit designers, who create "circuit diagrams" as part of their job. These diagrams are based on considerations of electrical interference and yield, and they also create "layout diagrams" to determine the placement of materials within the circuit. These circuit and layout designs significantly impact the quality and electrical efficiency of the final product. A paper summarizing the acquisition of expert performance [1] found that a minimum of 10 years of experience is required to master a wide range of highly skilled skills, including artists such as poets, writers, musicians, athletes, scientists, and chess players. It is said that several years to decades of experience are required for analog semiconductor circuit designers to develop designs that can be commercialized or patented. Throughout their long-term professional careers, analog semiconductor circuit designers need to continually assess their skills and undergo training and learning that matches their level of expertise to improve their design capabilities effectively. To understand their skill level, evaluations of their circuit and layout diagrams, as well as the yield of the produced semiconductors, are considered. However, while it is possible to evaluate logical coherence from the initial stages to advanced levels, it is challenging to specifically evaluate the differences between highly skilled designers, often referred to as "masters," who combine logical design with intuition based on experience.

Therefore, this study targets analog semiconductor circuit designers and evaluates not only the circuit and layout diagrams and the final products but also measures eye movements and brain activity during the evaluation of these diagrams. This approach aims to elucidate behavioral differences at various proficiency levels using physiological signals. By doing so, analog semiconductor circuit designers can recognize their level of proficiency and use this knowledge to enhance their training and learning processes according to their skill level.

2 BACKGROUND

This study categorizes the expertise levels of analog semiconductor designers into three stages, based on previous research [2] (Novice corresponds to "task-oriented designers", mid-career corresponds to "logical designers", and master corresponds to "creative designers"). According to a semi-structured interview conducted with 24 analog semiconductor designers in the prior study [1], it was revealed that designers with over 20 years of experience rely more on intuition and sensory-based design compared to those with less than 10 years of experience.

Next, we propose a hypothesis that relates the stages of expertise in analog semiconductor design to brain activity. At the "1. Novice to Task-Oriented Stage," novice designers learn the basics of design through repetitive tasks. As they progress to the "2. Logical Designer Stage," mid-career designers begin to understand the logical meaning of semiconductor circuits. In the subsequent "3. Creative Designer Stage," intuitive thinking, which arises from experience,

complements logical thinking. This allows master designers to select the best or most feasible design from multiple logically sound options by leveraging intuition and creativity.

As a physiological index to evaluate expertise, previous studies have clarified the difference in brain activity according to the expertise level of participants by measuring the prefrontal cortex with fNIRS [3]. In addition, the proficiency level of a task can be judged from the measurement of gaze movement such as gaze time at a fixation point, and it is sometimes used in skill training to show beginners the gaze movement of a master [4].

3 APPALATUS

3.1 fNIRS

To quantify the psychological activities of the experimental participants, we measured brain blood flow. Changes in brain blood flow can be used to identify active regions. In this study, we employed optical topography (ETG-4000, Hitachi) for brain function measurement. Based on functional Near-Infrared Spectroscopy (fNIRS), we measured the concentration changes of Oxy-Hb (oxygenated hemoglobin) and Deoxy-Hb (deoxygenated hemoglobin) as time-series data [5].



Figure 1. List of Optical Topography Locations and Correspondence Between Channels [6]

The brain activity measurement device was mounted to cover the prefrontal cortex of the experimental participants. The numbers 2 to 52 in the diagram represent the serial numbers of the 52 channels (referred to as Ch.) being measured. The light-receiving probe between Ch.5 and Ch.6 is positioned at Fpz, according to the international 10-20 system for EEG electrode placement. Due to the mounting method of this device, the Oxy-Hb concentration in the areas indicated by eight colors in the diagram can be measured with over 80.0% accuracy. The numbers in the legend indicate the division numbers in the Brodmann areas, which are the anatomical divisions of the cerebral cortex.

3.2 Eye-tracker

To measure the fixation points and eye movements of the participants on the diagrams, we used the stationary eye-tracking device Tobii Pro TX-300. This eye-tracker consists of an infrared emitter and measurement unit, along with a monitor for image presentation. Infrared light is

emitted towards the participants' eyes, and the reflected light is measured to calculate the distance between the eyes and the monitor. For this study, the data acquisition frequency was set to 60 Hz. Participants sat in a chair positioned in front of the eye tracker and display (screen size: 27 inches, face-to-display distance: 57 cm), placing their chin on a chin rest installed directly in front of them. Calibration was performed in this setup to ensure accurate data acquisition.

4 METHODS

The participants in the experiment were four analog semiconductor designers who provided informed consent in accordance with the regulations of Chuo University's ethics committee. The attributes of the participants, including their levels of expertise (see [2]), are summarized in Table 1. During the experiment, participants sat in a chair placed in front of an eye-tracking device on a desk, with their chin resting on a chin rest attached to the desk, and a brain activity measurement device attached to their heads. Circuit diagrams or layout diagrams were presented interspersed with control images (control tasks). Participants viewed the images while evaluating the diagrams. After viewing each set of diagrams, they responded to a questionnaire evaluating the diagrams.

Participant Number	gender	age	Work experience	attribute
A	Male	24	3 years	Novice
В	Male	36	1 decade	Mid-career
С	Male	60	4 decades	Master of circuit designer
D	Female	42	2 decades	Master of layout designer

Table 1. the attribute of participants

4.1 Questionnaire

During the experiments with circuit diagrams and layout diagrams, subjective evaluation questionnaires were administered. The questionnaires were presented on the screen after a set of circuit or layout diagrams was shown, with a resting image (CT) in between. Participants answered the questions verbally. The questionnaire items, based on a previous study [2], included negative evaluation items (Table 2). In addition, for the circuit diagram, functional beauty, logical beauty, and suitability for commercialization were assessed, while for the layout diagram, beauty of the layout, visibility, and suitability of the layout in relation to the circuit diagram were assessed on a 7-point Likert scale.

Table 2. Circuit diagram and layout diagram questionnaire items (multiple choice)

Circuit diagrams	Layout Diagrams
------------------	-----------------

Neat drawing style	The orientation of the elements is aligned.
Fact to follow signal flow	The arrangement of the elements is consistent.
	There is a sense of unity in the size of the
Accurate w/L sizing.	elements.
Logical composition of each block.	There is no dead space.
Functional composition of each block.	The analog and digital areas are properly divided.
Minimal design with no waste.	The placement and wiring balance of PAD and
Circuit diagram considers layout arrangement.	DRIVER is maintained.
Circuit compensates for process variations.	Block placement is done with top wiring in mind.
Confident that this circuit would sell without fail.	Separation of wiring area and element placement
There is a sense of discomfort.	area.
There are points that need improvement.	There is a sense of discomfort.
	There are points that need improvement.

4.2 Impression Evaluation Experiment of Circuit Diagrams and Layout Diagrams

In this study, impression evaluations, as well as brain activity and eye movement measurements, are conducted for both circuit diagrams and layout diagrams. The procedure for the circuit diagram experiment is shown in Figure 2. First, the brain blood flow measurement device is attached to the head, and the calibration of the eye tracker is performed to complete the device setup. Next, the control image (CT) is displayed on the monitor. CT is created by randomizing the color location of pixels in the stimulus image.



Figure2. experimental procedure

Two sets of circuit diagrams (stimulus images) are prepared. These circuit diagrams include one set of good circuit diagrams, which were evaluated positively by analog semiconductor designers not participating in this experiment (set A, consisting of 10 sheets representing one product), and one set of poorly evaluated circuit diagrams (set B, consisting of 11 sheets representing one product). The prior evaluation results of the circuit diagrams are not disclosed to the experiment participants. Each image is displayed for 20 seconds. The two sets of circuit diagrams are presented with resting images in between, and the experiment participants answer a questionnaire displayed on the screen orally afterward. Given the small number of participants (four), the presentation order of the circuit diagrams is standardized to display set A followed by set B. After the circuit diagram experiments, we also conduct experiments on layout diagrams. We ask the participants to evaluate the good and bad layout diagrams (sets of three) in the same way as we did with the circuit diagram experiments.





Figure 3. Samples of Circuit diagram (left) and layout diagram (right)

5 RESULT AND ANALYSIS

5.1 Subjective Evaluation

From the questionnaire used in the experiment, subjective evaluations were obtained for four participants across four types (two circuit diagrams and two layout diagrams). Due to the limited number of participants, statistical analysis was not conducted, and the results are presented in Figure 4. The alphabet in the first row represents symbols used to distinguish the participants. For items corresponding to the diagrams, responses indicating correspondence were converted to 1, while non-correspondence was coded as 0. Items 1 to 9 were scored based on evaluation criteria from previous research for the content of the diagrams.

The questionnaire regarding relevant items in the circuit diagrams shows that, except for Designer D, who is an expert in layout design, the participants rated circuit diagram A highly. Regarding the layout diagrams, all designers rated layout A highly. The evaluations of the circuit diagrams and layout diagrams conducted beforehand by designers who did not participate in the experiment do not appear to deviate significantly.



Figure 4. subjective evaluation of circuit(left) and layout(right) diagrams

5.1 fNIRS measurement

List the channels that were not used in the analysis due to noise during the measurement. In circuit diagrams Novice: 17, 30, Mid-Career: 23, Master of Circuit: 17, Master of Layout: 6, 17, in

layout diagrams Novice: 17, 39, 49, 50, Mid-Career: 23, Master of Circuit: 17, 23, 33, Master of Layout: 6, 17, 23.

Figure 5 presents heatmaps of brain activity when Mid-career designer looked circuit diagrams A. The intensity of Oxy-Hb measurements is indicated by varying shades of red for high values and shades of blue for low values. The orientation of the heatmap corresponds to the participant's brain, with the right side representing the right hemisphere and the left side representing the left hemisphere. The upper part of the heatmap is closer to the eyes and nose, while the lower part is closer to the top of the head.



Figure 5. Brain activity in a Mid-Career looking good circuits and hypothesis of brain functions

5.2 Eye-tracking

In the eye-tracking analysis, we created a heatmap illustrating the relationship between the duration of fixation and the location of fixation within the images, as well as a gaze plot recording the trajectory of fixations. In the heatmap, colors shift from green to yellow and red as fixation duration increases. For confidentiality reasons, circuit diagrams and layout diagrams in the eye-tracking results are presented in a scaled-down format.



Figure 6. Example of heatmap(left) and gaze plot(right)

Furthermore, we compiled the values for the fixation points used in the gaze plot for each designer and circuit diagram, we conducted a one-way analysis of variance to determine if there were differences in the number of fixation points among designers. Significant differences were found at a significance level of 5%. Subsequently, we conducted post-hoc multiple comparisons using Tukey's method (significance level = 5%). The results are shown in Figure 7.



Figure 7. average fixation points of each participant

Significant differences were observed between Mid-career designer and Master designer of layout (p < 0.001), Master designer of circuit and Master designer of layout (p < 0.001), and between Novice designer and Mid-career designer (p = 0.0140). A significant trend was observed between Novice designers and Master designer of circuit (p = 0.0638).

6 DISCUSSION

6.1 Subjective Evaluation

Regarding the assessment of item relevance, while there are individual differences, all designers can provide positive evaluations for both circuit diagrams and layout diagrams. However, Master designers are also able to provide negative evaluations for items 10 and 11. Therefore, it is speculated that master designers are able to make decisions on the acceptance or rejection of diagram proposals more quickly and reliably by identifying not only the positive aspects but also the negative aspects of the diagrams. In Figure 4, all designers prioritized the logical consistency of the schematic diagram, followed by functionality and suitability for productization. However, in the evaluation of layout diagrams, the relationship between basics and applications was not confirmed, especially in terms of placement, visibility, and suitability.

6.2 fNIRS measurement

Novice designer A exhibited less brain activity when viewing poor circuit diagrams compared to good ones. This suggests that while good circuit diagrams may stimulate brain activity, poor ones may decrease it, possibly due to the significant influence of image order effects. In brain activity measurement, the order effect refers to the phenomenon where brain activity increases when similar stimuli (images) are presented for the first time. Both good and bad circuit diagrams were characterized by Novice designer maintaining a high level of brain activity throughout the presentation of circuit images.

Mid-career Designer B exhibited a time series change in brain activation. From the start of the circuit diagram image stimulus to 20 seconds, activation occurred in the central area (prefrontal pole), then shifted to the left and right in the DL-PFC area, and by 50 seconds, the left and right edge areas were completely activated. The prefrontal pole is said to function as integrating high-level abstract information and simultaneously maintaining multiple pieces of information while performing multiple tasks consecutively, and the left edge of the

measurement location in this study corresponds to the language area. Therefore, it is believed that the process from acquiring information to verbalizing an evaluation of the circuit diagram was confirmed.

Master designer of circuit C experienced a rapid decrease in brain activity after about 50 seconds when viewing both good and bad circuit diagrams. This suggests that after viewing just 2 or 3 images, they were able to adequately evaluate the quality of the circuits. Master designer of Layout D not only exhibited low brain activity initially when viewing bad circuit diagrams but also experienced a rapid decline in brain activity after about 20 seconds. According to comments from colleagues, Designer D typically evaluates the circuit diagrams underlying the layout diagrams quickly. Therefore, similar to Designer C, it is inferred that Designer D made an early judgment about the quality of the circuits. Prefrontal cortex activity is thought to represent sustained effort to solve a problem, and previous research has shown it to result in novices abandoning a task [2]. This result may also indicate that the experts completed their evaluation.

6.3 Eye-tracking

From the heatmap, a trend can be observed where the fixation points become more concentrated as the design expertise progresses from Novice designer to Master designer of circuit. This is likely because as proficiency increases, individuals become quicker at recognizing the areas to be checked within the circuit diagram and subsequently fixate on those areas. Depending on the circuit diagram, it was also noted that individuals with lower proficiency levels spent more time confirming text if present. This could be because as individuals become more skilled, there is less need to read explanatory text. In contrast, the gaze plot indicates that Novice designer takes more time to confirm each individual point, whereas Mid-Career and Master Designer of Circuit spend less time per fixation point, suggesting an increase in finer, less noticeable fixation movements that cannot be observed in the heatmap.

Therefore, although individual differences need to be considered, the data from the gaze plot could potentially be utilized to distinguish between Novice and Mid-Career in circuit diagrams. Furthermore, the one-way analysis of variance comparing the number of fixation points in circuit diagrams per designer revealed significant differences between Mid-Career and Novice / Master of Layout, as well as between Master of Circuit and Master of Layout. There was also a significant trend between Novice and Mid-Career. Looking at the total number of fixation points in the layout diagrams, as Master of Circuit and Master of Layout had a higher number of fixations. Previous research has shown that experts had shorter fixation durations than novices [4], which corresponds to the results of this study, where the number of proficiency level.

7 CONCLUSION

7.1 Summary

The objective of this study is to conduct preliminary experiments concurrently with biometric measurements to investigate whether changes in physiological indicators such as brain activity

and eye movements occur according to the proficiency level of designers, who engage in analog semiconductor design and evaluate the impression of circuit diagrams and layout diagrams.

In subjective evaluations of diagram impressions, it is suggested that highly skilled designers not only evaluate the positive aspects of diagrams but also identify and evaluate the negative aspects, possibly aiding in the selection and rejection of designs. Particularly in circuit design, it is hypothesized that a stage can be reached where diagrams with high functionality and suitability for productization are created based on logic as a foundation.

Regarding brain activity, it was revealed that Mid-Career designers may engage the language area while evaluating diagrams, potentially verbalizing their assessment of the diagrams. Furthermore, it has been shown that reduced prefrontal activity may indicate the completion of an expert diagram evaluation task.

Regarding eye movements, analysis of the gaze plot revealed that designers with higher proficiency levels tended to have more frequent shifts in fixation points, indicating more efficient examination of diagrams. The total number of fixation points suggested a potential indicator of proficiency level.

7.2 Prospects

This study conducted a preliminary experiment with only four participants, which is very small. While the small sample size facilitated data confirmation, it often limited the use of statistical analysis. Therefore, it is deemed necessary to recruit more participants and further advance data acquisition. In this study, significant individual differences among participants were observed, suggesting the need to recruit multiple participants at each proficiency level of designers.

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POSITIONING MAPPING OF COLORED MASKS IN JAPAN: CORRELATION ANALYSIS OF HUE, SATURATION, BRIGHTNESS, AND IMPRESSION OF MASKS

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ABSTRACT

In Japan, masks of various colors gained popularity owing to COVID-19. However, it is not fully clear how the hue, saturation, and brightness of masks affect facial impression. In this study, we conducted an experiment to subjectively evaluate 69 different colored masks with the aim of determining the affective utility of mask colors. Positioning mapping using correspondence analysis revealed that the brightness and saturation of masks were positively correlated with impressions of being "kawaii (KAWAII)" and "flamboyant (HADE-NA)," respectively. The a* chromaticity coordinate that the positive direction indicates reddish hue in the CIELAB color space tended to correlate with the impression of being "brilliant (HANAYAKA-NA)," and the b* that the negative direction indicates bluish hue tended to correlate with the impression of being "intellectual (INTERI-FŪ)." Also, it was shown that the degree of influence of mask colors on facial impression tended to be stronger in the order of brightness, saturation, and hue.

Keywords: face mask, color, fashion, kawaii, kansei/affective evaluation

1 INTRODUCTION

Owing to the COVID-19 pandemic, when the Japanese government and the World Health Organization (WHO) recommended wearing masks when going outside (Ministry of Health, Labour and Welfare, Japan, 2020; Prime Minister's Office of Japan, 2020), masks in various colors such as coral pink, beige, and lavender began to be purchased in Japan around the summer of 2020 (Shiseido, 2020). This purchasing behavior may be attributed to the functional needs to prevent infectious diseases, as well as an increased affective needs to match the color

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of the mask with the impression around the face. However, mask colors that have been subject to quantitative evaluation in related studies (Ito & Kawahara, 2018; Nagashima et al., 2022) have been limited to achromatic colors such as white and black or warm colors, and the psychological effects of the three attributes of mask color, concretely, hue, saturation, and brightness (HSB), on the impression around the face, have not been fully determined.

Against this background, the authors have conducted several subjective evaluation experiments of colored masks, including a preliminary experiment conducted in the winter of 2020 (Honda et al., 2021; Kishi et al., 2023; Tada et al., 2024). This study reports the results of an integrated analysis of experiments (Kishi et al., 2023; Tada et al., 2024) in which 69 different pleated colored masks were evaluated, with the aim of determining the affective effects of hue, saturation, and brightness of the colored masks on the impression around the face.

2 MATERIALS

In this experiment, three composite images of fictitious person's faces and masks were used for evaluation. Figure 1 shows the selection procedure for the facial images subject to evaluation in this experiment and the 69-color palette used to color the masks. This chapter describes the procedure for generating images of colored mask wearers based on Figure 1.



Figure 1. Selection procedure for facial images and the 69-color palette

2.1 Generation and selection of facial images

Facial images selected for evaluation were generated using an image generation system based on Generative Adversarial Networks (GANs) (ACworks Co. Ltd., n.d.), a type of generative AI. In this experiment, we first generated 32 fictitious portrait images using this system, and then FaceNet (Schroff et al., 2015) was used to recognize facial regions and obtain facial features. Figure 1a shows the scatterplot of principal component scores of the facial features. The three facial images that were the farthest distance apart in Figure 1a were selected for evaluation in this experiment, and were designated as Faces 1, 2, and 3. The selected facial

images are showed in Figure 1b. These facial regions have the modes of CIE LAB L* values of 78, 82, and 75, in order from Face 1. A related study (Yamamoto et al., 2003) showed that the L* of preferred skin in Japan, China, and Korea is normally distributed in the range of 72 to 82; this system (ACworks Co. Ltd., n.d.) tends to generate portrait images that resemble fashion models preferred by Japanese people. The resolution of the facial images was 512×512 px, the background area was filled with light gray with Red, Green, and Blue (RGB) values of (241, 241, 241), and the clothing area was multiplied with black.

2.2 Selection of colors to multiply with the mask

The colors of the masks to be evaluated were selected from the Color Image Chart (Nagumo, 2016, 2022). The chart lists 168 chromatic colors, and the color palette, comprising 12 colors of different hues, is classified into groups called Color Images. Each Color Image is assigned a symbol, such as p (Pure) or c (Clever), to which a numerical value such as $1, 3, \dots, 23$ is added to express the difference in hue. Further, the chart lists 9 achromatic colors, with the symbol w for white and k for other achromatic colors. Moreover, these symbols are accompanied by a numerical value such as $0, 10, \dots, 100$ to express the difference in shading. The combination of these symbols and numerical values, such as "p1," is called the Color Index in this chart.

Figure 1c shows a list of the colors selected for evaluation in this experiment. As shown in Figure 1c, the 69-color palette has 5 selected hues, 1-red, 5-yellow, 11-green, 17-blue, and 21-violet, selected from 12 hues in the chart, and has 4 achromatic colors, w0, k25, k50, and k90, selected from 9 achromatic colors. Furthermore, considering the fatigue of the subjects due to the large number of colored masks to be evaluated, the subjective evaluation experiment of colored masks was conducted in two separate sessions, in 2022 and 2023; the 69-color palette also separated 34 and 35 colors in each session, as shown on the right side of Figure 1c. As shown in Figure 1d, a non-woven pleated mask (PL-FM03NWH50EC, MS Solutions) was photographed to fit the contour of each facial image, and the mask image area was cropped from this image and composed with the facial image. The colored mask images were generated by multiplying the RGB values of the color palette in Figure 1c by the white mask images in Figure 1d. Figure 1e shows an example that image of each the person's face with a colored mask multiplied by the RGB value of f1, which is light pink.

3 METHODS

This experiment was conducted with the approval (04-002) of the Human Bioethics Review Committee of Tokyo Denki University. As mentioned in Section 2, the authors conducted two separate subjective evaluation experiments of colored masks, however, both experiments were held during the winter season to mitigate factors of seasonal internal and external disturbances such as seasonal changes in color perception (Shoyama et al., 1997). Specifically, this experiment was conducted in two sessions, from November 25 to December 23, 2022, and from November 13 to December 26, 2023. The participants were students in their 20s living in Japan whose color vision was deemed to be normal by the Ishihara color test. In this experiment, 27 individuals participated in the 2022 session and 17 individuals participated in the 2023.

session. These 44 individuals comprised 20 males and 24 females. The participants in the 2022's session evaluated 105 facial images (34 colors x 3 faces with mask + 3 faces without mask), and the participants in the 2023's session evaluated 108 facial images (35 colors x 3 faces with mask + 3 faces without mask). The order in which the facial images were presented was randomized for each participant to account for order effects and counterbalance. Also, to reduce the fatigue of the participants, as shown in Figure 2a, the sessions had the 3 parts for evaluating one-third of the facial images; there were two break times of 3 minutes among the parts.

Facial image impression was evaluated by asking the participants to choose whether the selected evaluation words were "applicable" or "not applicable." The evaluation words were selected from a group of words used to describe the color palette in the Color Image Chart (Nagumo, 2016, 2022) described above. The chart contains 160 words that describe the meaning of color palettes (Color Image Words) divided into 4 major categories, B (budding), G (growth), R (ripen), and W (withering). And, a total of 16 words were selected, 4 words from each of these 4 categories, such as "flamboyant (HADE-NA)" and "brilliant (HANAYAKA-NA)." In addition, with reference to other related studies (Nagashima et al., 2022), 6 words used to evaluate facial expressions and fashionability were added: "stern (KOWASOU-NA)," "kindly (YASASHISOU-NA)," "elderly (FUKETA)," "conservative (HIKAEME-NA)," "energetic (GENKI-NA)," and "kawaii (KAWAII)," and 22 words were selected in total. The order of presentation of the evaluation words was randomized. The words in parentheses listed together with the evaluation words represent the Japanese pronunciation that was demonstrated to the participants in the experiment. However, the Japanese word "KAWAII" is used in this study as it is in Japanese, because related studies (Berque et al., 2019; Pellitteri, 2018) have reported that it has a broader meaning than "cute" and includes various positive impressions such as "sweet" and "lovely."

The facial images and the response form for the evaluation words were displayed on a 24.1-inch liquid crystal display monitor (CG2420-Z, EIZO). The screen was calibrated with a peak luminance of 200 cd/m2 and a color gamut of sRGB. As shown in Figure 2b, one facial image was displayed on the left side of the screen in dot-by-dot format, and option button groups with the evaluation words were displayed on the right side. The background was filled gray RGB values of (128, 128, 128). The viewing distance was approximately 0.97 m, which is three times the screen height *H*. The screen was viewed while seated in a chair under a D₆₅ light source (Z-209PRO-6500K, Yamada Shomei Lighting Co., Ltd.).

Figure 2. The experimental procedure and questionnaire form

4 RESULTS AND DISCUSSION

4.1 Positioning mapping of colored masks

Figure 3 shows the biplots (positioning maps) using correspondence analysis (CA), a type of constrained principal component analysis, and the figure shows the overall relationship between the face images with/without the colored masks and the evaluation words. The R and ca packages (Ver. 0.71.1) were used for the analysis. Figure 3a shows the biplot with the first component on the horizontal axis and the second component on the vertical axis, and Figure 3b shows the biplot with the third component on the horizontal axis and the fourth component on the vertical axis. The four convex hulls in Figure 3a show the ranges in which the face images with the colored masks in "Pure Color," "Light Clear Color," "Shade Clear Color" and "Fusion Color" in the Color Image Chart (Nagumo, 2016, 2022) described above, and the five convex hulls in Figure 3b show the range in which hues of 1-red, 5-yellow, 11-green, 17-blue, 21-violet in the Color Image Chart. Table 1 shows the Pearson's product-moment correlation coefficients between the scores of the first through fourth components obtained in the CA and the three attributes of color. Here, in HSB, H stands for hue, S for saturation, and B for brightness. And, in CIE LAB, L* stands for brightness, a* for the red/green coordinate, and b* for the yellow/blue coordinate.



Figure 3. Biplots of the face images and evaluation words

		HSB		CIE LAB						
	н	S	В	L*	a*	b*				
Component 1	0.019	-0.662***	0.813***	0.884***	-0.051	0.162*				
Component 2	0.241***	0.456***	0.358***	0.121	0.108	0.217**				
Component 3	0.330***	0.080	-0.066	-0.163*	0.638***	0.219*				
Component 4	-0.467***	0.150*	0.139*	0.177*	-0.170*	0.533***				

Table 1. Correlation coefficients between components (axes) and the three attributes of color

*** P < 0.001, ** P < 0.01, * P < 0.05

Figure 3 shows that the contribution rate of each component (axis) determined by the CA was 43.1%, 29.2%, 9.8%, and 6.3%, in order from the first component, and the cumulative contribution of these four components reached 88.4%. This result shows that the variance of the responses to the evaluation words is well described in the four-dimensional space of Figure 3. Also, as mentioned in Section 2, the authors conducted the subjective evaluation experiment of the colored masks in two separate sessions. To investigate whether this affected the analysis results, the authors applied tests of no correlation to the results of the component 1 to 4 of the evaluation words obtained by applying correspondence analysis to both sessions. As a result, it was significantly shown that the correlation coefficients between in each the first, second, third, and fourth components were 0.764, 0.708, 0.888, and 0.925 (p < 0.001), in order from the first.

Table 1 shows that the first component has a strong positive correlation with brightness B of the colored masks (r = 0.813, t = 20.0, p < 0.001) and a similarly strong positive correlation with L* (r = 0.884, t = 27.1, p < 0.001). Thus, it is thought that the brightness of the colored masks has a significant effect on the impressions of our faces, and that a higher brightness tends to provide a higher probability of the impressions of the evaluation words appended on the right side of Figure 3a, such as "kawaii (KAWAII)."

Table 1 shows that the saturation S of the colored masks has a negative correlation with the first component (r = -0.662, t = -12.6, p < 0.001), and a positive correlation with the second component (r = 0.456, t = 7.34, p < 0.001). Thus, it is thought that the "Pure Colored" masks with high saturation have a high probability of providing the impressions of the evaluation words appended on the upper left corner in Figure 3a, such as "flamboyant (HADE-NA)."

In Figure 3a, the "Light Clear Colored" masks created by mixing white with "Pure Color" tend to be positioned on the right side, the "Fusion Colored" masks created by mixing gray with "Pure Color" tend to be positioned on the lower right side, and the "Shade Clear Colored" masks created by mixing black with "Pure Color" tend to be positioned on the lower side. It is noteworthy that the "Neutral colored" masks which are achromatic colors tend to be positioned on the outer edge of the lower part of the three convex hulls except for "Pure Color." It is thought that the achromatic colored masks provide the impressions of being "neat (SEISO-NA)," "conservative (HIKAEME-NA)," "plain (JIMI-NA)," "elderly (FUKETA)," or "stern (KOWASOU-NA)," in descending order of brightness, whereas that the chromatic colored masks except for "Pure Color" provide either one of the aforementioned impressions depending on the brightness of the achromatic colors that are mixed in.

Table 1 shows that the third component has a positive correlation with the chromaticity coordinate a* (r = 0.638, t = 11.9, p < 0.001). Thus, it is thought that the reddish hue tends to provide the impression of the evaluation word appended to the right side in Figure 3b, such as "brilliant (HANAYAKA-NA)." Similarly, the fourth component has a positive correlation with the chromaticity coordinate b* (r = 0.533, t = 9.01, p < 0.001). Thus, it is thought that the bluish hue tends to provide the impression of the evaluation word appended to the lower part in Figure 3b, such as "intellectual (INTERI-FŪ)." However, since the total contribution rate of the third and fourth components is approximately 16%, the hue of the mask has a smaller effect on the facial impression than the brightness and saturation.

4.2 Correlation Between Representative Evaluation Words and the Three Attributes of Color

Four words were selected with reference to the results in the previous section in order to clarify the detailed relationship between individual evaluation words and the three attributes of mask colors; (1) "kawaii (KAWAII)" in relation to brightness B and L*, (2) "flamboyant (HADE-NA)" in relation to saturation S, and (3) "brilliant (HANAYAKA-NA)" and (4) "intellectual (INTERI-FŪ)" in relation to hue (chromaticity coordinate a* and b*). Correlation analysis and generalized linear mixed model (GLMM) were applied to them. Figure 4 shows the response probabilities of the experiment participants who answered "applicable" to each evaluation word. In Figure 4, the horizontal axis represents the Color Index of the mask and the vertical axis represents the response probabilities for Faces 1, 2, and 3, from left to right, respectively, and the line graph represents the average of these probabilities. The Color Index on the horizontal axis of each figure is arranged in ascending order according to the average of the response probabilities, and the correlation between this ranking and the three attributes of color associated with each evaluation word was evaluated using Spearman's rank correlation coefficient. The shaded Color Indexes represent the mask colors that have a significant

difference (p < 0.05) in two conditions: without and with the colored mask. These differences were evaluated using GLMM and the regression model with the mask colors as a fixed effect, and the experiment participants and facial images as random effects. The R and Ime4 packages (Ver. 1.1.31) were used for the analysis.



Figure 4. Response probabilities for (a) "kawaii," (b) "flamboyant," (c) "brilliant," and (d) "intellectual"

Figure 4a shows the results of arranging the Color Index in ascending order according to the response probability to "kawaii (KAWAII)." This sequence of the rank had a significantly strong positive correlation with the brightness B of the mask ($\rho = 0.851$, S = 8165, p < 0.001), as well as a significantly strong positive correlation with the brightness L* ($\rho = 0.784$, S = 11802, p < 0.001). In the case of the face images without mask, the average response probability to "kawaii (KAWAII)" was 62.1%, however, the p21 to m5 masks on the left side of Figure 4a significantly reduced the response probability (p < .05). The p21 mask, which has the lowest "kawaii (KAWAII)" impression, reduced the average response probability to 1.2%, and this reducing effect was also observed for all four achromatic colored masks. On the other hand, the mt1, y1, and f1 masks on the right side of Figure 4a significantly improved response probability (p < .05). The f1 mask, which had the highest response probability, indicated an average of 92.1%. Therefore, it is thought that the brightness of the mask has a strong correlation with the "kawaii (KAWAII)" impression, and that masks with high brightness of chromatic color, particularly those with a reddish hue, have the effect of improving the "kawaii (KAWAII)" impression.

Figure 4b shows the results of arranging the Color Index in ascending order according to the response probability to "flamboyant (HADE-NA)." This sequence of the rank had a significant positive correlation with the saturation S of the mask ($\rho = 0.820$, S = 9835, p < 0.001). In the case of the face images without mask, the average response probability to "flamboyant

(HADE-NA)" was 17.4%, however, the w0 to e1 masks on the left side of Figure 4b significantly reduced the response probability (p < .05). On the other hand, the h11 to p1 mask on the right side of Figure 4b significantly improved response probability (p < .05). The p1 mask, which had the highest response probability, indicated an average of 96.3%. Therefore, it is thought that the saturation of the mask has a strong correlation with the "flamboyant (HADE-NA)" impression. However, since the effect of significantly increasing the "flamboyant (HADE-NA)" impression was also observed in the achromatic k90 mask, this impression is also conceivably related to its contrast with the skin and clothing colors.

Figure 4c shows the results of arranging the Color Index in ascending order according to the response probability to "brilliant (HANAYAKA-NA)." This sequence of the rank had a significant positive correlation with the chromaticity coordinate a* of the mask ($\rho = 0.428$, S = 31336, p < 0.001). In the case of the face images without mask, the average response probability for "brilliant (HANAYAKA-NA)" was 53.8%, however, the h5 to mt11 masks on the left side of Figure 4c significantly reduced the response probability (p < .05). The h5 and k25 masks, which had the lowest "brilliant (HANAYAKA-NA)" impression, reduced the average response probability to 0.0%, and this reducing effect was also observed for all four achromatic colored masks. On the other hand, the 11 masks from pn1 to m1 on the right side of Figure 4c significantly improved response probability (p < .05), and 9 of these masks (p1, c1, m1, y1, f1, t1, s1, fa1, pn1) had a hue of 1-red. Therefore, it is thought the chromaticity coordinate a* that the positive direction indicates reddish hue is correlated with the "brilliant (HANAYAKA-NA)" impression, were "Light Clear Colors," suggesting that this enhancing effect emerges in the case of chromatic colors with medium or higher brightness.

Similarly, Figure 4d shows the results of arranging the Color Index in ascending order according to the response probability to "intellectual (INTERI-FŪ)." This sequence of the rank had a significant negative correlation with the chromaticity coordinate b^{*}, of the mask ($\rho = -0.536$, S = 84092, p < 0.001). In the case of the face images without mask, the average response probability to "intellectual (INTERI-FŪ)" was 53.8%, however, the 11 masks from pn17 to hd17 on the right side of Figure 4d, significantly improved the response probability (p < .05), and 7 of these masks had a hue of 17-blue (c17, y17, s17, hd17, fa17, mt17, and pn17). Therefore, it is thought the chromaticity coordinate b^{*} that the negative direction indicates bluish hue is correlated with the "intellectual (INTERI-FŪ)" impression. The 11 masks that improved the "intellectual (INTERI-FŪ)" impression, 6 were fusion colors (hd17, fa17, mt11, mt17, mt21, pn17) and 2 were gray (k25, k50), suggesting that this enhancing effect emerges when both the brightness and saturation are medium for chromatic colors, and when the brightness is medium for achromatic colors.

5 CONCLUSION

This study subjectively evaluated various colored masks including pure, light clear, shade clear, fusion, and achromatic colors, and created a positioning map using correspondence analysis. The results suggest that colored masks significantly change the impression around the

face, and that the effect indicates stronger in the order of brightness, saturation, and hue. However, this experiment only evaluated adult Asian women, and did not consider the affective evaluation in the case of the mask wearers had different external appearances resulting from their genetic traits, such as gender, age, or skin color. Future work includes clarifying the detailed relationship between the impression of colored masks and the wearer's facial features.

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UNIFIED-USAGE-BEHAVIOR BASED KANSEI SHARING AMONG WHO HAVE SIMILAR KANSEI BACKGROUND

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ABSTRACT

Values based on sensitivity, attracting attention as a new standard of value for traditional crafts and other items, are difficult to share because sensitivity depends on how each person perceives things. However, if a commonality in the cultural background supports each person's sensitivity ("sensitivity background" below), people often have similar impressions about the same things. Therefore, we thought that people with similar cultural backgrounds could share the same feelings and sensibilities through unified usage behavior. In this paper, we unified the action of opening a tea canister between persons. Regarding the transfer of sensitivity, the analysis of 76 adjective pairs measured using the Semantic Differential method showed that 52 pairs tended to move in the proximity direction with a probability of over 50%. Even when the analysis was limited to those with over 90% probability of moving in the proximity direction, 30 adjective pairs could be extracted, and even when limiting it to those with a probability of over 95%, 22 adjective pairs could be extracted. This result suggests that uniform usage behavior allows sharing of a certain degree of sensitivity between people with similar sensitivity backgrounds.

Keywords: Sensitivity sharing, tee-canister, Japanese traditional craft, motion emulation

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1 BACKGROUND

Values based on sensitivity, attracting attention as a new standard of value for traditional crafts and other items, are difficult to share because sensitivity depends on how each person perceives things. However, if a commonality in the cultural background supports each person's sensitivity ("sensitivity background" below), people often have similar impressions about the same things. Therefore, we thought that if people have similar cultural backgrounds, sharing the same feelings and sensibilities through unified usage behavior would be possible.

In this paper, we have unified the action of opening a tea canister and compared the sensitivity values felt at that time. The action was unified based on the internal air pressure fluctuations of the tea canister when it was opened. The unification was achieved through the subjects' efforts and the assistance of mechanical control using an air pressure sensor and proportional solenoid valve. This approach is called Assisted effort Emulation in this paper.

Regarding the transfer of sensitivity, the analysis of 76 adjective pairs measured using the Semantic Differential method showed that 52 pairs tended to move in the proximity direction with a probability of over 50%. Even when the analysis was limited to those with over 90% probability of moving in the proximity direction, 30 adjective pairs could be extracted, and even when limiting it to those with a probability of over 95%, 22 adjective pairs could be extracted. This result suggests that uniform usage behavior allows sharing of a certain degree of sensitivity between people with similar sensitivity backgrounds.

2 JAPANESE TRADITIONAL CRAFT USED IN THE EXPERIMENT

In this experiment, we used a tea canister, shown in Fig. 1, one of Japan's traditional craft products. It is a product of Kaikado, a traditional craft studio in Kyoto. It is a highly airtight can, and the current Craft master says, "We want you to enjoy the strange feeling of the sticky, soft texture when opening the can." We took this comment to heart and examined the transmission of the sensitivity values obtained from the feeling when opening the canister.



Figure 1. Tee canister of Kaikado (A Japanese Traditional Craft)

2.1 Modification of a tea canister for an experiment

In this study, Kaikado tea containers were modified for the project. The modifications were carried out under the supervision of the current craft master. The craft master did not damage the characteristic of a "mysterious soft and sticky feeling when opening the can" of the product.

The craft master confirmed that the modified tea containers had the same feel as the unmodified product.

Fig. 2 shows the tea canister after the modification. Three holes were made in the bottom of the tea canister to create a USB cable outlet and proportional solenoid valve connection ports. The USB cable uses a connector that a magnetic connection can separate so the airtightness of the container is maintained. As mentioned above, the craft master has confirmed that the "sensation of use is equivalent to the non-modified product." The reason for using a wired connection instead of a wireless connection is that wireless connections such as Bluetooth are cut off when the container is closed because of a high level of airtightness.



Figure 2. The custom tee canister

A USB hub is connected to the connector of the wired USB cable inside the canister. The TSND151, a compact wireless multi-function sensor from ATR-Promotion, and the mbed LPC1768 are connected to the USB hub. The recording of internal air pressure changes was carried out via the TSND151. To avoid interfering with the recording of TSND151, the internal air pressure adjustment during the operation was carried out using the mbed LPC1768, which is a separate system from the TSND151. The air pressure sensor connected to the mbed LPC1768 is the BMP388 digital barometric pressure sensor from Mouser Electronics. The air pressure adjustment uses the PVQ31 compact proportional control valve from SMC. The internal air pressure is automatically adjusted according to the time series data of air pressure changes downloaded to the mbed LPC1768 in advance. The start of opening the canister is automatically detected when the stable internal air pressure becomes a negative value.

3 HOW TO MEASURE SENSITIVITY

This study measured sensitivity using the Semantic Differential method (hereafter referred to as the SD method). The SD method is a representative method for measuring impressions and images. Multiple adjectives related to the evaluation target are prepared in pairs with adjectives with opposite meanings, and each evaluation item is evaluated on a scale of 5 or 7 levels. For example, adjectives such as "bright-dark" are evaluated in pairs.

Here, we need to be careful. Because the SD method uses adjective pairs to evaluate, the results are strongly influenced by language and cultural background. For example, the Japanese word "穏やかな" in the Japanese cultural sphere does not match the English word "serene" on a one-to-one basis. In addition, even in countries where English is the native language, there

may be differences in nuance depending on whether it is the United States or the United Kingdom.

Therefore, please be aware that this paper's results are the results of the SD method using Japanese in the Japanese cultural sphere. Therefore, the references used to select the adjective pairs are also in Japanese and quoted as is. English translations also accompany the adjective pairs, but the Japanese expressions are also used as is.

3.1 Japanese Adjective Pairs Selection

Studies conducted in Japan, e.g., Nou, Sato, Shimokawa, & Ishizuka, 2020; Yamashita, Ryoke, & Nakamori, 2013; Yamashita, Ryoke, & Nakamori, 2012; Kang & Takamiya, 2009, have shown that it is common to use around 10 to 30 adjective pairs. However, in this study, to select adjective pairs suitable for evaluating the sensibility of tea canisters, we did not select adjectives. Instead, we used 76 adjective pairs, referring to the Adjective Pair Table (Fukuda & Fukuda, 2009) for selecting adjective pairs in factor analysis. The 76 adjective pairs are shown in Tab. 1, together with sample translations. When evaluating, we randomized the order of the 76 adjective pairs and obtained sensibility evaluation scores on a 7-point scale.

Japanese Adj.	Sample Translation	Japanese Adj.	Sample Translation
Pairs		Pairs	
悪い-良い	Bad-Good	異端な-正統な	Heterodox-Orthodox
間違った-正しい	Wrong-Right	乾いた-湿った	Dry-Wet
冷たい-熱い	Cold-Hot	暗い-明るい	Dark-Bright
古い-新しい	Old-New	自由な-窮屈な	Free-Constrained
悲観的な-楽観的な	Pessimistic-Optimistic	まずい-おいしい	Tasteless-Delicious
消極的な-積極的な	Passive-Active	左右非対称の-左右	Asymmetrical-Symmetrica
			1
		対称の	
偶然の-意図的な	Accidental-Intentional	下品な-上品な	Vulgar-Elegant
ざらな-まれな	Often-Rare	広い-狭い	Wide-Narrow
不完全な-完全な	Imperfect-Perfect	うんざりした-爽や	Weary-Refreshing
		かな	
恥辱な-名誉な	Shameful-Honorable	非競争的な-競争的	Non-competitive-Competi
		+	tive
		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
遅い-速い	Slow-Fast	苦しい-楽しい	Painful-Joyful
成熟した-若い	Mature-Young	軽い-重い	Light-Heavy
タイミングの悪い-	Ill-timed-Well-timed	地味な-鮮やかな	Plain-Vivid
良い			
懐疑的な-軽信的な	Skeptical-Gullible	乱れた-整った	Disordered-Orderly
単純な-複雑な	Simple-Complex	醜い-美しい	Ugly-Beautiful

Table 1. 76 Adjective Pairs

防御的な-攻撃的な	Defensive-Offensive	おどけた-真面目な	Playful-Serious
利己的な-利他的な	Selfish-Altruistic	退屈な-面白い	Boring-Interesting
愚かな-賢い	Foolish-Wise	一時的な-継続的な	Temporary-Continuous
酔った-しらふの	Drunk-Sober	失敗した-成功した	Failed-Successful
地味な-派手な	Plain-Flashy	明確な-曖昧な	Clear-Vague
非社交的な-社交的	Unsociable-Sociable	温和な-粗暴な	Mild-Rowdy
な			
不健全な-健全な	Unhealthy-Healthy	未熟な-洗練された	Immature-Sophisticated
不安定な-安定な	Unstable-Stable	低い-高い	Low-High
遠い-近い	Far-Near	小さい-大きい	Small-Big
冷淡な-親切な	Indifferent-Kind	鈍感な-敏感な	Insensitive-Sensitive
柔らかい-硬い	Soft-Hard	私的な-公的な	Private-Public
感情的な-理性的な	Emotional-Rational	意味のない-意味の	Meaningless-Meaningful
		ある	
同質の-異質の	Homogeneous-Heterogene ous	女性的な-男性的な	Feminine-Masculine
うらめしい-ありが	Resentful-Grateful	丸みがかかった-角	Rounded-Angular
たい		張った	
弱い-強い	Weak-Strong	傲慢な-謙虚な	Arrogant-Humble
狂気の-正気の	Insane-Sane	些細な-重要な	Trivial-Important
不確実な-確実な	Uncertain-Certain	受動的な-能動的な	Passive-Active
不調和な-調和した	Dissonant-Harmonious	曲がった-まっすぐ	Crooked-Straight
		な	
穏やかな-厳しい	Mild-Harsh	主観的な-客観的な	Subjective-Objective
軽率な-慎重な	Rash-Prudent	退歩的な-進歩的な	Regressive-Progressive
習得的な-生得的な	Acquired-Innate	落ち着いた-興奮し	Calm-Excited
		た	
不潔な-清潔な	Dirty-Clean	鈍い-鋭い	Dull-Sharp
従順な-強情な	Submissive-Stubborn	寛大な-つつましい	Generous-Modest

## 3.2 Quantifying the Effect of Shared Sensitivity

The effect of sharing sensitivity was quantified in the following steps. First, each person opened the tea canister as they liked and recorded their sensitivity using the SD method and 76 adjective pairs. The evaluation value for Subject A is A_A. At this time, the internal air pressure fluctuation value is also recorded as data on how the tea canister was opened.

Next, Subject A reproduces the behavior of the other subjects based on the data on how to open the tea canister (the details of the reproduction method will be discussed later in section 4). When reproduction is sufficiently achieved, the sensitivity felt with the behavior is recorded

using 76 adjective pairs. This paper writes the recorded value as  $A_s$  (s  $\in$  a reproduction target group, e.g., B, C, D, E)).

Next, the evaluation results ( $A_A$ , and  $A_S$  ( $s \in$  the replication target group)) by A are combined and normalized so that the maximum value becomes 1 and the minimum value becomes -1. After that, for example, the sensitivity sharing score  $S_{A-B} = |A_{B-} B_B| - |A_{A-} B_B|$  is calculated to determine whether the sensitivity of A was shared with that of B. Therefore, if the shared score  $S_{A-B}$  becomes negative, A's sensitivity to a particular adjective pair has become closer to B's.

#### 4 HOW TO UNIFY OPENING CANISTER BEHAVIOR: ASSISTED EFFORT EMULATION

The unification of the canister-opening behavior was carried out in the following way. The subjects practiced the canister-opening behavior while watching the reference waveform of the air pressure fluctuation shown in Fig. 3 and tried to match the waveform. At this time, the proportional solenoid valve built into the canister automatically adjusted the internal air pressure to match the reference waveform. The subject only needs to make rough adjustments, and the built-in proportional solenoid valve will take care of the finer corrections. After the movements became sufficiently similar, the sensitivity values were obtained.



**Figure 3**. An example of an air pressure graph Dotted line: reference, Solid line: actual air pressure

## 5 EXPERIMENT TO SHARE SENSITIVITY

This experiment was conducted on seven subjects (1-7). In addition, we obtained the sensitivity value data and canister opener motion data to be emulated from another nine subjects (A-I) in advance. Due to the realistic experiment time length, the number of communication experiments per person was set at seven. We made sure that the subjects to be emulated were evenly distributed. The assignments are shown in Tab. 2.

				Targets							
			А	В	С	D	Е	F	G	Н	Ι
jec 1	1	х	Х	Х	х	Х			х	х	
Sub	Ť	2	Х		х	х		Х	х	х	х

Table 2. Kansei Transfer experiment map

	3	х	х	х		х	х	Х	Х	
	4	Х	Х	Х	х	Х		х		х
	5	Х	Х	Х	х	Х	Х			х
	6	Х	Х	Х			Х	х	х	х
	7		х		х	Х	Х	х	х	х
cour	nts	6	6	6	5	5	5	5	5	6

## 5.1 Removal of random fluctuation factors

In this study, to eliminate the random factors from the experimental results, we conducted a goodness-of-fit test using the chi-square test on distributions of random fluctuations and each adjective pair of results. The Benjamini-Hochberg method was used to solve the multiple-testing problem of 76 pairs. After screening using the criterion of p < 0.05, the following four adjective pairs were excluded from the following analysis as there was no significant difference from random fluctuations: "意味のない-意味のある / meaningless-meaningful," "感情的な-理性的な / emotional-rational," "受動的な-能動 / passive-active," and "柔らかい-硬い / soft-hard." Meaningless-Meaningful, Emotional-Rational, Passive-Active, and Soft-Hard". Thus, there are 72 adjective pairs in the analysis.

#### 5.2 Estimation of Effect Size

In this experiment, the effect size was calculated using Bayesian statistical modeling. The application used was STAN. As a result of checking the distribution shape of the remaining 72 adjective pairs, an unimodal distribution with many outliers was confirmed, so the Student's t distribution was used to estimate the effect size. Tab. 3 shows the mean value of the estimated Student's t-distribution and the probability of the mean value being less than zero (in Tab 3, it is written as Lt. Zero Prob.). Less than zero probability refers to the probability that the emotional value will be shared and change in the direction of proximity.

Table 3. Kansei Sharing effects							
Japanese Adj. Pairs	Sample Translation	Est. Mean	Lt. Zero Prob.				
遅い-速い	Slow-Fast	-0.386	1.000				
冷淡な-親切な	Indifferent-Kind	-0.185	1.000				
下品な-上品な	Vulgar-Elegant	-0.226	1.000				
利己的な-利他的な	Selfish-Altruistic	-0.176	0.999				
落ち着いた-興奮した	Calm-Excited	-0.300	0.999				
非社交的な-社交的な	Unsociable-Sociable	-0.179	0.999				
女性的な-男性的な	Feminine-Masculine	-0.206	0.997				
非競争的な-競争的な	Non-competitive-Competitive	-0.229	0.996				
傲慢な-謙虚な	Arrogant-Humble	-0.191	0.995				
低い-高い	Low-High	-0.130	0.994				

温和な-粗暴な	Mild-Rowdy	-0.228	0.993
些細な-重要な	Trivial-Important	-0.132	0.985
地味な-鮮やかな	Plain-Vivid	-0.151	0.983
地味な-派手な	Plain-Flashy	-0.153	0.981
弱いー強い	Weak-Strong	-0.184	0.980
同質の-異質の	Homogeneous-Heterogeneous	-0.115	0.979
穏やかな-厳しい	Mild-Harsh	-0.176	0.976
鈍い-鋭い	Dull-Sharp	-0.112	0.975
習得的な-生得的な	Acquired-Innate	-0.124	0.969
防御的な-攻撃的な	Defensive-Offensive	-0.181	0.957
偶然の-意図的な	Accidental-Intentional	-0.130	0.955
従順な-強情な	Submissive-Stubborn	-0.133	0.950
狂気の-正気の	Insane-Sane	-0.087	0.941
愚かな-賢い	Foolish-Wise	-0.058	0.938
消極的な-積極的な	Passive-Active	-0.109	0.936
古い-新しい	Old-New	-0.063	0.931
丸みがかかった-角張った	Rounded-Angular	-0.123	0.930
不安定な-安定な	Unstable-Stable	-0.113	0.923
不確実な-確実な	Uncertain-Certain	-0.106	0.919
乱れた-整った	Disordered-Orderly	-0.101	0.909
私的な-公的な	Private-Public	-0.082	0.878
酔った-しらふの	Drunk-Sober	-0.057	0.873
異端な-正統な	Heterodox-Orthodox	-0.085	0.864
不健全な-健全な	Unhealthy-Healthy	-0.032	0.833
広い-狭い	Wide-Narrow	-0.069	0.820
恥辱な-名誉な	Shameful-Honorable	-0.021	0.815
一時的な-継続的な	Temporary-Continuous	-0.075	0.802
明確な-曖昧な	Clear-Vague	-0.046	0.799
おどけた-真面目な	Playful-Serious	-0.051	0.753
冷たい-熱い	Cold-Hot	-0.043	0.728
未熟な-洗練された	Immature-Sophisticated	-0.040	0.727
小さい-大きい	Small-Big	-0.029	0.713
不潔な-清潔な	Dirty-Clean	-0.026	0.710
寛大な-つつましい	Generous-Modest	-0.038	0.709
退歩的な-進歩的な	Regressive-Progressive	-0.029	0.705

退屈な-面白い	Boring-Interesting	-0.032	0.688
まずい-おいしい	Tasteless-Delicious	-0.015	0.678
乾いた-湿った	Dry-Wet	-0.020	0.655
鈍感な-敏感な	Insensitive-Sensitive	-0.016	0.630
失敗した-成功した	Failed-Successful	-0.018	0.615
軽率な-慎重な	Rash-Prudent	-0.022	0.587
苦しい-楽しい	Painful-Joyful	-0.008	0.559
悪い-良い	Bad-Good	0.003	0.483
うらめしい-ありがたい	Resentful-Grateful	0.004	0.451
成熟した-若い	Mature-Young	0.028	0.371
懐疑的な-軽信的な	Skeptical-Gullible	0.022	0.351
単純な-複雑な	Simple-Complex	0.029	0.336
遠い-近い	Far-Near	0.016	0.325
軽い-重い	Light-Heavy	0.040	0.312
醜い-美しい	Ugly-Beautiful	0.036	0.300
うんざりした-爽やかな	Weary-Refreshing	0.026	0.295
不調和な-調和した	Dissonant-Harmonious	0.045	0.248
暗い-明るい	Dark-Bright	0.058	0.202
主観的な-客観的な	Subjective-Objective	0.055	0.196
間違った-正しい	Wrong-Right	0.037	0.169
タイミングの悪い-良い	III-timed-Well-timed	0.087	0.148
曲がった-まっすぐな	Crooked-Straight	0.056	0.136
左右非対称の-左右対称の	Asymmetrical-Symmetrical	0.057	0.121
ざらな-まれな	Often-Rare	0.054	0.080
不完全な-完全な	Imperfect-Perfect	0.108	0.031
悲観的な-楽観的な	Pessimistic-Optimistic	0.144	0.008
自由な-窮屈な	Free-Constrained	0.216	0.003

#### 6 **DISCUSSION**

From Tab. 3, we can see that 52 out of 72 adjective pairs tend to move in the direction of proximity with a probability of over 50%. Even if we limit the analysis to those with a probability of over 90%, we can still extract 30 adjective pairs. If we limit it to those with a probability of over 95%, we can still extract 22 adjective pairs. This result suggests that unifying actions can share a certain level of sensitivity. In this study, we define this as shared sensitivity.

On the other hand, the 20 adjective pairs tend to diffuse due to the unification of actions. If we limit it to those that diffuse with a probability of 90% or more, there are four adjective pairs. These are sensibilities that each person may have a different standard. In this study, we define this as individual-specific sensibility.

## 7 CONCLUSION

In this paper, regarding sensitivity, which depends on each person's way of perceiving things that are difficult to communicate, we analyzed the possibility of sharing sensitivity between people with similar sensitivity backgrounds through the unification of usage behavior. We unified the behavior of opening a tea container and compared the sensitivity values felt. We collected and analyzed the sensitivity values using the SD method with the 76 adjective pairs shown in Tab. 1. As a result, of the 72 adjective pairs that were analyzed, 52 pairs showed a tendency to move in the proximity direction with a probability of over 50%. Even when the analysis was limited to those with over 90% probability of moving in the proximity direction, 30 adjective pairs could be extracted, and even when limiting it to those with a probability of over 95%, 22 adjective pairs could be extracted. This result suggests that uniform usage behavior allows sharing of a certain degree of sensitivity between people with similar sensitivity backgrounds.

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# **OPTIMAL DESIGN OF KANSEI QUALITY BASED** ON ELECTROENCEPHALOGRAPHY (**EEG**)

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## ABSTRACT

Due to the maturation of science and technology, it becomes increasingly difficult to differentiate products in terms of performance, functional features, or price. Therefore, companies are required to differentiate their products based on Kansei qualities, i.e. subjective and abstract qualities that are evaluated by the customer's senses, such as aesthetics and comfort. This research focuses on Kansei quality, which can be evaluated by measurements using EEG, such as comfort, and proposes a method for obtaining optimal product design from measurements using EEG. The proposed method consists of measurement using EEG, design of experiment, and response surface method. More specifically, Kansei quality is calculated from the measurements arranged by design of experiment and the response surface with Kansei quality as the response variable and the design variables as the explanatory variables is identified. The design variables that maximize/minimize Kansei quality on the identified response surface result in the optimal product design. In the case study, the optimal design of a chair setting was carried out for 13 subjects and the results show that for most subjects, the optimal settings obtained for each subject are quite close to their subjective preferences.

*Keywords:* Kansei engineering, EEG, design optimization, design of experiment, response surface method

## **1** INTRODUCTION

Due to the maturation of science and technology, it becomes increasingly difficult to differentiate products in terms of performance, functional features, or price. Therefore, companies are required to differentiate their products based on Kansei qualities, i.e. subjective

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and abstract qualities that are evaluated by the customer's senses, such as aesthetics and comfort.

Aesthetic design is one of the qualities elements that is purely evaluated based on the customer's Kansei, independent of its function or performance. Aesthetic design is an important quality element, especially in consumer products. In the field of Kansei engineering, various types of methods have been developed to quantitatively measure the impressions and preferences that customers receive from products and to create new aesthetic designs based on them. Questionnaires based on the semantic differential (SD) method [xx] are widely used to measure the impressions customers get from products. In the creation of aesthetic design, various techniques such as artificial neural network (Hsiao & Huang, 2022)(Kobayashi & Kinumura, 2015), deep learning (Dai, Li & Liu, 2018)(Benaissa, Kobayashi & Kinoshita, 2022)(Kobayashi & Kume, 2024), fuzzy set theory (Hsiao & Huang, 1998), multidimensional scaling (Kobayashi & Kinumura, 2015), rough set theory (Kobayashi & Niwa, 2018)(Kuramaru, Takanashi & Mori, 2001)(Ohki, Harada & inuiguchi, 2012)(Yamada, Morga & Unehara, 2012), self-organizing map (Kobayashi & Kinumura, 2015), etc. are used to analyze the relationship between the impressions / preferences that customers receive products and the aesthetic design elements that constitute the product, and to find the product design that best suits the customer.

Comfort is also one of the qualities elements that is evaluated based on the customer's Kansei. Comfort is an important qualities element for many products such as chair, bed, air conditioner, automobile etc. A subjective evaluation by the customer, i.e. a questionnaire, is widely used when evaluating comfort. However, sometimes an objective evaluation that is not influenced by the evaluator's subjectivity is required. In response to this, there also are many cases where biological signals such as brain activity and heartbeat are used. There have been studies into the relationship between product design parameters and comfort for various types of products. Reed and Schneider (1999) investigated the relationships between headroom and comfort using a reconfigurable vehicle mockup. Yoshida, Imamori and Kawabara (2022) investigated the influence of interior design and sound on comfort using VR. Saito, Kawanami and Inoue (2023) investigated the effect of chromatic colors of lighting on comfort and task performance. Asada and Ueno (2007) investigated the relationships between comfort and chair part design. On the other hand, there are very few studies attempting to derive optimal design parameters based on comfort evaluations.

In this research, an optimal design method for Kansei quality based on electroencephalography (EEG) is proposed. The proposed method consists of design of experiment, response surface method, and measurement of brain activity using EEG. More specifically, measurements using EEG arranged based on the design of experiments are carried out, and the value of the Kansei quality is calculated from the measurement results. This Kansei quality is handled as the objective function for design optimization. Then, the relationship between the design variables and the objective function is identified using a response surface method with a polynomial function, and the design solution that maximizes or minimizes the objective function is explored using the identified function. Any kind of emotional quality can be

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used as the objective function for optimization, as long as it can be calculated from the results of EEG measurements. For example, comfort is dealt with in the case study.

## 2 PROPOSED METHOD

The proposed design process consists of the following four steps.

Step1: Arrangement of measurements based on design of experimentStep2: Measurements using EEG and calculation of Knasei qualityStep3: Identification of the response surfaceStep4: Design optimization

## 2.1 Step1

First, the design variables for optimization are selected from the many design elements that constitute the aesthetic design of the target product. The number of levels of the design variable is then determined. Once the number of design variables and their levels have been determined, measurements are arranged based on the design of experiments. For example, the case study had three design variables and three levels, and 16 measurements were arranged using a Box-Behnken design.

## 2.2 Step2

Measurements arranged by the design of experiments are carried out using EEG, and the value of sensory quality for each measurement is calculated.

#### 2.3 Step3

The response surface is identified using the calculated Kansei quality as the response variable and the design variables as the explanatory variables. The type of function suitable for the response surface depends on the complexity of the optimization problem being identified. For example, in the case study, a second-degree polynomial was used.

#### 2.4 Step4

Finally, using the identified response surface, the design variables that maximize/minimize the Kansei quality are explored.

## 3 CASE STUDY

In order to explain the flow of optimal design using the proposed method, design optimization using a chair setting as the design target and comfort as the target Kansei quality is carried out.

#### 3.1 Overview of the case study

The design target is setting of the AKRacing Wolf gaming chair (AKRacing) shown in Figure 1. As shown in Figure 2, the seat height, armrest height, and backrest reclining angle are handled as design variables. The ranges for the seat height, armrest height, and reclining angle are 440

to 540 mm, 150 to 240, and 100 to 130 degrees, respectively. Please note that this is only a part of the actual adjustable range.

Thirteen male undergraduate students from Toyota Technological Institute participated as subjects. Since their body sizes differ and they also have different preferences for chair settings, the optimal settings are explored for each subject.

The FUTEK Brain Pro FM-939 EEG device (Futek Electronics, Co., Ltd.) shown in Figure 3 was used for the measurements. This device measures brain activity by placing sensors on the frontal lobe and a ground electrode on the earlobes.



Figure 1. AKRacing Wolf gaming chair



Figure 2. Seat height, armrest height, and backrest reclining angle



Figure 3. FUTEK Brain Pro FM-939 EEG device

## 3.2 Step1

There were three design variables: seat height, armrest height, and backrest reclining angle. There were three levels for each design variable: maximum, minimum, and median. Based on the Box-Behnken design, 16 measurements were arranged as shown in Table 1.

Evet No	Backrest reclining	Seat height	Armrest
εχρι. Νο.	angle (°)	(mm)	height(mm)
1	100	440	195
2	100	540	195
3	130	440	195
4	130	540	195
5	100	490	150
6	100	490	240
7	130	490	150
8	130	490	240
9	115	440	150
10	115	440	240
11	115	540	150
12	115	540	240
13	115	490	195
14	115	490	195
15	115	490	195
16	115	490	195
Minimum	100	440	150
Median	115	490	195
Max	130	540	240

**Table 1**. Chair settings of 16 measurements

## 3.3 Step2

Based on the arrangements in Table 1, the brain activity when the subject was sitting in a chair was measured using EEG. Figure 4 shows the measurement process. The subject wears the EEG device and waits for 5 minutes for calibration. The subject then sits in a chair and closes his eyes, and the measurement is carried out. The measurement time is 1 minute. After the measurement is completed, the subject stands up and waits for 1 minute. During that time, the chair setup is changed. The 16 patterns are then measured repeatedly. After 16 measurements, the subject was given ample time to freely try various chair settings and to find the setting that he feels most comfortable. This setting is handled his subjective preference.

Next, the EEG records are analyzed to calculate the subject's comfort level for each setting. There is a possibility that various types of noise are superimposed on EEG records. These noises are often larger and more instantaneous than the waves of brain activity. Therefore two 4-second periods of data without significant noise are manually extracted. The extracted data is converted to the frequency domain using FFT. The signal intensities of the alpha and beta frequency bands are summed, respectively, and  $\beta/\alpha$  is calculated. The smaller the  $\beta/\alpha$ , the more comfortable it is. Figure 5 shows an overview of the analysis process.



#### 3.4 Step3

Response surfaces are identified by parameter estimation using the least-squares method with measurement results. Comfort calculated in Step2 is handled as the response variable while the seat height, armrest height, and reclining angle are handled as the explanatory variables. A second-order polynomial shown in the equation below is employed as a function of the response surface.

 $y = ax_1 + bx_2 + cx_3 + dx_1^2 + ex_2^2 + fx_3^2 + g(x_1x_2) + h(x_1x_3) + i(x_2x_3) + j$ 

y:  $\beta/\alpha$  (Confort)  $x_1$ : Reclining angle  $x_2$ : Seat height  $x_3$ : Armrest height  $a \sim j$ : Unknown parameters

Figure 6 shows an example of the identified response surface.



Figure 6. Example of the identified response surface

## 3.5 Step4

Using the response surface obtained for each subject, the optimal setting that each subject feels most comfortable with is explored. Table 2 shows the optimal settings for each subject. For comparison, this table also shows the settings that the subjects subjectively felt to be the most comfortable.

	Reclining angle (°)		Seat hei	ght (mm)	Armrest height (mm)		
Subjects	Optimized	Subjective preference	Optimized	Subjective preference	Optimized	Subjective preference	
Α	115.6	109	470.7	440	212.2	225	
В	119.5	127	440.0	460	191.8	195	
С	121.0	121	539.3	520	240.0	240	
D	117.0	121	478.7	490	200.9	195	
E	117.1	115	496.9	440	211.2	225	
F	118.6	124	483.2	440	205.1	195	
G	126.4	130	440.0	480	240.0	195	
Н	128.8	121	440.0	520	240.0	240	
l I	118.3	112	491.9	490	240.0	195	
J	100.4	106	479.2	465	204.3	195	
K	117.1	109	518.7	540	240.0	180	
L	130.0	140	540.0	540	192.4	240	
М	120.2	119	440.0	460	240.0	195	

Table 2. O	ntimal i	results a	and sub	iective	preferences
	punnari	Courts o	and Sub	JCCLIVC	preferences

#### 3.6 Discussion

This table shows that optimal settings, especially the reclining angle, close to the subjects' preferred settings were obtained. Although not quite as good as the reclining angle, the seat height and armrest height were also close to the preferred settings of the subjects. These results show that the proposed method was able to correctly determine the settings that the subjects feel comfortable with.

## 4 CONCLUSION

To obtain product designs that maximize/minimize Kansei quality through measurements using EEG, optimal design method consisting of arrangement of measurements based on the design of experiment, measurement of brain activity using EEG, identification of the relationship between Kansei quality and product design variables using response surface methodology and design optimization based on the identified response surface. In the case study, design optimization of chair settings was carried out and the results show that for most subjects, the optimal settings obtained for each subject are quite close to their subjective preferences.

The limitation of the proposed method is the lack of consideration for the diversity of customer Kansei. In the proposed method, the optimal solution is obtained for each customer. As the chair settings can be changed by the user, it is worth finding the optimal settings for each subject. However, when the proposed method is used in the product design itself, excluding

custom-made products, the product is used by the whole range of customers. If the variation in customer Kansei is small, it is possible to design a product that all customers feel comfortable with using the proposed method as it is, but if the variation in customer Kansei is large, it is difficult. Therefore, the next goal is to consider the diversity of customer Kansei.

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# RELATIONSHIP BETWEEN CONFLICT HANDLING STYLES AND TEAM CLIMATE IN INTERDISCIPLINARY DESIGN COURSE

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## ABSTRACT

To understand how conflict with peers influences interdisciplinary teams, the study discussed the relationship between conflict handling styles and the team climate. Fifty-eight students in interdisciplinary design courses responded to a self-report questionnaire to evaluate their conflict handling styles and team climate. Pearson correlation analysis and multiple regression analysis were utilized to investigate the relationship. Integrating style positively correlated with the four team climate factors, Vision, Participative safety, Task orientation, and Support for innovation, and could predict all of them while the Obliging style positively correlated with four factors of team climate, but could only predict Participative safety and Task orientation. High concern for self was as important as high concern for others to build good team climate. In sum, the Integrating style was appropriate for students to handle conflict with peers and to im-prove team climate.

Keywords: Rahim conflict handling styles; team climate; interdisciplinary; design thinking

#### **1** INTRODUCTION

Design education not only aims to develop students' design expertise but also educates them to use creativity to solve problems with people from various fields. To enhance interdisciplinary learning and cooperation skills, interdisciplinary design courses combining design thinking and design processes have been developed (Li et al., 2019; Tu et al., 2018; Wrigley & Straker, 2017). Design thinking involves gaining insight into user needs and proposing innovative solutions (D.School, 2011), and it is not limited to design fields. Wrigley and Straker (2017) outlined the knowledge or competencies of the design thinking learning, and emphasized the importance of communication and cooperation among students. Communication is challenging and also leads to increased conflict in interdisciplinary design courses (Claus & Wiese, 2019) because of students' different expertise and mindsets. Therefore, understanding how to handle team conflict and the influence of conflict with members on the team are essential.

The theory of handling conflict explores how people manage interpersonal conflict and indicated the conflict handling styles. Rahim and Bonoma (1979) identified five conflict handling styles (the Integrating, Obliging, Dominating, Avoiding, and Compromising styles), separated by two dimensions "concern for self" and "concern for others". Rahim Organizational Conflict Inventory–II (ROCI–II) was created to examine the styles of handling organizational conflict (Rahim, 1983c). The effect of the conflict handling styles on teams in work environments (companies and organizations) (Cheung et al., 2006; Shih & Susanto, 2010; Tabassi et al., 2019) and educational fields (Kantek & Gezer, 2009; Valente & Lourenço, 2020; Zurlo et al., 2020) has been discussed. Kantek and Gezer (2009) discovered that people who were lower in the Obliging style usually conflict with others and additionally, they handled conflict successfully when their Integrating and Obliging styles were higher. The Integrating style positively correlated with negotiation outcomes (Cheung et al., 2006) and job performance (Shih & Susanto, 2010).

However, previous studies have focused on handling conflict between instructors and students in educational fields, while fewer studies have explored the impact of handling conflict with peers on the team. This issue is critical in interdisciplinary design courses, which involve numerous discussions and mutual learning with other students, and what is more, team climate relates to team cooperation (Claus & Wiese, 2019), which influences team performance (Johnson, 2018). As a result, this study aims to investigate the relationship between conflict handling styles and team climate in interdisciplinary design courses with a focus on conflicts with peers. We expect the results could improve the understanding of handling conflict, help people handle conflict effectively, and educate people with interdisciplinary abilities.

## 2 LITERATURE

#### 2.1 Design Thinking and Interdisciplinary Design Courses

Design thinking is a problem-solving approach to create innovative solutions to ill-defined problems in human-centered. After combining creativity theories and concepts, D. School and IDEO proposed the structures of design thinking which were thought of as the best approach to solve complex or ill-defined problems (Löwgren & Stolterman, 2004). Recently, design thinking has become a popular approach to innovation, and more and more people from non-design fields made use of it. At the same time interdisciplinary design courses integrating design thinking have been developed to improve students' participation, learning effectiveness, and the communication and interaction between teachers and students (Tu et al., 2018). In order to improve design thinking learning, Wrigley and Straker (2017) organized what needs to be taught and how to teach it in design thinking courses and addressed the Educational Design Ladder, which indicated the necessity of peer learning in different fields.

Team communication and cooperation were essential interdisciplinary competencies (Claus & Wiese, 2019; Dosi et al., 2018). Dosi et al. (2018) designed a measurement for evaluating the design thinking mindset, and the constructs of "Team Working" and 'Multi-/ inter-/ cross-disciplinary collaborative teams" were assessed. Communication can be a challenge for members of interdisciplinary teams owing to their different mindsets (Claus & Wiese, 2019). A limitation in communication can lead to bad team climate, such as a lack of trust and safety, which causes negative effects (Johnson, 2018).

#### 2.2 Rahim Organizational Conflict

Styles of handling organizational conflict came from the Managerial grid model (or Managerial grid theory), sorting organizers' or managers' conflict handling by their "concern for production" and "concern for people" (Blake & Mouton, 1964; Blake et al., 1962). The concept has been applied to interpersonal conflict handling, and Rahim (2001) integrated models including 2 to 5 styles of handling interpersonal conflict. Rahim and Bonoma (1979) proposed conflict handling styles separated by "concern for self" and "concern for others." The former refers to the degree how people attempt to satisfy their own concerns, whereas the latter was the degree how people attempt to satisfy other people's concerns. Both dimensions involved high or low degrees, and the combination of the two dimensions led to five conflict handling styles: Integrating, Obliging, Dominating, Avoiding, and Compromising, as shown in **Figure 1**.



Figure 3. Concept of conflict handling and five styles (Rahim & Bonoma, 1979) p.1327

The following briefly introduced the characteristics of each style (Rahim, 2001; Rahim & Bonoma, 1979; Rahim & Magner, 1995). First, high concern for self and others is the Integrating style (IS), where groups exchanged information, collaborated, and came up with a proposal acceptable to both groups. The style could lead to a creative and potential solution when dealing with complex or ill-defined issues. The Obliging style (OS) indicated low concern for self and high concern for others. The style tried to decrease the discrepancy between groups and emphasized the similarities to satisfy the concern of the other groups. Dominating style (DS) expressed high concern for self and low concern for others. The style may ignore the concerns or expectations of other groups in order to reach their own achievement. Then, low concern for self and others was Avoiding style (AS) related to withdrawal, shirking responsibility, or apathy. The last style, Compromising (CS) demonstrated a middle concern for self and others. The style involved in giving, taking, and sharing stressed that both groups gave up something to reach an acceptable agreement. Compromising style was considered a medium style of handling conflict. Rahim (1983a) summarized appropriate and inappropriate situations for each conflict handling style.

#### 2.3 Relationship between Conflict Handling Styles and Team

Previous studies searched the relationship between the conflict handling styles of managers in private companies or government agencies and team performance or members' feelings. For instance, Tjosvold et al. (2006) explored the influence of two conflict handling styles, cooperative and competitive approaches, on conflict types and team effectiveness in China and indicated that the cooperative approach positively related to team effectiveness while the competitive approach negatively related to team effectiveness. The two styles were also used to discover the correlations between conflict handling styles, team innovation performance, and team climate of the online teams (Yin, Qu, Li, et al., 2022). The relation between conflict handling styles and psychological safety was confirmed, but the influence between them decreased as team trust increased. The cooperative approach increased team psychological safety and indirectly enhanced team innovation performance, and positively and positive team emotional climate (Yin, Qu, Liao, et al., 2022).

Next, the influence of Rahim's five conflict handling styles on teams was reviewed. The correlation between conflict handling styles and organizational status was demonstrated (Brewer et al., 2002). People with lower organizational status (non-management or supervisory) were higher in the Obliging and Avoiding styles, whereas people with upper organizational status were higher in the Integrating style. Cheung et al. (2006) predicted the negotiation outcomes by conflict handling styles and pointed out that sacrificing oneself, controlling others, or withdrawing from an argument may not be useful to solve conflict and the Integrating style could solve problems and improve relationships to reduce conflict. Besides, the positive relationship between the Integrating style and job performance was revealed in private companies as well as in government agencies (Shih & Susanto, 2010).

In addition to the work environment, the influence of conflict handling styles in courses or other educational fields was discussed. Kantek and Gezer (2009) inspected how nursing students handle conflict with their instructors and directed that students were higher in the Integrating style, but lower in the Dominating style, and besides, those who were lower in the Obliging style conflicted frequently. Furthermore, students who used the Integrating and Obliging styles felt successful in conflict handling, while those who used the Avoiding and Compromising styles felt unsuccessful. Valente and Lourenço (2020) investigated the connection between the conflict handling styles of instructors and emotional intelligence in European countries. The Integrating style is positively related to emotional intelligence, while the Obliging, Dominating, and Avoiding styles are negatively related to emotional intelligence. Teachers' conflict handling styles were explored in junior high school and four modes were proposed through cluster analysis (Zurlo et al., 2020). For example, teachers in the Multi-strategic and Engaged mode were lower in the Avoiding style, but used the other four styles appropriately. They attempted various approaches to mediate and negotiate with students, but they used their power to solve conflict, if necessary. Another mode was Control-Oriented and Avoidant which involved higher Dominating and Avoiding. Teachers declared their power, instructed how to handle the conflict, and avoided confrontation with students in public.

## 2.4 Summary of Literature Review

To increase the competence of interdisciplinary learning and cooperation, interdisciplinary design courses combining design thinking and design process are common in universities. These courses offer opportunities for students to collaborate and learn with others from diverse backgrounds, but may also lead to increased conflict; therefore, understanding the influence of conflict on a team and developing effective conflict resolution skills are necessary. Previous studies have explored the relationship between conflict handling styles and team performance or members' emotions. However, the influence of conflict handling with peers on team climate in educational settings has received less attention. The conflict handling styles does not reflect the handling of each conflict, but measures the general approach of the subjects when facing conflict. Our study also focuses on this perspective to understand how students usually handle the conflict. Given the emphasis on collaboration and communication with peers in interdisciplinary design courses, this study aimed to investigate the relationship between conflict handling styles with peers and team climate.

Course Title	Credit	Design Task	Final Presentation
Design Workshop: Project Planning	2	Cultural-based ritual designs	Students delivered their ritual service design in Tainan
Practice and Promotion of Design Thinking	3	Plan design thinking teaching courses for elementary school students	Students taught their courses at Jiangong, Gangwei, and Zhumen Elementary Schools
Design Thinking Learning by Teaching	2	Plan design thinking teaching courses for high school students	Students taught their courses at National Tainan Girls' Senior High School

Table 2. Information about the target courses

Retrieved from https://class-qry.acad.ncku.edu.tw/syllabus/online_display.php?syear=0111&sem=1&co_no=FZ20100&classcode=; https://class-qry.acad.ncku.edu.tw/syllabus/online_display.php?syear=0111&sem=2&co_no=P370900&class_code=; https://class-qry.acad.ncku.edu.tw/syllabus/online_display.php?syear=0111&sem=2&co_no=P371000&class_code=

## 3 METHODS

## 3.1 Measures

Our study involved an investigation consisting of two parts questionnaires, the conflict handling styles, and the team climate. Both questionnaires were self-report, and students accessed the situation of the course on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

**Conflict handling styles.** Students' conflict handling styles were evaluated by ROCI–II (Rahim Organizational Conflict Inventory–II) Form C and the questionnaire had good reliability and only took 10 minutes to respond (Rahim, 1983b; Rahim & Magner, 1995). ROCI–II involved three forms and Form C, a 28-item questionnaire that measures five conflict handling styles: Integrating, Obliging, Dominating, Avoiding, and Compromising (Rahim, 1983c). was used in our study to evaluating students' conflict handling styles with their team members (peers).

**Team climate.** Team Climate Inventory examined the four climate factors: Vision, Participative safety, Task orientation, and Support for innovation (Anderson & West, 1998; West, 1990). Later, a shorter version consisting of 14 items proposed by Kivimaki and Elovainio (1999) was used in our study.

Course	Ger	ıder	Number of		
Course	Male (%)	Female (%)	Students	Teams	
Design Workshop: Project Planning	3(10.0)	27(90.0)	30	5	
Practice and Promotion of Design Thinking	4(28.6)	10(71.4)	14	3	
Design Thinking Learning by Teaching	10(71.4)	4(28.6)	14	4	
Total	17(29.3)	41(70.7)	58	12	

#### Table 3. Information about the students

	Conflict Handling Styles					Team Climate			
	IS	OS	DS	AS	CS	v	PS	то	SI
Mean	4.33	4.20	3.10	3.66	4.15	4.44	4.45	4.19	4.44
Std. Deviation	.52	.50	.78	.66	.53	.54	.61	.62	.53
Variance	.27	.25	.61	.44	.29	.29	.37	.39	.29
Minimum	3.14	3.17	1.20	2.17	3.00	2.75	2.75	3.00	3.33
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Range	1.86	1.83	3.80	2.83	2.00	2.25	2.25	2.00	1.67

Note. IS: Integrating style, OS: Obliging style, DS: Dominating, AS: Avoiding, CS: Compromising, V: Vision, PS: Participative safety, TO: Task orientation, SI: Support for innovation

## 3.2 Target Course and Participants

The target courses were "Design Workshop: Project Planning," "Practice and Promotion of Design Thinking," and "Design Thinking Learning by Teaching." These were interdisciplinary

design courses driven by design thinking and design process and required students to work in groups and engage in a lot of discussion with their team members. The information about the course can be found in **Table 1** and more details would refer to the website. Fifty-eight students from freshmen to graduate students took part in the investigation. **Table 2** presented some information about the students' gender and majors.

## 3.3 Procedure

At the end of the course, we informed the participants about the research purpose, the survey process, and how we would handle the questionnaire results, and additionally, their participation was voluntary and did not impact their course achievements. The process took about 10 to 15 minutes to respond to the conflict handling styles and the team climate questionnaires.

## 3.4 Data Analysis

The scores of five conflict handling styles and four team climate factors were calculated. Then, Pearson correlation analysis was performed to inspect the relationship between each team climate factor and conflict handling styles. After that, regression analysis was conducted to determine how conflict handling styles predict team climate.

## 4 RESULTS

The study explored the relationship between the conflict handling styles and the team climate among thirty undergraduate students taking the interdisciplinary course which was driven by design thinking and design process. Good reliability (Cronbach's  $\alpha > 0.85$ ) of the two questionnaires was demonstrated according to reliability analysis, and the descriptive statistics for the variables were presented in **Table 3**.

Pearson correlation analysis was used to examine the connection between the team climate factors (Vision, Participative safety, Task orientation, and Support for innovation) and conflict handling styles. Multiple regression analysis (backward elimination) was then conducted to develop prediction models for each team climate factor based on conflict handling styles.

First, Vision could be predicted by the Integrating style ( $R^2 = .64$ , F = 19.43, Beta_{Integrating style} = .49). The Integrating and Obliging styles positively predicted Participative Safety ( $R^2 = .38$ , F = 16.96, Beta_{Integrating style} = .40, Beta_{Obliging style} = .29); additionally, the Integrating style explained more variance than the Obliging style. Then, both the Integrating and Obliging styles were significant predictors of Task orientation ( $R^2 = .55$ , F = 11.83, Beta_{Integrating style} = .29, Beta_{Obliging style} = .32), and moreover, the Obliging style explained more variance in Task orientation than the Integrating style. Finally, Support for innovation could be predicted by the Integrating style ( $R^2 = .63$ , F = 36.66, Beta_{Integrating style} = .63).

Table 5. Summary	of the Results	of Regression Analysis
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Team climate	Conflict handling styles
Vision	Integrating style (positive)

Participative safety	Integrating style, Obliging style (positive)		
Task orientation	Integrating style, Obliging style (positive)		
Support for innovation	Integrating style (positive)		

#### 5 DISCUSSION

The study investigated the relationship between conflict handling styles and the team climate and the results of regression analysis were summarized in **Table 4**. The following sections discussed the conflict handling styles correlating and not correlating with team climate, as well as the conflict handling styles that students typically used when dealing with conflicts with peers. After that, we propose the approach to reduce the limitation of the evaluation of the conflict handling styles and the suggestion to improve the team climate in interdisciplinary design courses.

Firstly, the Integrating style positively correlated with all four factors of team climate and was able to predict all of them. Previous studies have established the association between team climate and team performance, as well as members' positive emotions (Johnson, 2018). Our study further discovered a link between the Integrating style and team climate, indicating the importance of both "high concern for self" and "high concern for others" in teamwork. The Integrating style was particularly useful in solving complex or challenging problems that were difficult for people in one field (Rahim, 1983a). This is consistent with the purpose of interdisciplinary design courses, which aim to educate students to collaborate with others from different fields to solve ill-defined issues together. Therefore, it is reasonable to suggest that the Integrating style predicts all four factors of team climate.

The Obliging style positively correlated with four factors of team climate as well, but could only predict Participative safety and Task orientation. Participative safety emphasized trust and help among team members; besides, task orientation indicated a commitment to achieving outstanding team performance. Because both Integrating and Obliging styles, with a high concern for others, could predict Participative safety and Task orientation, concern for others seems more important than concern for self under certain situations. Despite the Obliging style being sorted in win-win situations (Rahim & Bonoma, 1979), it could only predict two factors of team climate which implies that sacrificing oneself for the team (low concern for self) may not effectively improve team climate, such as increasing students' understanding about team goals and values (Vision) or help students work with team members to find innovative approaches or ideas (Support for innovation).

The other three styles, Dominating, Avoiding, and Compromising, do not seem to impact team climate. Since all of them show lower concern for others compared to the Integrating and Obliging styles, making people feel respected in the team is essential to improve the team climate. However, these styles are not useless, based on the previous studies. The Avoiding style, for example, increased the team coordination and performance in the temporary multicultural teams (Tabassi et al., 2019), and besides, the Dominating and Compromising styles positively predicted negotiation effectiveness (Pérez-Yus et al., 2020). These styles are useful in

the situations emphasizing team efficiency, such as trivial issues or speedy decisions (Rahim, 1983a), whereas they may not help improve members' emotional feelings like team passion (Yin, Qu, Liao, et al., 2022) or the feeling of successfully handling the conflict (Kantek & Gezer, 2009), as well as team climate in our study.

According to the means of the conflict handling styles, we found students tended to use the Integrating and Obliging styles to handle conflict, while rarely utilizing the Dominating style in the interdisciplinary design course. The intensive course may encourage students to actively engage in conflict resolution instead of avoiding it. Another possible explanation is that conflicts with peers in the course are more equal relationships among members than any other situations like in a company or organization, which may explain the lower use of the Dominating style. Furthermore, we discovered an intriguing correlation with team variances in conflict handling styles, team climate, and team conflict. The teams with the highest and lowest variance are identified and we collected students' reports on how they felt about the course. Two students from the team with the highest variance mentioned the team conflict. Student A stated, "I felt a little annoyed since someone could not catch the point or even fell asleep during the discussion." Student B directed, "I am confused that someone could not filter a lot of information effectively. Thus, our discussion was often at a deadlock." On the contrary, none of the students in the team with the lowest variance indicated a team conflict. This suggests that the variances in conflict handling styles and team climate may play a role in team conflict. While our findings are based on only five teams (30 students) from Design Workshop: Project Planning, we believe that collecting more data will help us establish a more specific relationship.

In addition, the evaluation of the conflict handling styles does not reflect the handling of each conflict, but reveals a preference rather than an absolute criterion. To better understand the relationship between conflict handling and individual differences, we propose combining the Big Five personality traits with conflict handling styles. Previous studies have explored the link between personality traits and conflict handling styles (Barbuto et al., 2010; Pérez-Yus et al., 2020), and the Big Five personality traits are relatively stable for adults (Cobb-Clark & Schurer, 2012). By doing so, we can gain a better understanding of how personality traits relate to conflict handling styles and team dynamics, particularly in the case of the Integrating style.

In conclusion, the Integrating style is appropriate for students to handle conflict with peers and improve team climate in the interdisciplinary design course. Although some findings stressed the importance of concern for others, effectively building good team climate required a balance between both a high concern for others and a high concern for self.

## 6 CONCLUSION

Our study investigated the relationship between conflict handling styles and the team climate and the main findings are as followed:

First, the Integrating style was found to positively predict the all four team climate factors -Vision, Participative safety, Task orientation, and Support for innovation. The connection between team climate and the Integrating style reveals the necessity of "high concern for self" and "high concern for others" in teamwork. Besides, the Obliging style positively predicted Participative safety and Task orientation. Although concern for others seems more important than concern for self in some situations, high concern for others and a high concern for self could building good team climate effectively. Next, the Dominating, Avoiding, and Compromising styles do not significantly connect with team climate and we suppose that making team members feel respected (higher concern for others) is crucial in improving team climate. Finally, students usually handled conflicts using the Integrating and Obliging styles but seldom utilized the Dominating style in the interdisciplinary design course.

Here are the limitations of our study. For one thing, we focused on one course, where the proportion of students' gender was imbalanced. Further investigations from other interdisciplinary design courses can help mitigate the limitation of the sample size and the gender imbalance of participants in our study. For another, apart from the conflict among team members, the influence of the team leader's conflict handling styles on the team is interesting. Since conflict in courses or other educational fields is more equal than in the work environment, the relationship between team members and the team leader may be more like peers than subordinates. Other perspectives for measuring conflict can also be incorporated, such as examining the handling of each conflict within a team and exploring teamwork cooperation, or combining personality traits or conflict types with future investigation. As we mentioned above, previous studies have indicated the potential relationship between the Big Five personality traits and conflict handling styles (Barbuto et al., 2010; Pérez-Yus et al., 2020). Moreover, the conflict handling styles influence people's recognition of the conflict types (relational conflict and task conflict) (Jehn, 1997) which affected their performance (Tjosvold et al., 2006). Integrating these issues with the research could provide a more comprehensive understanding of the conflict handling styles and the team.

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# COMPARISON OF FACIAL ATTRACTIVENESS MODELS USING GEOMETRIC MORPHOMETRICS BETWEEN JAPAN AND AMERICA

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# ABSTRACT

Facial attractiveness is an important factor in forming interpersonal impressions. For this reason, many studies have been conducted. In this study, we conducted a web experiment with Japanese and American participants using various facial images to investigate the influence of the gender and culture of the rater on facial attractiveness. Using geometric morphometrics for analysis, we visualized facial images highlighting facial features related to attractiveness for each rater. The results showed differences in trends based on the gender and culture of the raters. Japanese preferred relatively elevated eyebrows and sharp contours, while Americans preferred relatively lowered eyebrows and smaller mouths. Differences were also found for rater gender, particularly for features related to sexual dimorphism. These results suggest that facial attractiveness criteria vary by culture and gender. This study will help apply Kansei engineering, such as face editing and beautification techniques that consider the diversity in the perception of facial attractiveness.

Keywords: Facial attractiveness, Cultural difference, Morphometrics

# **1** INTRODUCTION

Facial attractiveness is a socially important interface for interpersonal relationships. For this reason, many studies on facial attractiveness have been conducted. Previous studies have emphasized that facial attractiveness is universal, as there is a high degree of agreement among the majority in the criteria for evaluating facial attractiveness concerning what faces are rated as attractive (Cunningham et al., 1995; Langlois et al., 2000).

However, in addition to individual differences by gender (Little et al., 2001, 2002), it has been pointed out that these evaluation trends may be diversified by the circumstances, environment, and culture surrounding the individual (Chatterjee, 2003; Leder et al., 2016) A recent study

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has shown that the culture and gender of the rater and the race of the facial image are important factors influencing attractiveness ratings (Voegeli et al., 2021).

In this study, focusing on gender and culture factors among Japanese and American participants, we aimed to investigate gender and cultural differences in attractiveness-related morphometric features using geometric morphometrics, which is a method for studying the shape of biological structures, capturing and analyzing their geometric properties.

## 2 METHOD

We conducted the Web experiments using Cross Marketing's QiQUMO and Global QiQUMO platforms. Based on the differences in platform policies and fees, we designed the experiments to collect as many face image ratings and respondents as possible in each.

QiQUMO created the experimental screen for the experiment on Japanese participants. The stimuli used were 400 face images from the Chicago Face Database, 50 each of Asian, Black, White, and Latino men and women. These face images were selected from all the images in the Chicago Face Database (Ma et al., 2015), and 50 images were selected from each race and each gender in descending order of age distribution from the mean. The experiment consisted of a 7-point scale procedure in which each participant responded to the attractiveness of 100 face images. The design of the experiment consisted of a pattern of four experiments that yielded ratings of 400 face images. The results collected were for responses over 20 years of age, and 192 responses were included. Participants who had the same value for all responses were excluded from the data as participants who were not diligent, and data from a total of 173 participants (85 males and 87 females, mean age  $44.5 \pm 16.4$ ) were used in the analysis.

Global QiQUMO created the experimental screen for the experiment on American participants. The stimuli used were 160 face images from the Chicago Face Database, 20 each for Asian, Black, White, and Latino men and women. These face images were selected from all the images in the Chicago Face Database, and 20 images were selected from each race and each gender in descending order of age distribution from the average. They were the same images used in the experiment with Japanese participants. The experiment was designed to obtain 160 ratings of face images by four experimental patterns, with each participant responding to the attractiveness of 40 face images using a 7-point scale. The results collected were for responses over 20 years of age, and 192 responses were included. Participants who had the same value for all responses were excluded from the data as participants who were not diligent, and data from a total of 270 participants (144 males and 126 females, mean age 42.5  $\pm$  13.1) were used in the analysis.

In this paper, in order to examine the differences between the tendencies of Japanese and American raters, we analyzed 160 face images that were graded by both raters. We used ANOVA analysis and geometric morphometrics to confirm the effects of gender and country of the raters and gender and race of the face images.

#### **3 RESULTS**

#### 3.1 Results of ANOVA

We conducted an ANOVA analysis to examine the effects of the rating of facial attractiveness. The analysis was based on the average attractiveness score for each face image, by gender and country of the rater, and by sex and race of the face image. The mixed-design ANOVA analyzed the effects of each effect.

Here, we present only the significant main effects and interactions from the ANOVA results. The ANOVA results indicated significant main effects of race (F(3, 152) = 9.725, p < .0001), sex (F(1, 152) = 135.732, p < .0001), country (F(1, 152) = 229.214, p < .0001), and gender (F(1, 152) = 108.963, p < .0001).

Significant interactions were found between race and sex (F(3, 152) = 2.845, p < .05), race, sex, and country (F(3, 152) = 4.318, p < .01), race and gender (F(3, 152) = 10.265, p < .0001), race, sex, and gender (F(3, 152) = 5.162, p < .01), race, country, and gender (F(3, 152) = 6.389, p < .001), sex and country (F(1, 152) = 195.193, p < .0001), sex, country, and gender (F(1, 152) = 14.780, p < .001), and race, sex, country, and gender (F(3, 152) = 3.298, p < .05).

Post hoc pairwise comparisons of race based on sex, country, and gender conditions were conducted, and the results are illustrated in the accompanying Figure 1.

The analysis revealed that the gender and country of the rater and the gender and race of the face image affect attractiveness, with complex interactions in each. Overall, we found that White facial images were rated more attractive. Next, a geometric morphometric analysis was conducted to visualize the facial features that may be involved in the differences in rating trends by gender and country of the raters and race of the facial images. In this study, the number of face images was considered, and for robust analysis, the race of the face images was pooled and modeled to confirm the trend of change.


Figure 1. Average attractiveness scores by country and gender of the rater and by race and sex of the face image

#### 3.2 Results of morphometrics analysis

The obtained ratings were then used to generate face images that highlighted facial features related to attractiveness using geometric morphometrics to investigate features corresponding to attractiveness.

To prepare the geometric morphometrics, 68 facial landmarks were automatically assigned to each face image by Python using the lib library. Next, we decided to use all 65 landmark points, excluding the three landmark points densely located around the mouth, for smooth visualization. Procrustes analysis (Kendall, 1984) was then used to minimize the distance from the reference, and the center of gravity was aligned as the reference position of the landmark points. Warps were then calculated from landmark points using thin-plate splines, and fragments between landmarks were concatenated and smoothed. Warps correspond to changes in facial morphology. Multivariate regression analysis was conducted for men and women using warps as the dependent variable and face attractiveness scores as the independent variable. In other words, we constructed a regression model showing changes in shape information linked to the attractiveness score. Next, landmark locations and face images were visualized. We used tpsRelw (version 1.75) for standardization of landmark points, tpsRegr (version 1.50) for regression analysis and visualization of landmark points, and tpsSuper (version 2.06) for imaging (Rohlf, 2021).

Visualization showed that in the male images, Japanese male raters tended to have longer noses, sharper jawlines, and raised eyebrows when facial features corresponding to attractiveness were emphasized. Japanese female raters tended to have larger eyes and narrower brows. American male raters tended to have lower eyebrows and smaller mouths. American female raters tended to have lower eyebrows and smaller mouths. The results are shown in Figure 2.

In the female images, Japanese male raters tended to have thinner eyebrows, a sharper jawline, and a smaller mouth and nose when the facial features corresponding to attractiveness were emphasized. Japanese female raters tended to have thinner eyebrows, a sharper jawline, and slightly lower eyebrows. American male raters tended to have thinner eyebrows and smaller noses and mouths. For American female raters, the eyebrows tended to be wider and the eyebrow angle slightly lower. The results are shown in Figure 3.

These results indicate that facial features associated with attractiveness differ depending on the gender and country of the rater.



Figure 2. Results of geometric morphometrics of male facial images

Visualization results of the superimposed average male face images by raters using the geometric morphometrics method. Low (-5SD, -3SD) indicates the result when the attractiveness ratings is manipulated toward -SD, and High (+3 SD, +5SD) indicates the result when the attractiveness ratings is manipulated toward +SD.



Figure 2. Results of geometric morphometrics of female facial images

Visualization results of the superimposed average female face images by raters using the geometric morphometrics method. Low (-5SD, -3SD) indicates the result when the attractiveness ratings is manipulated toward -SD, and High (+3 SD, +5SD) indicates the result when the attractiveness ratings is manipulated toward +SD.

#### 4 DISCUSSION

The results of ANOVA analysis suggested that facial features related to facial attractiveness may differ depending on the culture and gender of the rater. The country and gender of the rater, as well as the race of the facial image, are important factors that influence attractiveness ratings, in consistent with a previous study (Voegeli et al., 2021). The results of the relatively high attractiveness ratings for White facial images suggest that both groups may be familiar with White facial features. Further details revealed that there were differences in facial features related to attractiveness in morphometric analysis. In the case of male images, American raters tended to emphasize features such as a small mouth and lowered eyebrows more than Japanese raters. These features are related to dominance impressions (Montepare & Dobish, 2003) and may have been influenced by cultural aspects of communicating with others. In

addition, among Japanese raters, male raters tended to find faces with raised eyebrows and sharp contours more attractive, whereas female raters tended to find faces with large, rounded eyes more attractive. These characteristics may be related to the sexual dimorphism traits of masculinity and femininity. Regarding the effect of masculinity on male faces, some studies reported that faces with more masculine facial morphological features were rated as attractive (DeBruine et al., 2006), while others reported that male faces with more feminine facial morphology were rated as attractive (Little et al., 2001; Perrett et al., 1998), this discrepancy has been attributed in part to individual differences in the preferences of female raters (Johnston, 2006). In the present results, too, the female rater's selection may depend on the selection of the female rater since male faces with relatively feminine impressions were considered more attractive by the female rater.

In the case of female images, large eyes and sharply angular contours were important for attractiveness among Japanese raters, which is in agreement with a previous study using geometric morphometrics and deep learning (Sano & Kawabata, 2023). In addition, we found a difference in rater gender among American raters. Female raters tended to find faces with larger noses, mouths, and wider eyebrows more attractive than male raters. These may be related to estrogen-enhanced sexual dimorphism, but the details require further investigation. One limitation of this study was the small number of face images per race, making it difficult to perform morphometric analysis for each race. Subsequent studies are needed to confirm the details of differences by race.

# 5 CONCLUSION

In this study, we used morphometric analysis to confirm cultural and gender differences in facial attractiveness between Japanese and American raters. The results showed that there were differences in each factor, suggesting the possibility that faces considered attractive are diverse across cultures and individuals. Understanding individual sensitivities and cultural differences in attractiveness will contribute to Kansei engineering applications such as face editing and beautification.

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# INVESTIGATION OF FACTORS AFFECTING THE IMPRESSION OF SOCCER THUMBNAIL IMAGES

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# ABSTRACT

In this study, we investigated the relationship between soccer thumbnail images and impressions to construct a system that automatically extracts thumbnails from soccer videos based on impressions. First, we conducted an experiment evaluating 100 soccer thumbnail images using 19 impression word pairs. Four factors, *speed, evaluation, passion,* and *potency,* were extracted from factor analysis of the average evaluation scores of all participants. To investigate the relationship between playing situations and these factors, we categorized the extracted thumbnail images into 13 situations. The results of the distribution of factor scores for each category indicate that *Celebration* has a positive distribution of *speed* factor scores. We also extracted features from the images and calculated their correlations with factor scores. The results explained the relationship between the factor score associated with *speed* and the leg angle feature. The size of the players and their leg angles in images are difficult to explain impressions related to the *evaluation* and *potency* factors.

Keywords: soccer, thumbnail, impression, factor analysis, image feature extraction

# **1** INTRODUCTION

With the advancement of streaming services, many soccer match videos have been circulating on the Internet in recent years. More than 500 hours of content is uploaded to YouTube every minute²⁴. Soccer is a popular sport around the world, with the 2023 World Cup championship game attracting 1.5 billion viewers, increasing by more than 0.3 billion from the previous tournament's final match²⁵. As the content volume increases, viewers will have more options. Good thumbnails attract more viewers (Song et al., 2016). Thumbnails provide important information to viewers when selecting videos on the Internet. Although thumbnail

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² YouTube Official Blog. https://blog.youtube/press

²⁵ INSIDE FIFA. https://inside.fifa.com/tournaments/mens/worldcup/qatar2022/news/onemonth-on-5-billion-engaged-with-the-fifa-world-cup-qatar-2022-tm

selection is a crucial factor, it is labor-intensive and time-consuming if performed manually. To address this issue, a system was proposed to automatically perform thumbnail selection for soccer in a previous study (Husa et al., 2022). This system defines a good thumbnail as an image that represents a soccer video and selects candidate for thumbnail images. However, this system does not extract thumbnails according to impressions. Thus, even if a team that loses a match uploads images of the match using the system, the system may select images of the opposing players being happy.

The goal of this study is to construct a system that automatically extracts thumbnail images from soccer videos according to impressions by selecting impression words. The proposed system will help reduce the cost of selecting thumbnail images. In this study, as the first step in constructing the system, we investigated the relationship between the features extracted from soccer thumbnail images and impressions.

# 2 RELATED WORK

Although many automatic thumbnail selection systems have been developed, most employ convolutional neural networks (CNNs), object recognition, and event detection (Jiebo et al., 2009; Baoquan et al., 2020; Evlampios et al., 2021). Some studies used not only image information but also textual information and video tags (Yuli et al., 2009; Haojie et al., 2014).

Several studies have been conducted on soccer video production systems, including event detection and video segmentation. For soccer video segmentation, Peng et al. proposed an algorithm to determine the boundary between play and break (Peng et al., 2001). For soccer event detection, Grigorios et al. proposed an architecture for goal detection based on CNNs and autoencoders. Their study employed pretrained CNNs to extract both spatial and temporal features and considered autoencoders for fusing different information sources, and their experiments reported 98% accuracy (Grigorios et al., 2017). In addition, although most event detection methods use only visual information, Rongved et al. combined visual and audio information to improve accuracy (Andre et al., 2021).

Although research on automatic thumbnail selection and soccer video production systems has been conducted, research on soccer systems is rare. Husa et al. proposed a system based on machine learning to automatically select soccer thumbnail images that satisfy a specified rule (Husa et al., 2022). The rule is to select a good-quality image of a person in the video, which is established based on previous studies (Song et al., 2016). These studies on automatic thumbnail selection did not consider image impressions but instead selected images representing the video as thumbnail images. This study investigates the relationship between soccer images and impressions and creates thumbnails according to these impressions.

# **3** IMPRESSION EVALUATION EXPERIMENT

# 3.1 Purpose

Data were collected to investigate the relationship between the features of soccer thumbnail images and impressions. Participants were asked to view and evaluate soccer thumbnail images using impression word pairs.

# 3.2 Images

Images used in the experiment were clipped from full-match soccer videos downloaded from SoccerNet²⁶. Images clipped from the video of the four games were classified into 13 categories, and 100 images were selected for the experiment such that no bias was observed among the categories. At most, one image was selected from a single-play sequence to avoid selecting similar images. In image selection, thresholds were set for image quality and person size based on the definition of a good thumbnail in a related study (Husa et al., 2022). Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE) (Mittal et al., 2012.) was used to evaluate image quality, and YOLOv8²⁷ was used for human size estimation. The maximum size of a person in an image was at least one-tenth of the image size, and a BRISQUE score of 70 or less was used.

# 3.3 Impression words

Impression word pairs were determined by grouping using the KJ method (Kawakita, 1970). Five university students participated in the grouping process. For grouping, we used 273 words extracted from a dictionary. The 19 impression word pairs used in the experiment are listed in Table 1.

# 3.4 Method

Eleven university students (11 males, Average age: 23.00; standard deviation: 1.00) participated in the experiment. The participants looked at thumbnail images presented on a

No	Impress	sion	word pairs	No	Impression word pairs	
1	wonderful	_	terrible	11	plain – gorgeous	
2	heavy	-	cold	12	powerful – powerless	
3	slow	-	fast	13	sharp – dull	
4	rational	-	emotional	14	dislikable – likable	
5	strong	-	weak	15	static – dynamic	
6	attractive	-	unattractive	16	bright – dark	
7	tense	-	relaxed	17	ordinary – unique	
8	beautiful	_	ugly	18	gloomy – cheerful	
9	hopeful	_	hopeless	19	ambiguous – clear	
10	warm	-	cold			

 Table 1. Impression word pairs used in the experiments

personal computer display (Dell, U2720Q) and evaluated them using a seven-point semantic differential scales (Osgood & Sugi, 1957) for impression word pairs. The participants sat in a position where the distance between their eyes and the display was 70 cm. Before the

²⁶ SoccerNet. https://www.soccer-net.org/data

²⁷ YOLOv8. https://docs.ultralytics.com/models/yolov8/#supported-tasks

experiment, the participants were instructed to evaluate an image intuitively, without comparing it with a previous image, and to evaluate only the impression of the image, not considering their personal preferences for the players or teams in the image.

#### 3.5 Results

As an example of the impression evaluation results, Figure 1 shows the average evaluation scores of the participants for each impression word pair for Samples 17, 42, and 53 shown in Figure 2. The results demonstrate that the average scores for Samples 17 and 53 are comparable. Sample 42 has opposite ratings to the other two samples for many impression word pairs. This finding suggests that the playing conditions inferred from the images may have influenced some impressions. For the impression words powerful–powerless and static–dynamic, significant differences were observed in the evaluation scores between the three samples. This result suggests that images showing a shot being taken provide a more powerful and dynamic impression than images showing a player walking. These results suggest that whether the players are running or making some plays affects the impression.



Figure 1. Impression evaluation results for Samples 17, 42, and 53



(a) Sample 17



(b) Sample 42



Figure 2. Samples 17, 42, and 53

# 4 ANALYSIS OF THE RELATIONSHIP BETWEEN THUMBNAIL IMAGES AND IMPRESSIONS

# 4.1 Factor analysis

To clarify the overall semantic structure of the impression word pairs used in the experiment, factor analysis was performed. The average evaluation scores of all participants were analyzed using the principal factor method and Varimax rotation. The factor loading matrix is presented in Table 1. Four factors (F1–F4), each with an eigenvalue greater than 1, were extracted. These

	F1	F2	F3	F4
slow–fast	-0.881	-0.099	0.157	0.373
tense–relaxed	0.874	0.212	0.108	0.277
static-dynamic	-0.873	-0.114	0.275	0.287
sharp–dull	0.827	0.366	-0.100	-0.268
powerful–powerless	0.792	0.337	-0.409	0.060
plain–gorgeous	-0.638	-0.349	0.626	0.082
attractive-unattractive	0.336	0.850	0.026	-0.240
beautiful–ugly	0.229	0.844	0.033	-0.319
dislikable–likable	-0.289	-0.828	0.288	0.193
ambiguous–clear	-0.126	-0.731	0.411	-0.039
hopeful-hopeless	0.621	0.699	-0.055	-0.151
strong–weak	0.646	0.654	-0.118	-0.034
bright–dark	0.066	0.613	-0.461	-0.514
wonderful-terrible	0.511	0.599	-0.573	0.006
rational-emotional	-0.041	0.018	0.941	0.030
ordinary–unique	-0.456	-0.088	0.749	-0.054
warm–cold	-0.049	0.506	-0.688	-0.304
heavy–light	-0.262	-0.104	0.002	0.904
gloomy–cheerful	0.035	-0.500	0.067	0.797
Eigen value	10.506	2.610	2.196	1.426
Cumulative contribution ratio (%)	29.7	57.4	75.4	88.1

Table 2. Factor-loading matrix

factors were interpreted as *speed, evaluation, passion,* and *potency*. The higher the score for each factor, the more pronounced the impressions of fast, unattractive, emotional, and light.

#### 4.2 Relationship between factor scores and playing situations

#### 4.2.1 Categorization of playing situations

To investigate the influence of playing situations on the impression of each factor, we defined 13 categories: *Celebration, Protest, Dribble, Shoot, Set Play, Goal, Tackle, Pass, Foul, Header, Ball Touch, Goal Saves,* and *Others.* This is the same categorization used to select images for the experiment. *Dribble* is defined as a situation in which a player attempts to overtake an opponent, whereas *Pass* is a situation in which the ball is passed to a teammate. When a player moves forward with the ball into a space where there is no opponent or when a player receives the ball and controls it to pass, this situation is classified as *Ball Touch.* Action involving the handling of a ball with the head is classified as *Header.* The moment when a player shoots the ball is defined as *Shoot.* An image of the moment when a shot yields a goal is classified as *Goal.* An image of a defensive player blocking a shot is classified as *Goal Save.* A situation in which a player attempts to steal the ball from an opponent is defined as *Tackle;* however, if the referee judges the situation to be a foul, it is defined as *Foul.* An image of a player who is preparing the ball in a free or corner kick situation is defined as *Set Play.* An image of a defensive wall is defined as *Others* rather than *Set Play.* 

#### 4.2.2 Factor scores for each playing situation

Scatter plots of the factor scores for each thumbnail image are shown in Figures 3 and 4. Figure 3 shows that *Celebration* and *Protest* are positively distributed in the F1 factor score. *Dribble* and *Shoot* are negatively distributed in the F1 factor score. These results suggest that





whether a player is playing or not affects the impression of F1. Figure 3 shows that *Foul* and *Protest* are positively

Figure 4. Factor scores for each playing situation (F3, F4)

distributed in the F2 factor score. *Celebration* and *Set Play* are negatively distributed in the F2 factor score. These results suggest that F2 factor scores are higher in *Foul* situations and lower after scoring or in situations that are more likely to lead to scoring. Conversely, Shoot and Pass are widely distributed in the F2 factor score. Figure 4 shows that Tackle and Celebration are positively distributed in the F3 factor score. *Set Play* and *Dribble* are negatively distributed in the F3 factor score. *Set Play* and *Dribble* are positively distributed in the F3 factor score. *Set Play* and *Celebration* are positively distributed in the F4 factor score. Figure 4 also shows that *Dribble* and *Celebration* are positively distributed in the F4 factor score. *Set Play* and *Tackle* are negatively distributed in the F3 factor score. These results indicate that the distribution of factor scores is unique depending on the playing situation and that the playing situation influences the impression. Conversely, the factor scores for *Pass* and *Ball Touch* are widely distributed in all factor scores. These results suggest that these situations do not have a strong relationship with specific impressions.

#### 4.3 Relationship between factor scores and image features

#### 4.3.1 Image features

To investigate how the features of images affect impressions, the correlation coefficients between the features extracted from images and factor scores were calculated. According to the factor scores for the three images shown in Figure 2, the F1 factor scores for Samples 17, 42, and 53 are 1.36, 1.37, and -1.14, respectively. From these results, we conclude that the F1 factor score is higher for motion images. In motion images, players are typically running, and their arms and legs are bent. In addition, multiple players are typically present in images with

running and shooting scenes. Therefore, we hypothesize that the number of players in an image and their size and leg and arm angles affect the impression of F1. Figure 3 shows that the F2 factor score is higher for images of players protesting. They are also lower for images with dribbling scenes. A player protest scene has more close-up images than dribbling and other scenes; typically, only the upper body of the players is shown. Therefore, we hypothesize that the size and aspect ratio of the players in images affect the impression of F2. Figure 4 shows that the F3 factor score is higher for images containing celebrating and tackling scenes. They are also lower for images with Set-Play scenes. A tackling player typically slides and opens up his/her body. In addition, when players celebrate a goal, they are typically gathered. Conversely, in images that capture Ball Touches or Set-Play kickers, players typically do not have their legs or arms widely open, and many players are not included in such images. Therefore, we hypothesize that the aspect ratio and number of players in images affect F3. Figure 4 shows that the F4 factor score is higher for images with dribbling scenes. They are also lower for images with Set-Play scenes. In dribbling situations, players' legs and arms are typically bent, and Set-Play kickers are typically upright. Therefore, we hypothesize that the angles of the players' legs and arms affect F4.

From these hypothesizes, nine features, number of players, player size (maximum), player size (average), aspect ratio of the largest-size player, right-leg angle, left-leg angle, right-arm angle, left-arm angle, and leg opening, were extracted from the images. The size, number, and aspect ratio of player were calculated using YOLOv8. The angles of the arms and legs were calculated using YOLOv8. The angles of the arms and legs angles include the angles of the shoulder, elbow, and wrist; the leg angles include the angles of the shoulder, elbow, and wrist; the leg angles 0°–180°, indicating the extent of bending. An angle of 0° was obtained if the target part was not in the image and could not be recognized.

# 4.3.2 Correlation between image features and factor scores

Pearson's product-rate correlation coefficient was used to calculate the correlation between factor scores and image features. The results are presented in Table 3. The results show a significant correlation between the number and size of players, the angles of their legs and arms, and their F1 scores, as hypothesized. There was a positive correlation between the F3 factor scores and the three features related to the size and aspect ratio of the player in the image. These results suggest that the size of the player affects the impression of F3. Another reason may be that recognizing emotions from faces in images captured from a distance is difficult. There was a negative correlation between the F3 factor scores and the angles of players' legs. These results indicate that the impression of *emotion* is influenced by whether the given shot is a close-distance shot. There was a correlation between the F4 factor score and the number of players. A possible

	F1	F2	F3	F4
number of players	-0.423* *	-0.016	0.151	-0.219*

Table 3.	Correlation	coefficient b	petween image	features and	factor scores *	p < 0.05.	** <i>p</i> < 0.01
	conclution	COCHICICITE	Jetween minuge	icutui co unu		$p \sim 0.00$ ,	p . 0.01

player size (maximum)	0.463**	0.046	0.461**	-0.056
player size (average)	0.505**	0.000	0.318**	-0.029
aspect ratio of the largest-size player	0.109	0.026	0.529**	-0.044
right leg angle	-0.474* *	0.036	-0.382* *	0.068
left leg angle	-0.514* *	0.058	-0.372* *	0.094
right arm angle	-0.237*	-0.075	-0.192	0.038
left arm angle	-0.237*	-0.012	-0.143	0.160
leg opening	-0.508* *	0.093	-0.055	-0.022

reason for this result is that images with dribbling scenes typically contain few players. There was no correlation between F2 factor scores and features. These results suggest that the impression of *evaluation* is difficult to explain using physical features.

# 5 CONCLUSIONS

This study investigated the relationship between soccer thumbnail images and impressions. Our results can be summarized as follows:

1. Most impressions of soccer thumbnail images can be explained by four factors: *speed, evaluation, passion,* and *potency*.

2. Images with *Celebration* scenes tend to evoke positive impressions for the *speed* factor. *Ball Touch* and *Pass* do not have a strong relationship with any impressions.

3. The features *player size* and *angle of legs* affect the *speed* factor. There is a relationship between the condition of the players in an image and the factor of *passion*. Factors of *evaluation* and *potency* are difficult to explain using player size or foot conditions.

These results indicate that selecting thumbnails from soccer videos based on players' size and leg angles can control the impression of *speed*. Conversely, we could not extract features that could explain *evaluation* from soccer images. In future research, we will further investigate what influences thumbnail impressions of *evaluation* and *potency*. To investigate players' emotions numerically, we will extract information from their faces, such as the corners of their mouths.

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# CAN BIAISO (NON-SOCIABILITY ASSESSMENT FACTORS) BE USEFUL AS A New UX DESIGN PERSPECTIVE TO REDUCE DISSATISFACTION WITH UNATTENDED SERVICE SYSTEMS?

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# ABSTRACT

In recent years, Japan has seen a shift from face-to-face customer service to systemization, such as the introduction of self-checkout systems in supermarkets, and a certain number of people are dissatisfied with these systems. The cause of such dissatisfaction can be attributed to the lack of a design perspective in UX design. Therefore, design using evaluation from more perspectives is required. The purpose of this study is to apply the three components of the Buaiso Impression Scale for Interpersonal Relationships, namely the communication anxiety factor, the self-presentation factor, and the unpleasant emotion expression factor, to the evaluation of artifacts. Buaiso is a word of Japanese origin. For example, Buaiso is sometimes used to refer to a person who is quiet with few words and no change in facial expression. Buaiso is also used here to refer to an interpersonal reaction in which the person does not look directly into the other person's face or eyes, but instead gives the impression of appealing to one's own abilities or expressing negative emotions. In this study, an experiment was conducted to create artifacts that give a Buaiso impression and to extract factors that strengthen the Buaiso impression from the artifacts.

Keywords: Design perspective, Agent interaction, System design, UX, Service design

# **1** INTRODUCTION

In recent years, services using agents such as self-checkout have become a part of our daily lives in Japan. A cash register in which customers themselves perform all the scanning of products and payment by themselves is called a self-checkout. For example, according to the Japan Supermarket Association (2023), the percentage of companies with self-checkout facilities from 2021 to 2023 is 23.5% (2021), 25.2% (2022), and 31.1% (2023), showing an increasing trend. Thus, lately, the number of situations in which people and artifacts communicate with each other has been increasing. Yahoo! News and IT media Business Online

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jointly conducted an online (2022) survey on February 18, 2022, and found that the most common reasons for difficulty in using the system were "Worried about system errors (29.8%)." The next most frequent response was "Worried about scanning mistakes (28.1%)." Furthermore, in a survey conducted by MS & Consulting Inc (2023). from January 4 to 9, 2023, on consumers' impressions of the "introduction of self-checkout systems," the percentage of respondents who answered "nothing in particular" about self-checkout systems increased 10 points from the previous year, suggesting that self-checkout systems have become an everyday item for consumers. On the other hand, negative opinions such as "I have resistance" also increased by 7 points compared to the previous year (MS&Consulting,2023). As described above, there are a certain number of people who are anxious about the operation and dissatisfied with the fact that they have become familiar with self-checkout systems. This is thought to be due to a lack of perspective in designing the system. For this reason, it is necessary to design a system that can be evaluated from more different perspectives.

In this study, we focused on the Buaiso impression scale of Ito (2021) to examine a new perspective in system design. In Ito's study (2021), he created the Buaiso impression scale for 230 Japanese subjects in their teens to 80s. It defines "Buaiso" as "an interpersonal reaction in which a person does not look directly into the other person's face or eyes, and in which the person feels an appeal to one's own abilities or an expression of negative emotions. For the purposes of this study, "Buaiso" is defined as anything that fits this definition. In the Japanese dictionary, Its opposite is "Aiso" is the opposite of "Buaiso," which defines as "an attitude toward people, or a friendly attitude" (Digital Daijisen, 2024).

Ito's Buaiso impression scale classifies impressions (Ito,2021) perceived as the Buaiso in interpersonal relationships into three factors: "Communication anxiety" "Awkward self-presentation" and "Unpleasantness" and indexes them using items corresponding to each factor. However, since the Buaiso impression scale (Ito,2021) was developed for interpersonal communication, it is not clear whether it can also be used for communication with artifacts. The purpose of this study is to devise an evaluation model based on the Buaiso impression scale.

Note that Kuba Krys et al. (2016) conducted a study on cross-cultural differences in intelligence and sincerity perceived by smiling, which involved more than 5,200 people in 44 countries between 2011 and 2015. Based on their results, they stated that smiling is perceived as less intelligent and more insincere in India and Iran. Therefore, the Aiso and the Buaiso criteria may have cultural differences, and the findings of this study may not necessarily be applicable to cultures other than Japan, but that study will not be addressed in this paper.

# 2 PREVIOUS STUDY

Kitamura and Toyohira (2023) focused on the Buaiso of artifact design, the three factors of "Communication anxiety," "Awkward self-presentation," and "Unpleasantness" in Ito's Buaiso impression scale (Ito,2021) were replaced from the viewpoint of artifacts, and the results were analyzed to determine what kind of products are likely to be imagined and which factors are pointed out. In addition, in order to clarify which factors are pointed out, reports on existing products assigned in class are analyzed (Kitamura&Toyohira,2023). In this study, "Communication anxiety" was replaced with a gaze from the artifact, "Awkward self-presentation" with one-sided assertiveness, and "Unpleasantness" with unintentional unpleasantness felt from the artifact. Kitamura and Toyohira (2023) reported from this investigation that they obtained the hypothesis that, in artifacts, "one-sided self-presentation" and "unintentional unpleasantness" are more likely to be evaluated as Buaiso impressions than "gaze" received from the product, and that they may feel uncomfortable with the sound and evaluate it as Buaiso impression.

Another study related to the design perspective of artifacts is Ohkura et al.'s study on Kawaii (2007). In this study, cute attributes are systematically analyzed for the construction of Kawaii products. The hypothesis is that "Japanese men, especially middle-aged and older men, tend to treat kawaii only as an adjective for living creatures and their appearance/character. On the other hand, Japanese women perceive kawaii not only for creatures but also for artifacts. To verify this, we conducted a simple experiment on "kawaii-ness" using four magnets of different shapes (cat, puzzle piece, whale, and heart) on men and women in their early 20's and early 50's. As a result, they reported that the kawaii scores for each magnet differed depending on the age and gender of the subjects, verifying the above hypothesis.

# **3** EXPERIMENTAL SYSTEMS

#### 3.1 Sumary

Based on the findings of the study by Kitamura and Toyohira (2023), we considered that vending machines, microwave ovens, and other products that were originally thought to be Buaiso were not appropriate for this experiment. Therefore, in this experiment, we used products that were not considered the Buaiso in the study by Kitamura and Toyohira (2023), but were given a new system in order to avoid any variation in the experimental setting.

As a product, we decided to use capsule toys based on the research of Yoshioka et al (2020). Capsule toys are small vending machines developed in the U.S. and sold in Japan since 1977, and they are still very popular (The Japan Toy Association,n.d.). Yoshioka et al. tested a mechanism using capsule toys based on the hypothesis that stimulating children's minds and playfulness will induce behavior to address the problem of poor communication. As a result, they were able to induce behaviors that activated communication. Two capsule toy systems were prepared for the experiment: type A was designed to behave amiably to the user, while type B was designed to satisfy the element of Buaiso behavior to the user. Table 1 shows the sequence of operation of systems Type A and Type B. First, Type A of "calling out" only calls out once when a user comes in front of it, while Type B calls out repeatedly until a user comes in front of it, and stops calling out the moment a user comes in front of it. Next, Type A of the "Error Notification" function informs the user that the problem is on the system side, and an apologetic picture appears, while Type B informs the user that the problem is on the user side, and the entire screen turns red and blinks. Type A of "operation instructions" tells the user only once, while type B repeats the operation instructions several times and tells the user quickly. Figure 1 shows the actual capsule toy used in the experiment.





# 3.2 Expected usage scenarios

The participants were informed that the capsule toys were installed under the following conditions when they were used in the experiment. Figure 2 was shown as an image of the location where the capsule toy was located.

• Capsule toys placed for product design research in the company.

• The capsule toy is equipped with a display, and the display provides voice announcements on how to operate it.

- Questionnaires are mounted for product design research.
- You can get a product by answering the questionnaire.
- You can spin it for free using special coins.
- There are some people around.

# **4 EXPERIMENT**

# 4.1 Purpose

The purpose of this experiment is to examine whether the system can actually produce Buaiso-like impressions by adding elements that are considered Buaiso to artifacts, as found in a previous study (Kitamura&Toyohira,2023).

# 4.2 Methods

Experimental participants were asked to use two types of capsule toys in the system: Type A, which was created to be more Aiso, and Type B, which was created to be more Buaiso, and their impressions of each were verified. In the questionnaire, in addition to "Buaisoness," "satisfaction," "convenience," and "peace of mind," which were frequently used among the factors affecting users' satisfaction experience investigated in Doi and Yamaoka's study, were used as evaluation words (2019).



Figure 1. Capsule toy system used in the experiment



Figure 2. The location where the capsule toy system is installed (This image presented to participants).

#### 4.3 Contents

Twenty-two people participated in the experiment, and it was assumed that they would be able to easily visit the experiment site, have basic knowledge of UX design, and be able to understand the experiment concept. Therefore, all participants were university and graduate students in their 20s. The experiment was conducted on a university campus in Japan. Prior to the experiment, we explained to the participants that the provided data would be discarded and would not be used for further research purposes, and that the data would be anonymized so that they would not be linked to any individual. The experiment took 20 days from December 22, 2023, to January 10, 2024, and lasted approximately 20 minutes per person.

#### 4.4 Results

Figure 3 shows the results of multiple regression analysis between Type A and Type B in the "calling out" category, with Type A showing a significant difference in "Peace of mind," and Type B also showing a significant difference in "peace of mind. The above results indicate that the factors that decrease the user's "peace of mind" in the voice contact reinforce the impression that the user is Buaiso.

Figure 4 shows the results of multiple regression analysis between Type A and Type B in "Error Notification." Type A showed no significant difference, while Type B showed a significant difference in "Satisfaction" and "Convenience." Figure 5 shows the results of multiple regression analysis for only "Satisfaction" and "Convenience" in Type B. Here, only "Satisfaction" and "Convenience" in Type B. Here, the adjusted R2 for "Satisfaction" and "Convenience" as explanatory variables was lower than the original adjusted R2, and the coefficients were also lower than the original values, respectively. Therefore, "satisfaction" and "convenience" are considered to contribute significantly to the Buaiso impression in this model. The above results indicate that the user's impression of Buaiso is enhanced when the user's "satisfaction" decreases and "convenience" increases at the same time when the user is notified of a problem.

Figure 6 shows the results of multiple regression analysis for Type A and Type B in "operation instructions." Type A showed significant differences in "satisfaction" and "security," while Type B showed no significant differences. The above results indicate that "Satisfaction," "Convenience," and "Peace of mind" did not increase Buaiso's impression of the operation

instructions. However, it was shown that a high level of "satisfaction" and a low level of "security" lead to a good impression of Buaiso.

These results indicate that "peace of mind" before the experience and "satisfaction" and "convenience" during the experience contribute to the impression of Buaiso, while "satisfaction" and "peace of mind" contribute to the impression of Aiso after the experience, but not to the impression of Buaiso.



Figure 3. Results of Multiple Regression Analysis in "Calling Out"



Figure 4. Results of Multiple Regression Analysis in "Error Notification"



Figure 5. Results of regression analysis with "Satisfaction" and "Convenience" as explanatory variables in "Error Notification"



Figure 6. Results of Multiple Regression Analysis in "Operation Instructions"

#### 5 DISCUSSION

Figure 3 shows that the Buaiso impression of "calling out" is enhanced by the decrease in "peace of mind. In the present case, Type A is "calling out" only once, while Type B is "calling out" multiple times. From these results, it is possible that the users felt that the artifact was broken when they were called multiple times.

Figures 4 and 5 show that the impression of Buaiso increases as "satisfaction" declines and "convenience" rises at the same time. Therefore, it can be said that although they are dissatisfied by the intense "Error Notification," they feel convenience because they are able to notice the problems themselves. Many of the post-experiment participants reported that the sudden appearance of the flashing red light was frightening, but none of them reported that it was convenient. From these results, it can be inferred that the negative image of the artifact is given priority over the usefulness of the artifact.

#### 6 CONCLUSIONS

Based on Ito's Unsociable Impression Scale, this study examined the design elements that give capsule toys an unsociable impression when given a system. We plan to investigate whether this result is caused by the small sample size or other factors. In addition, we plan to conduct similar experiments on other products to explore the generalizability of the results.

#### **ACKNOWLEDGMENTS**

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# POP ADVERTISEMENT GENERATION SYSTEM BASED ON REGULATORY FOCUS THEORY AND IEC

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# ABSTRACT

In recent years, Japan's digital advertising market has grown significantly, driven by personalized Internet advertisements. However, these ads often lack persuasive impact, as they rely on users' search histories without considering their thoughts and sensibilities. Regulatory Focus Theory has gained attention for explaining the relationship between information processing and consumer behavior. This study aims to enhance purchase intentions by using Regulatory Focus Theory to create appeals that consider individual thoughts and emotions, optimizing regulatory focus for each person. Quantifying regulatory focus is challenging due to its dependence on individual sensitivity. To address this, we used Interactive Evolutionary Computation (IEC), which optimizes based on subjective evaluations. We propose a system to promote purchase intention by optimizing regulatory focus with Point-of-Purchase (POP) advertisements. Preliminary experimental results show that the proposed system effectively measures users' regulatory focus and information needs, producing optimal POP advertisements. This study introduces a novel approach to personalized advertisement optimization, incorporating cognitive and emotional factors through Regulatory Focus Theory and IEC.

*Keywords:* Regulatory Focus Theory, Interactive Evolutionary Computation, POP-advertisement

# **1** INTRODUCTION

In recent years, the proliferation of personalized advertisements has led to significant growth in Japan's digital advertising market. Personalization allows for the dissemination of information tailored to each customer, as opposed to the traditional uniform information and services

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provided to the masses, thus meeting diversified needs. However, these personalized advertisements are typically based on user search histories and other similar data, and cannot be said to take into account the users' thoughts and sensibilities. Consequently, modern Internet advertisements often fail to leave a good impression and lack persuasive effect.

One theory that has gained attention in the field of advertising research is Regulatory Focus Theory (RFT). Proposed by Higgins (1997), RFT posits that differences in goal orientation affect individual behavior regulation (Higgins, 1997). There are two types of focus in this theory: promotion focus and prevention focus. People with a promotion focus have a goal orientation aimed at achieving positive outcomes, whereas those with a prevention focus aim to avoid negative outcomes. For example, in the context of disaster preparedness, an emphasis on achieving higher safety standards reflects a promotion focus, while a desire to minimize damage reflects a prevention focus. The reason RFT is used in advertising research is its relevance to information processing in consumer behavior (Mitsumura & Takagi, 2012).

Ozaki and Karasawa (2011) state that individuals possess both promotion and prevention focus tendencies and switch between them depending on the situation (Ozaki & Karasawa, 2011). Traditional methods have activated either focus based on situational and environmental differences, classifying individuals into a binary of promotion-focused or prevention-focused orientations. However, it is believed that most individuals fall into one of three situations: (1) a predominance of promotion focus with some prevention focus, (2) a predominance of prevention focus, or (3) minimal difference between the two foci.

To address these three situations, it is necessary to measure each user's regulatory focus more accurately. However, because regulatory focus depends heavily on human sensibility, it is considered very difficult to quantify it numerically. Therefore, when optimizing a user's regulatory focus, a method based on subjective evaluation is necessary. Among methods that optimize based on subjective evaluation, those using evolutionary computation are called interactive evolutionary computation (IEC) (Takagi, 2001). IEC is effective for problems related to human sensibility, such as user interface design (Quiroz, Louis & Dascalu, 2007), music composition (Jónsson, Hoover & Risi, 2015), etc. to generate novel and personalized solutions based on user preferences and feedback.

Therefore, this study proposes a system that uses IEC to measure the optimal regulatory focus of users and promote their purchase intentions. In this system, the regulatory focus is measured using IEC based on users' subjective evaluations of presented solution candidates. By presenting advertisements tailored to the measured regulatory focus, we anticipate that users' purchase intentions can be effectively promoted.

#### 2 PROPOSED SYSTEM

#### 2.1 Overview

In the proposed system, users engage in fruit shopping in a virtual space to optimize the regulatory focus and information volume of POP advertisements according to each user. In this

system, regulatory focus is treated as a categorical value rather than a binary value of promotion or prevention focus. This approach allows for a more nuanced representation of individual preferences. Consequently, the proposed system aims to enhance users' purchase intentions by optimizing POP advertisements.

The proposed system consists of two phases: the regulatory focus measurement phase and the optimization phase. In the regulatory focus measurement phase, the user's regulatory focus is measured using IEC. As this study treats regulatory focus as a categorical value, POP advertisements are represented using a binary tree. In this phase, the proposed system presents POP advertisements to users from this binary tree and records their selection history. In the optimization phase, the system optimizes the regulatory focus suitable for the user through virtual shopping. The regulatory focus is optimized using a Huffman tree, which is constructed based on the user's selection history of POP advertisements from the measurement phase, including the selected POP advertisements and their selection frequencies. The system presents POP advertisements to the user from the created Huffman tree and iteratively reconstructs the Huffman tree based on the user's subsequent selections. In the prototype system, POP advertisement content is related to fruits, as they are a target product category that is reasonably familiar to most consumers. The interface of the system implemented using the Unity game engine is shown in Figure 1.

# 2.2 Representation of Regulatory Focus Using Binary Trees

In the proposed system, POP advertisements are represented using a binary tree structure as illustrated in Figure 2. In this representation, the depth of the binary tree corresponds to the amount of information, with deeper nodes containing more detailed content in the advertisement messages. Additionally, for genetic coding of POP advertisements, elements related to promotion focus are denoted by 1, while elements related to prevention focus are denoted by 1, while elements related to prevention focus are denoted by 1, while elements related to prevention focus are denoted by 0. For example, in the binary tree depicted in Figure 2, a node labeled as 10 indicates a POP advertisement with 2 units of information, featuring appealing phrases in the order of promotion and prevention focus. Table 1 provides an example illustrating the relationship between genetic information and the appeal of POP advertisements.



Figure 1. The interface of the system



Figure 2. Binary Tree

Table 1. Relationship between genetic information and appeal

Genetic Information	POP Advertisement
1	Bananas are rich in vitamin B and often referred to as beauty vitamins. Vitamin B can promote a healthy scalp and hair.
10	Bananas are rich in vitamin B and often referred to as beauty vitamins. Vitamin B can promote a healthy scalp and hair. These vitamins also help reduce spots and wrinkles.
100	Bananas are rich in vitamin B and often referred to as beauty vitamins. Vitamin B can promote a healthy scalp and hair. These vitamins also help reduce spots and wrinkles. In addition, the often-discarded banana streaks are rich in polyphenols, which are excellent for preventing dry skin and skin oxidation. To maximize the anti-aging benefits, consume the entire banana, including the stringy parts.

The system currently utilizes 15 fruits as the target for generating advertisements. To clarify user intentions and provide a diverse range of advertisement content, this study narrows down the target of POP advertisements to four target categories – beauty, diet, exercise, and stress – with each of the 15 fruits in the system being associated with all four target categories. During their interaction with the proposed system, users are asked to select one of these targets, and a corresponding POP advertisement is generated accordingly. Based on the binary tree, the system generates 14 unique information units for each fruit-target categories × 14 information, resulting in a total of 840 POP advertisements (15 fruits × 4 target categories × 14 information units) used to form the system's POP database.

# 2.3 Regulatory Focus Measurement Phase

As mentioned earlier, the user's regulatory focus is measured using IEC. The system weights the binary tree based on the user's selection of one of the two presented POP advertisements. In this particular case, bananas are used as the target of the POP advertisement.



**Figure 3**. Huffman tree weighting process when the presented POP advertisements contain the same amount of information



Figure 4. Huffman tree weighting process when the presented POP advertisements contain different amount of information

Let's outline the flow of this phase. First, the system randomly presents a POP advertisement to the user. Subsequently, the user selects their preferred option from the two presented POP advertisements. The system uses the user's selection to guide the next POP advertisement it presents. It does this by adjusting the weights in the binary tree based on the user's choice. The system repeats this process three times within the regulatory focus measurement phase. To reduce any potential bias that might arise from the initial selection, the entire regulatory focus measurement phase is carried out five times. Additionally, the system records all selected POP advertisements along with the frequency of selections.

The method for adjusting the weights varies depending on the amount of information in the two POP advertisements compared by the user. If both POP advertisements have the same amount of information, the system assigns weight to the node of the selected POP advertisement. For instance, if a POP advertisement with a genetic information value of 100 is selected, the weight is assigned to its parent node, which is 10. Figure 3 illustrates how the Huffman tree is weighted when the compared information amounts are equal. This weighting scheme increases the likelihood that the system will present POP advertisements such as those starting from nodes with genetic information values of 10, 100, and 101 next.

Conversely, if the information amounts in the two POP advertisements differ, the system assigns weight based on the information amount of the selected POP advertisement node. Figure 4 depicts how the Huffman tree is weighted when the compared information amounts differ. For example, if a POP advertisement with genetic information value 10 is selected, weight is assigned based on its information amount, which is 2. This weighting increases the likelihood that the system will present POP advertisements such as those with information amounts of 00, 01, 10, and 11 next.

#### 2.4 Optimization Phase

In this phase, the regulatory focus is optimized using Huffman trees. Initially, the system constructs a Huffman tree based on the selection history and frequency of selected POP

advertisements from the regulatory focus measurement phase. Subsequently, the system determines and presents POP advertisements added to fruits from the created Huffman tree to the user. Finally, the system updates the Huffman tree by having the user select a POP advertisement.

Next, the procedure for creating a Huffman tree from the information recorded in the regulatory focus measurement phase is detailed below:

- 1. Arrange POP advertisements in ascending order of selection frequency.
- 2. Merge the two nodes with the lowest selection frequencies into a new node.
- 3. Repeat step 2 until the tree structure is complete.

By repeating these steps, the system constructs the Huffman tree. Figure 5 illustrates an example of a constructed Huffman tree. Nodes represented by bold frames indicate nodes created in step 2, with numbers below indicating their respective selection frequencies. At this stage, each node's selection frequency serves as the weight for branches in the Huffman tree.

The method for determining the POP advertisements added to fruits from the created Huffman tree is described next. In this phase, POP advertisements are added to each of the 15 fruits following these steps:

1. Use a random number to decide whether to move to either child node from the parent node targeted in the Huffman tree.

2. If arriving at a node containing stored POP advertisements, add the POP advertisement stored in that node.

If reaching a merged node without a stored POP advertisement, return to step

Figure 6 depicts the procedure for determining the POP advertisements added to each fruit. For instance, in Figure 6, the root node is split into two nodes: one weighted 3 for genetic information 011 and another merged node with weight 5. Initially, following step 1, the system generates a random number less than the total of the two nodes. If the random number falls between 1 to 3, the system advances to the node with genetic information 011, where a POP advertisement is stored. Conversely, if the random number is between 4 to 8, the system moves to the merged node with weight 5. Since this node does not store a POP advertisement, it acts as a parent node, and the process repeats until reaching a node storing a POP advertisement. Consequently, in the example shown in Figure 6, the system ultimately adds a POP advertisement for genetic information 101 to the fruit.

Lastly, we outline the method for updating the Huffman tree. Initially, the user selects one





Figure 6. Procedure for determining the POP advertisements

#### Figure 5. Example of a constructed Huffman tree

favorite fruit from the 15 fruits with added POP advertisements. The system then increments the selection frequency of the genetic information of the POP advertisement added to the selected fruit by one. Furthermore, the system rebuilds the Huffman tree based on the updated selection frequencies. Subsequently, POP advertisements are allocated to the 15 fruits within the newly constructed Huffman tree. This entire process is repeated five times.

#### **3** EXPERIMENT

#### 3.1 Overview

To evaluate the effectiveness of the proposed system, we conducted an experimental evaluation with 10 participants, both male and female in their 20s. First, the subjects were instructed to select the target of POP advertisements from one of the four categories: beauty, diet, exercise, and stress. Subsequently, the subjects underwent the regulatory focus measurement phase, where they chose the better advertisement from two POP advertisements presented by the system. This selection process was repeated three times. To mitigate potential order effects, the regulatory focus measurement phase was conducted five times with randomized advertisement presentations. Following this, the subjects proceeded to the optimization phase, in which they selected one fruit from a set of 15 fruits displaying POP advertisements. This selection was repeated five times as well. Finally, the subjects entered the evaluation phase and completed a questionnaire about the system and their experience during the experiment.

The questionnaire used in this experiment consisted of two questions, as shown in Table 2. The first question (Q1) aimed to determine the subjects' motivation for selecting a particular fruit, with the available options being "because they liked the fruit" or "because they saw the POP advertisement." This question was designed to gauge whether the subjects' choices were influenced by their personal preferences or by the POP advertisements presented to them. The second question (Q2) aimed to assess the impact of the POP advertisements on the subjects' willingness to purchase the selected fruit. Labeled "How willing did you feel about buying the fruit?" this question was evaluated using a five-point Likert scale, with the following options: "Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," and

"Strongly disagree." The responses to this question provided insight into the effectiveness of the POP advertisements in influencing the subjects' purchase intentions. The subjects were required to answer both questions each time they selected a fruit during the optimization phase of the experiment. In addition to these two questions, the questionnaire also included a free description section where the subjects could provide additional comments and opinions.

Table 2. Questionnaire

Q1	Did the POP advertisement influence your decision to choose the fruit?
Q2	To what extent did the POP advertisement affect your willingness to purchase the selected fruit?

# 3.2 Results

The results of the questionnaire administered during the experiment provide insights into the subjects' selection criteria and the impact of POP advertisements on their purchase intentions. The responses to Q1, which aimed to determine the subjects' motivation for selecting a particular fruit, revealed that the number of subjects who chose fruits based on the POP advertisements increased until the third selection. However, from the third selection onwards, this number remained constant at six subjects, suggesting that the influence of the POP advertisements on the subjects' choices stabilized after a certain point. The responses to Q2, which assessed the impact of the POP advertisements on the subjects' willingness to purchase the selected fruit, exhibited fluctuations in the evaluation values. This instability in the ratings indicates that the effectiveness of the POP advertisements in influencing the subjects' purchase intentions varied throughout the experiment.

Next, several subjects expressed their thoughts on the POP advertisements. Some indicated a tendency to choose based on the number of characters rather than the content itself. One subject mentioned, "I felt that a large amount of information meant it was detailed, so I sometimes judged by the number of characters before reading the entire content." Another subject noted, "I didn't feel like reading advertisements with long texts." These comments suggest that the length and complexity of the POP advertisements played a role in the subjects' decision-making process, with some individuals preferring shorter and more concise advertisements over those with extensive text.

# 4 DISCUSSION

We investigated whether optimizing POP advertisements could stimulate subjects' purchase intentions. According to Figure 7, it seems that fruit preferences outweighed the influence of POP advertisements. Responses like "I didn't feel like reading lengthy advertisements" suggest subjects may have chosen POP advertisements based on fruit preferences without viewing the advertisements. Additionally, Figure 8 indicates that the optimization of POP advertisement using the proposed system insufficiently boosted users' purchase intentions. Therefore, it is necessary to exclude the influence of fruit preferences and reassess whether POP advertisements directly influenced

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**Figure 7**. Did the POP advertisement influence your decision to choose the fruit?

Figure 8. To what extent did the POP advertisement affect your willingness to purchase the selected fruit?

purchase intention.

Moreover, the free responses often emphasized the amount of information. This suggests that the difference in information quantity is more apparent than the difference in regulatory focus, leading subjects to perceive optimization based on information volume. Therefore, improving POP advertisements to make regulatory focus differences visible in advertisement messages is necessary, and re-evaluating whether optimization occurs due to variations in regulatory focus is crucial. Ishii (2018) also mentions that consumers in a prevention-focused mindset tend to favor extensive information to avoid negative outcomes (Ishii, 2018). As the impact of information volume varies depending on the focus conditions, it is important to develop tailored approaches for each scenario to effectively optimize the POP advertisements.

Additionally, the level of consumer involvement with the product plays a significant role in their response to POP advertisements. Researchers argue that highly involved consumers tend to focus more on product-related information (Celsi & Olson, 2002). In this study, the use of fruits as the subject suggests that the subjects may have had a high level of involvement. However, as Wang and Lee (2006) point out, consumers who are highly involved with a product tend to have a weaker regulatory focus, as they extensively consider product information, whereas those less involved rely more on heuristic product selection, making regulatory focus more influential (Wang & Lee, 2006). Therefore, to better understand the impact of regulatory focus on purchase intentions, future experiments should consider selecting subjects with low involvement in the product category.

#### 5 CONCLUSION

In this study, we proposed a purchase intention promotion system by optimizing the regulatory focus using POP advertisement as a medium and examined its effectiveness. RFT, which we focused on in this research, has been extensively studied for its effectiveness. However, these studies have the problem of low practicality and the inability to measure individuals' optimal regulatory focus. These problems are primarily due to a bias towards

experiments using scenarios and laboratory settings, and the verification being limited to the dichotomy of promotion focus or prevention focus.

Therefore, in this study, we proposed a system that uses IEC to measure the optimal regulatory focus of users and promote their purchase intentions. This system aims to enhance purchase intention by measuring users' subjective evaluations of the presented advertisement candidates using IEC and then presenting advertisements tailored to their regulatory focus.

The results of this experiment confirmed that the proposed system is effective in measuring users' focus and information volume for optimal POP advertisement production. However, in this experiment, the promotion of purchase intention was more influenced by the volume of information than by the aspect of regulatory focus. Future challenges include developing mechanisms to further promote users' purchase intentions and designing more user-friendly interface.

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# PRODUCT RECOMMENDATION SYSTEM THAT PROMOTES SELECTION USING DOMINANCE STRUCTURING PROCESS

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## ABSTRACT

In this paper, we propose a product recommendation system designed to promote user selection through the Dominance Structuring Process. This process is a central component of the Dominance Structure Search Model, which is a recognized decision-making framework. By presenting users with sentences that proceed Dominance Structuring Process, our system highlights key product features, thereby simplifying the selection process. The aim of this study is to enhance user satisfaction in product selection by employing the proposed system. In the present study, we focused on recommending "TVs that suit the user's preferences." Findings from a pilot evaluation confirm that the proposed system effectively promotes selection via the Dominance Structuring Process. However, it was observed that users did not place significant emphasis on the descriptive sentences intended to facilitate the Dominance Structuring Process.

Keywords: Recommendation System, Dominance Structure, Purchase Hesitation

## **1** INTRODUCTION

In recent years, the use of product recommendation systems on online shopping sites has significantly increased. A product recommendation system infers a user's preferences from data such as their purchase and browsing history, subsequently recommending suitable products (Konstan & Riedl, 2003). The proliferation of the internet and SNS has led to "information overload," where users need to sift through extensive data to find desired products or information. To address this challenge, recommendation systems have been developed to assist

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users in locating useful information. Such systems are prevalent on shopping sites like Amazon and Rakuten Ichiba.

Additionally, when shopping on these platforms, users often face difficulty in deciding which product to purchase, particularly when the options have multiple attributes. This confusion is exacerbated by the multitude of available choices. Shafir et al. hypothesize that decision-making involves identifying a "reason for choice" that satisfies oneself or others under conditions of uncertainty or confusion. They argue that when confronted with two alternatives and uncertainty, an abundance of options can hinder the decision-making process, preventing a purchase

(Shafir, Simonson, & Tversky, 1993). The Dominance Rule, a non-compensatory decision-making rule, assumes that when choosing between two options, the dominated option is selected (Kobashi, 1988). "Dominance" means that when comparing options, one is more desirable in at least one attribute and equally or more desirable in all other attributes. Dominance Structure Search Model is a decision-making process that employs the Dominance Rule as its fundamental principle.

Conventional product recommendation systems often suggest similar products, leading to user indecision and a decrease in post-purchase satisfaction. Therefore, this study proposes a product recommendation system utilizing Dominance Structure Search Model to promote product selection. This study will also verify the effectiveness of this system in facilitating product selection using the proposed model.

## 2 PROPOSED SYSTEM

## 2.1 Product Recommendation System for Promoting Selection

Traditional product recommendation systems acquire user preferences and present the optimal products for the user. However, they lack features that alleviate the hesitation users experience when selecting a product. Therefore, this study proposes a product recommendation system that facilitates selection using Dominance Structuring Process. Dominance Structuring Process is a key procedure of Dominance Structure Search Model, a decision-making process. Details about Dominance Structure Search Model will be discussed in the next section.

The proposed system aims to promote user decision-making and reduce hesitation by presenting text that undergoes Dominance Structuring Process. The overview of the proposed system is shown in Figure 2(left). The system comprises two stages: the preference acquisition stage and the final decision-making stage, the system gathers user preferences based on their product selection information. When users shop online, they search for products that interest them and decide on the best options from among multiple products. In the final decision-making stage, the system applies Dominance Structuring Process to the multiple products presented to the user, facilitating the final product selection.

As for the flow of the system, first, the system randomly presents multiple products to the user. Then, based on the information of the products selected by the user, it calculates how much importance the user places on the attributes of the products. Using this importance, the system calculates evaluation values for all products and recommends multiple top-evaluated products in the next generation. This recommendation process is repeated until the final decision-making stage. In the final decision-making stage, the system uses the importance of product attributes acquired in the preference acquisition stage to present multiple final options. At this stage, the system also presents users with text for Dominance Structuring Process.





#### 2.2 Preference Structure Exploration Model

Montgomery's Dominance Structure Search Model is based on the principle of dominance in decision-making (Montgomery,1983). It assumes that when one option dominates others, individuals can make satisfying decisions. The model posits that good decisions require solid reasons and justifications, with dominance providing these reasons and justifications. If no dominant option exists, the interpretation and representation of the decision context are altered to create a dominant option. Shina states that reconstructing the decision context to subjectively establish a dominance structure can resolve decision-making issues (Shina,2005). Figure 2(right) illustrates the flowchart of the Dominance Structure Search Model. In this model, Dominance Structuring Process is applied to the options to create a dominant option. The specific steps in Figure 2(right) are described below in points (1) to (4).

(1). Preliminary Editing: users consider the importance of each evaluation attribute of the options and determines a group of potentially dominant options.

(2). Selection of Promising Options: From the group of options determined in step (1), the user selects one option that is most likely to satisfy the dominance criteria.

(3). Dominance Check: The system checks whether the option selected in step (2) dominates the other options. If the selected option is dominant, the selection is finalized, and the process ends. If the option is not dominant, the system proceeds to step (4).

(4). Dominance Structuring Process: This process involves four operations: blurring, emphasizing, offsetting, and averaging. Blurring involves disregarding the shortcomings of promising options. Emphasizing involves highlighting the strengths of promising options or emphasizing the weaknesses of opposing options. Offsetting neutralizes the strengths and weaknesses of promising options. Averaging integrates the desirability of two or more attributes into one method. If there is no superior option, examine if there are any other candidate options. If no candidates are found, reconsider the evaluation attributes.

## 2.3 Calculation of Product Evaluation Values

In the proposed system, the user selects one product out of the five presented. Let  $x_{ij}$  be the normalized value of attribute i for the product selected by the user in the i-th generation. If the number of generations in which the user selects a product is m and the number of product attributes is n the choice matrix x as shown in Equation (1) is obtained.

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \#(1)$$

From this choice matrix, the importance weights are calculated. The arithmetic mean is used to calculate the importance weights. For each column j of the choice matrix  $X = [x_{ij}]$ , the

mean value of column j is denoted as  $k_{j'}$  and the arithmetic mean is obtained using Equation (2).

$$k_{j} = \frac{1}{m} \sum_{i=1}^{m} x_{ij} \#(2)$$

The arithmetic mean values obtained for each attribute are then normalized so that their sum is 1, and the importance weights for each attribute are calculated using Equation (3).

$$\{\omega_1, \omega_2, \cdots, \omega_n\} = \left\{ \frac{k_1}{\sum_{i=1}^n k_i}, \frac{k_2}{\sum_{i=1}^n k_i}, \cdots, \frac{k_n}{\sum_{i=1}^n k_i} \right\} \#(3)$$

Next, let q be the total number of products and  $\omega_j$  the importance weight of attribute j. The evaluation values  $W_1, W_2, \dots, W_n$  of the products are defined as shown in Equation (4).

$$\{W_1, W_2, \cdots, W_n\} = \left\{\sum_{i=1}^n \omega_i x_{1i}, \sum_{i=1}^n \omega_i x_{2i}, \cdots, \sum_{i=1}^n \omega_i x_{qi}\right\} \# (4)$$

The evaluation value of a product is the sum of the products of the normalized values of the product attributes and the importance weights for each attribute. Products with higher evaluation values are recommended to the user in the next generation.

## 2.4 Generation of Text for Dominance Structuring Process

Text generated for Dominance Structuring Process is presented to the user only during the final decision-making stage. To ensure that the product with the highest evaluation is prioritized during this stage, text for Dominance Structuring is generated. In this study, two types of Dominance Structuring Process, "Emphasizing" and "Blurring," are employed. Emphasizing involves presenting text that enhances the importance of attributes perceived as strengths, while Blurring entails presenting text that reduces the importance of attributes perceived as weaknesses, thereby prompting a reassessment of their significance.

The method for generating text involves extracting data from the database of Dominance structure based on the strengths and weaknesses of the products to be prioritized. Subsequently, the extracted data is incorporated into formatted text. The format of Sentences for Dominance Structuring Process (emphasized case) is "It is important that [attribute] is [evaluation] because [merit]", and the format of Sentences for Dominance Structuring Process (blurred case) is "You doesn't need to consider that [attribute] is [evaluation] because [merit]".

The database of Dominance Structuring Process contains information on attributes, evaluations for each attribute, and the advantages associated with each attribute's evaluation text. [attribute] refer to elements of products such as price or screen size. [evaluation] refer to

assessments of attributes, such as high or low. [merit] represent the content of the evaluation text used for Dominance Structure Processing.

A database of text is created using GPT 3.5, a large language model developed by OpenAI. For example, to create a text about the benefits of a large screen size for a product, the prompt used is "What are the advantages of a large TV screen?". From the generated text, a section highlighting the benefits is crafted.

Additionally, specific formats are utilized for the text generated for the two types of Dominance Structuring Process: Emphasizing and Blurring, as illustrated in Figures 3 and 4, respectively.

Finally, let explain the method for determining the strengths and weaknesses of the dominated products. At first, the average value  $x'_j$  of attribute j among the multiple products presented during the final selection stage is calculated. The difference between the calculated average value  $x'_j$  and the value  $x_j$  of attribute j for the product to be prioritized is then normalized using Equation (5).  $x_{jmax}$  represents the maximum value of attribute j, and  $x_{jmin}$  represents the minimum value. The normalized value  $d_j$  is used to determine the attribute with the highest importance as a strength and the attribute with the lowest importance as a weakness.

$$d_j = \frac{x_j - x_j}{x_{jmax} - x_{jmin}} \#(5)$$

## **3** EVALUATION EXPERIMENT

To verify the effectiveness of the proposed system, experiments involving human subjects were conducted. The study aimed to improve satisfaction with product selection by having participants use the proposed system. The product category selected for this study was "TVs that suit the user's preference." Participants were presented with sentences generated by the Dominance Structuring Process to promote decision-making and resolve uncertainties. This was assessed through a questionnaire and analysis of participants' product selection data.

The experiment involved 10 male and female university students. The flow of the system's input and output is illustrated in Figure 3. Users selected the most suitable product from several options presented. Then, importance was calculated from the product information chosen by the user. The evaluation value of each product was subsequently determined from the calculated importance, and products with higher evaluation values were displayed again. This process was repeated multiple times. Finally, multiple products and sentences generated by the Dominance Structuring Process were displayed for the user to make the final selection.

Sentences for the Dominance Structuring Process were generated using a database containing GPT-generated phrases associated with each attribute. Two types of sentences were

generated: those emphasizing strengths and those minimizing weaknesses. The databases for sentences used to emphasize strengths and minimize weaknesses are shown in Tables 1 and 2, respectively.

The questionnaire items related to the proposed system are shown in Table 3. In addition to the seven questions listed, a free-text survey was conducted. Responses were evaluated on a five-point scale ranging from "strongly agree" to "strongly disagree."



Figure 5. System operation flow

Table 1. Database of sentences for Dominance Structure Process (emphasized case)

Price	Increases the variety of available products			
Size	Provides a more immersive viewing experience			
HDMI Port	Can connect multiple devices like game consoles and Blu-ray players			
Number of USB Ports	Can connect multiple devices like external hard drives and USB memory sticks			
Release Year	Equipped with the latest technologies and features			

## **Table 2**. Database of sentences for Dominance Structure Process (blurred case)

Price	Likely to have high functionality			
Size	Suitable for small spaces regardless of room size			
HDMI Port	Reduces the need for unnecessary device connections, making operation simpler			

Number of USB Ports	Reduces power consumption, contributing to energy savings
Release Year	Only basic functions are included, making it easy to operate

#### Table 3. Questionnaire items

Q1	Were you satisfied with your final option?			
Q2	Were you unsure between multiple options after being presented with the text?			
Q3	Was the presented text persuasive?			
Q4	Did the presented text influence your option?			
Q5	Can you say the presented text was the deciding factor in your option?			
Q6	Did the presented text help resolve your indecision?			

#### 3.1 Experimental Results and Discussion

From the survey results, we evaluated whether the proposed system facilitated product selection for the users. Figure 6 shows the products chosen by the subjects from those presented. The survey results for the 10 male and female participants are displayed in Figures 4 to 6.

Firstly, concerning the selection outcomes and questions about the decision-making process for product selection (Q1), all participants selected products with high evaluation values, and the survey results indicated allowing them to make satisfactory selections (Figures 4, left chart).

Regarding the questions about the sentences used for the Dominance Structuring Process (Q2 to Q6), the results for Q3 and Q5 revealed that while the sentences were persuasive, they did not serve as the decisive factor in the selection process (Figure 5, left chart; Figure 6, left chart). Results for Q4 and Q6 indicated that users experienced some hesitation in product selection after viewing the presented sentences, but these sentences helped to alleviate that hesitation (Figure 5, right chart; Figure 6, right chart). These observations suggest that while users referenced the presented sentences, they did not completely resolve their hesitation.

Lastly, the free-text responses in the survey provided additional insights. Comments such as "Even if it's said that the release year is not an issue, I still prefer newer ones" and "I tend to focus on the latest models," indicate that the blurring effect of the Dominance Structuring Process used in this experiment had no significant impact. Additionally, several responses mentioned that the participants had not considered purchasing a TV much before, making the selection process difficult. This suggests that the products used in the experiment should be more familiar to the participants. Furthermore, responses like "Since products that suited me were presented early on, the sentences presented at the end were slightly off in terms of appeal points," highlight that the system did not accurately capture user preferences, leading to some dissatisfaction with the presented sentences and products.



**Figure 4**. Survey results for Q1 "Were you satisfied with your final selection decision?" (left), Q2 "Did you hesitate between multiple choices after the sentence presentation?" (right)



Figure 5. Survey results for Q3 "Were the presented sentences persuasive?" (left), Q4 "Did the presented sentences influence your decision?" (right)



Figure 6. Survey results for Q5 "Did the presented sentences decisively influence your choice?" (left), Q6 "Did the presented sentences help alleviate your indecision?" (right)

#### 4 CONCLUSION

This study introduced a novel approach to product recommendation systems by leveraging Dominance Structuring Process and assessed its efficacy in enhancing product selection. The findings demonstrate that while the proposed system effectively promotes product selection through dominance structuring processing, users did not attribute significant importance to the sentences generated by this method. This suggests a gap in user engagement and highlights the need for more persuasive and tailored recommendations to improve user satisfaction and decision-making.

The current limitations underscore several avenues for future research. Firstly, there is a need to delve deeper into understanding and capturing users' latent preferences more accurately. Furthermore, the identification and presentation of product strengths and weaknesses require refinement. Future iterations of the system should focus on improving the accuracy and relevance of the information provided to users during the decision-making process. Addressing these aspects will not only enhance the system's ability to guide users towards more satisfactory choices but also foster greater trust and reliance on the recommendation system.

In conclusion, while the proposed product recommendation system demonstrates promising potential in promoting product selection through dominance structuring processing, ongoing development and refinement are necessary to meet the evolving expectations and preferences of users.

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## EXPLORING CUTE CHARACTER DESIGN IMPACT ON AVATAR IMPRESSION AND USAGE MOTIVATION

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## Abstract

Avatar character design is vital in virtual learning activities as it extends users' physical forms and facilitates student-teacher interactions within virtual environments. The prevalence of cute character design expressions in the market today urged us to investigate the impact of cute avatar design on the impressions and motivation of the viewer. We conducted an online survey of 85 participants using the Survey Monkey Audience function. Five avatar character designs were presented as samples, each displaying distinct visual stylizations. Statistical analysis unveiled significant differences in the impressions and motivation for usage among the character design samples. Designs featuring baby-like proportions were perceived as cute, attractive, and inviting, whereas realistic and iconic design styles were associated with intelligence and respectability. These findings offer valuable insights into the implications of incorporating cute design elements into avatars, which can become favorable design choice for physical and virtual educational materials.

Keywords: cute, character design, avatar, impression

## **1** INTRODUCTION

Creating an appealing and appropriate character design is essential for avatar applications in virtual learning activities. An avatar is an extension of the user's physical body and identity,

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created to facilitate interaction with a virtual world. Like our relationship with our own physical body, the appearance of an avatar affects our experience with it (Kim et al., 2023). In virtual learning, avatars are direct interfaces that influence immersion, enjoyment, and positive interactions between students and teachers during virtual classroom sessions.

Literature on human-computer interaction has extensively discussed the risk of realistic-looking computer characters inducing the uncanny valley—an unpleasant emotion produced by an abnormally realistic humanoid (Seyama & Nagayama, 2007). Several suggestions have been made to incorporate a more stylized cartoon approach to alleviate this effect (Tinwell et al., 2011). Meanwhile, in the industry, computer-generated characters have evolved to include an increasing number of cases featuring cuteness. These cute characters have dominated the digital realm through entertainment media such as games, animated movies, and social media emote stickers (Yalcinkaya, 2024). By incorporating stylizations such as stubby body proportions and rounded shape language, designers enhance the attractiveness of each character to entice users. As the cute trend continues dominating the World Wide Web, it will seep into future avatar expressions in virtual and metaverse spaces. Therefore, consideration of cute design's impact on virtual learning environments is necessary.

Cute is a familiar impression that connotates a sense of endearment, attractiveness, and innocence in objects. The term describes many objects, from animal infants, fashion, product packaging, and fictional characters to automotive designs (Kinsella, 1995; May 2019). Although academic consensus on the fundamental element of cute design remains undecided, research in animal behavior has proposed infant features as an innate catalyst of cute feelings (Glocker et al., 2009). These features include body proportions, face proportions, and rounded or softened bodily contours. Moreover, investigations into human aesthetic preferences have identified an inclination towards objects with rounded forms, which are perceived as safer (Bar & Neta, 2006), thus contributing to the discussion of cute design elements.

Psychological inquiries correlate cuteness to positive emotion that encourages friendly human interaction (Nittono, 2016). Employing cute avatars in the metaverse is intended to capitalize on this natural charm to facilitate user communication. Although cuteness may occasionally be misconstrued as childish and unserious, as avatars in virtual spaces, cuteness may have a distinct value in enhancing interpersonal interactions.

In this study, we aim to understand how cute design choices affect viewers' impressions of an avatar character and its usage motivation. To achieve this objective, we address several questions: Does a baby-feature design style convey a cute and positive character impression? What are the differences in impressions between baby-feature design styles and other styles? Through this inquiry, we aspire to explore the implications of integrating cute avatar design within the educational metaverse spaces. These results would provide designers, developers, and stakeholders valuable insights into navigating the ever-evolving landscape of virtual interaction and metaverse platforms.

## 2 METHOD

This study used a survey method to explore how character design style affects impressions of avatars in a learning context. After viewing character design samples, we asked participants to evaluate their thoughts, feelings, and motivations regarding the samples.

## 2.1 Pre-test student workshop

Before conducting the survey, we organized a workshop to identify visual factors contributing to character cuteness. We invited Art and Design students (n = 12) from the University of Tsukuba to participate in this workshop as part of a special lecture in their coursework. During the workshop, students were introduced briefly to cuteness research and asked to join group activities. Each group was instructed to draw a human (model photo), an object (camera), and a shape (star of life symbol) in a cute style from reference pictures. They were also asked to discuss elements they altered to produce the cute quality. Based on their reports in Table 2.1, the researchers identified four visualisation methods commonly associated with cuteness: *shape simplification, body proportion, rounded shapes,* and *fantasy features*.

Group	Human	Camera	Star of Life
1	Make bighead	Give humanness	Make more round
	Make round face		Movement
	Make short limb		Bright color
			Emotion
2	Make head bigger	Use sharp color	Make more round
	Make body smaller	Add fantasy element	Make irregular
	Make it round		
3	reduce element	Lighten color	Eliminate corners
	add cute shape	Add patterns	
	add familiarity		
	empahsize element		
4	Make like baby	Simplify mechanism	Make curved
	Make head small	Use bright/pastel color	Make small
	Make size small	Rounded corners	Eliminate corners
	Put on costume	Make soft	Change color
	Make fat		Arrange many
			Not perfect

 Table 2.1. Record of visualization methods for each object tasked.

## 2.2 Developing Character Design Sketch

We created character design samples based on four visualisation methods confirmed from the student workshop. We configured a 2x3 factorial design with body proportion as the first factor and visual style as the second. Body proportion consists of adult and baby proportions. In contrast, the visual style factor consists of three previously confirmed visualisation methods: simplification (iconic), fantasy feature (animal element), and rounded shape. Particularly for the rounded shape level, due to its unavoidable inclusion in the simplification process from realistic reference to the simple drawing, we instead applied sharp-angled as a contrasting quality.

We conduct a second pre-test (n = 15) to confirm the cute impression of the sample character designs. The result confirmed the cuteness level of the samples. We decided to reduce the character style sample included in the primary survey by removing baby fantasy and adult sharp style. The two removed styles have a proportionately similar cute rating as the most cute, baby-simple style and the least cute, adult-fantasy. Finally, we included a realistic character drawing, which serves as a control. Five character style samples remained, as shown in Figure 2.1.



Figure 2.1. Five stimuli samples: 1) Realistic style, 2) Iconic style, 3) Baby-feature style, 4) Fantasy style, and 5) Sharp-angled style.

## 2.3 Questionnaire Development

The questionnaire consists of 15 items categorized into three impression categories. Parameters in the *Perceived Impression* category include liking, pleasing, cuteness, intelligence, and respectability. The *Emotion Evaluation* category assessed how viewing the character designs made respondents happy, excited, friendly, anxious, and trusting. The *Usage Motivation* category included questions regarding the intended use of the character, such as if they want to be the character, interact with it, use it in casual conversations, use it in meetings, or have it as a teacher figure. Each question was answered using a 7-point Likert scale, with 1 indicating strong disagreement and 7 indicating strong agreement.

## 2.4 Procedure

We conducted a data collection procedure utilizing the *Survey Monkey Audience*, a respondent-targeting service provided by the online survey software *Survey Monkey*. The service enables our survey to reach a specific pool of respondents. The target respondent for this survey was Japanese nationals aged 18 and above. At the start of the survey, a screen directed participants to an explanation page where they must consent to continue. Subsequently, they were immediately directed to the first character evaluation task. To complete the survey, each participant must evaluate all five-character designs presented in random order. Each image was displayed full-screen, followed by 15 survey questions. After completing the evaluation tasks, participants were instructed to answer demographic questions and confirm their consent again.

## 3 RESULT

The online survey collected 85 responses, 43 from male participants and the remainder from female participants. A repeated-measures ANOVA was conducted to examine the impact of character design style on each of the 15 impression variables.

(n = 85)				¢				(A) )}		Repe	ated me	asure
Perception	Realist	ic (1)	Iconic	(2)	Baby-feat	- ure (3)	Fantas	- 7 (4)	Shrap-angled (5)	F	P	η2
Like	3.3	39	4.0	0	4.29	)	2.99	Ð	3.74	13.52	<.05	0.08
Pleasing	3.5	56	4.0	8	4.31	L	3.28	3	3.52	9.16	<.05	0.06
Cute	3.0	)6	3.9	3	4.73	3	3.40	)	4.05	19.71	<.05	0.11
Intelligent	3.8	39	3.9	5	3.24	1	2.56	5	3.02	17.74	<.05	0.11
Respectable	3.6	50	3.6	8	3.42	2	2.63	l	2.94	14.12	<.05	0.08
Emotion												
Friendly	4.0	)1	4.5	8	4.74	1	3.67	7	4.20	9.34	<.05	0.05
Trustworthy	4.0	)4	4.2	5	4.07	7	3.02	2	3.51	13.38	<.05	0.08
Anxious	3.1	.6	2.7	9	2.87	7	3.56	5	3.31	5.31	<.05	0.03
Нарру	3.4	17	4.0	2	4.38	3	3.38	3	3.72	8.67	<.05	0.05
Excitement	3.2	26	3.5	6	4.12	2	3.49	)	3.64	5.12	<.05	0.03
Use Motivation										-		
WannaBe	3.0	)7	3.45		3.65		2.74		3.24	6.36	<.05	0.04
WannaInteract	3.2	26	3.7	1	3.92		3.09		3.53	6.70	<.05	0.03
WannaUseTalk	3.1	.5	3.68		3.94		2.95	5	3.41	9.62	<.05	0.05
WannaUseMeet	3.45		3.73		3.62		3.07		3.33	3.79	<.05	0.02
WannaTeacher	3.46		3.65		3.61		2.75		3.07	8.25	<.05	0.05
	Color leg	end								_		
	1.0	2.0	3.0	3.5	4.0	5.0	6.0	7.0				



In the perception category, the cuteness and intelligence parameters displayed the most notable differences. Regarding cuteness, all design styles exhibited variations in mean evaluation except for the comparison between realistic and fantasy styles, both of which scored low in cuteness. The design styles were ranked in succession, with the baby-feature style perceived as the cutest and the realistic style perceived as the least cute. The sharp-angled style was positioned as the second cutest, followed shortly by the iconic style.



Figure 3.2 Perceived impression pattern for each character design style.

Statistical analyses of character styles revealed significant differences among several pairs in measuring perceived intelligence. Particularly noteworthy were the disparities between iconic, baby, and fantasy styles. Comparative analysis among these styles indicated that the fantasy style was perceived as the least intelligent, while the iconic style was perceived as the most intelligent. Realistic and iconic styles were considered the most intelligent among the five styles.



Figure 3.3 Emotion evaluation pattern for each character design style.

In the emotion category, statistical analysis revealed that happiness, friendliness, and trust exhibited the most significant differences in impression among character styles. Regarding happiness, both baby and iconic styles received the highest scores among the five, followed by the remaining styles. Consequently, the scoring pattern across the five styles followed a similar trend in the variable of friendliness. Realistic, iconic, and baby-feature styles were rated higher than sharp-angled and fantasy styles in evaluating trustworthiness.

The analysis indicated fewer statistical differences in variables of the motivation category compared to the other two categories. The most notable differences in evaluation were observed in the variables of *motivation to interact*, use in conversation, and *use as a teacher figure*. The results indicated that iconic and baby-feature styles elicited higher motivation for interaction than realistic, fantasy, and sharp-angled styles. A similar pattern was observed in the evaluation of *motivation to use in conversation*, with more evident statistical differences between the iconic and baby-feature styles compared to the other styles. Analysis of the variable *motivation to use as a teacher figure* demonstrated a division in preference, with the realistic, iconic, and baby-feature styles receiving higher scores than fantasy and sharp-angled styles. Additionally, while variations between the styles are observed, the score evaluation was



within the midpoint threshold, which suggests a low usage motivation for all the styles.

Figure 3.4 Usage motivation pattern for each character design style.

#### 4 DISCUSSION

In this study, we conducted a survey to explore user impressions of character design styles. Our interest lies in observing potential contrasts in how these styles are perceived, their emotional effects, and whether they vary in usage motivation within an educational context.

The baby-feature style is perceived as pleasant and cute, eliciting friendliness, happiness, and excitement. In other words, this style promotes positive and welcoming feelings among viewers. Mean scores for this style consistently place it in the top half of measurements for positive impressions. This observed result aligns with the expected emotional effects of cuteness. Studies on cuteness have repeatedly shown evidence that cuteness possesses an attractive, positive, and welcoming effect (Nittono, 2016). This effect is known to result from the human natural response to baby features or *kinder schema*, which was first suggested in animal behavior science and psychology (Glocker et al., 2009). By incorporating baby features,

particularly manipulation of body and face proportions, into our character design, we simulate the cute style and successfully evoke the characteristic feelings associated with cuteness.

Realistic and iconic character designs are perceived as intelligent and respectable. However, we observe a different pattern in how they trigger positive emotions. The iconic style tends to score higher in positive emotions such as happiness and friendliness while causing less anxiety than the realistic style, suggesting that the iconic style is more positive and welcoming. This observation aligns with a study that found iconic instructor visualization is preferred by users who appreciate instructors who focus on developing a social relationship with students while working on class tasks (Gulz & Haake, 2005).

Additionally, when comparing realistic and iconic styles with baby-feature style in terms of positive impression, their mean scores form a pattern where the babyish style scores the highest, followed by the iconic character. In contrast, the realistic character is placed last. While the welcoming quality of the baby-feature style has been extensively explored, as previously discussed, the reason iconic style produces a friendlier impression than realistic style still needs clarification. One potential explanation comes from the field of comic studies. They theorize that character formed by abstraction through simplification is intended to create more emotionally engaging storytelling. The simplification strips away individual character details, thus improving the reader's emotional connection to the material (McCloud, 1994).

We expected the sharp-angled style to show a lower preference pattern than the baby-feature style. The result showed the expected outcome. The score for the sharp-angled style is consistently lower than the baby-feature style across all measures, suggesting that adding sharp edges decreases the positive evaluation. Sharp angles reduce the feeling of safety, which is required when feeling cute emotions (Bar& Neta, 2006) (Nittono, 2016). This hints at the possible operation of the cute factor, where each cute element adds to the overall positive impression.

The combination of baby-feature and sharp corners placed the sharp-angled style between the baby-feature style and the iconic style, suggesting that baby proportion is one of the most effective factors in predicting cuteness impressions. Even when line quality shows unsafe angular shapes, the complete form of the baby-proportioned character holds more importance in creating impressions. This finding aligns with the knowledge that cuteness results from baby features (Glocker et al., 2009).

The fantasy style exhibits the most distinct impression pattern among character styles, consistently scoring the lowest across most parameters except for anxiety. This suggests a general aversion to the fantasy style in educational settings. A typically formal setting that often demands a more conventional and professional appearance, contrary to the impression of the fantasy style. The high anxiety score of the fantasy style and its low perceived intelligence and respect further support this observation. Nevertheless, as demonstrated in the game industry, the fantasy character incorporating animal characteristics remains a valuable form of avatar (Vincent, 2016). It has become integral to contemporary game media, contributing to their imaginative and escapism quality.

We found that all character design styles received unexpectedly low evaluations in usage motivation category, indicating a limitation in generating strong motivation. Nittono's framework suggests that perceived cuteness can influence behavior only at the final stage of the cognitive process (Nittono, 2016). This indicates that behavior, such as that in the usage motivation category, is susceptible to external factors. Our survey used illustrated characters and an imagined education scenario, which may only partially reflect actual avatar interactions. This absence of real-time engagement with the avatar stimulus could be the reason for its diminishing impact. However, existing literature still supports the hypothesis that visual style can influence motivation, as seen with cute images increasing the likelihood of people answering self-administered surveys (Bellfield, 2011) and cute service avatars fostering more positive attitudes toward customer service representatives (Lv et al., 2021). Therefore, further research into the impact of cute avatar style on usage motivation in real-life avatar-assisted communication is still worth exploring.

This study's limitation is that we use hand-drawn character design sketches to test impressions. While the distinct general impressions of the five character design styles are observable, further exploration into computer-generated character designs is required. Understanding the impact of these design styles on CG characters could enhance user experience in virtual environments, such as online gaming, virtual reality, and educational platforms. Future research should also consider the adaptability of CG avatar styles to different contexts and user preferences, ensuring they can effectively meet the diverse needs of virtual activities.

## 5 CONCLUSION

This study focused on character design styles by incorporating four methods of visualizing cute designs: *simplification, baby features, fantasy,* and *rounded shapes.* The objective was to validate the positive impressions associated with cute character styles and discern their impression patterns with other styles within the context of educational avatars. The results indicate that integrating baby features successfully elicits the cutest impression among the characters. Its associated impression pattern embodies qualities perceived as welcoming and attractive for users in a learning environment. The baby-feature style pattern of evaluation differs from other styles, such as realistic and iconic, as it was not considered intelligent or respectable. These findings are invaluable for guiding design choices for both physical and virtual educational materials. The researcher intends to develop computer-generated avatar designs based on these findings and conduct further experiments to investigate avatar-style usage experiences in the live virtual learning environment.

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# EVALUATING THE IMPRESSION OF OPTICAL FLOW GENERATED IN THIRD-PERSON VIDEO GAMES: CONSISTENCY BETWEEN SUBJECTIVE EVALUATIONS OF RANDOM-DOTTED VIDEO AND ORIGINAL VIDEO

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## ABSTRACT

In video games, impressions obtained through avatar and camera movements, such as an impression of dynamic, are affective value that increases the game appeal. However, it is not clear whether the movements that impress dynamic in flight simulation games are evaluated similarly to those in driving simulation and action-adventure games. In this study, we reproduced the optical flow that occurs in third-person video games using random dot kinematogram. And, we conducted an experiment to generalize and evaluate the impressions of optical flow by verifying, whether there is a correlation between the subjective evaluation scores that were obtaind under the two conditions: (a) the original videos and (b) the random dot kinematograms. As a result of this experiment, it was showed extremely strong and positive correlations (r > 0.98) between the impressions of "dynamic," "easy viewable," and "motion-sickness" in both conditions. Therefore, it is possible to assume that the impression ratings expressed by the avatar and camera movements remain consistent across different game contents and genres.

*Keywords:* video game, third-person perspective, camera control, random dot kinematogram, Kansei/affective evaluation

## **1** INTRODUCTION

In developing third-person video games based on three-dimensional computer graphics (3DCG), the impression of dynamic expressed by the movement of the player-controlled character or vehicle, called the avatar, and the movement of the camera that serves as the user's viewpoint can be an affective value that enhances the game's appeal. Therefore, control algorithms for these movements have become an important design element in game development (Haigh-Hutchinson, 2009). For example, in a previous study (Inoue et al., 2020), the authors of this paper confirmed that when the avatar is blown away in an action-adventure

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game, swiveling the camera rather than simply moving it in parallel improves the impression of dynamic and may also reduce the impression of motion-sickness. However, it has not been fully clarified whether the camera control that is useful in action-adventure games with avatars running around on the ground is also useful in other game genres such as flight simulation.

Considering such content dependence, one way to subjectively evaluate the impression of the motion generated on the screen, or the optical flow, is to use random dot kinematograms. For example, the related studies (Ujike et al., 2004; Inoue et al., 2012; Hashimoto et al., 2011) confirmed that when original videos (OR condition) and random dot kinematograms reproducing the same motion (RD condition) were evaluated subjectively, a moderate or high correlation was observed between these results. However, as these studies evaluated first-person videos, it is still unclear whether similar correlations can be observed in evaluations of third-person game videos.

This study aimed to clarify whether the method of subjectively evaluating videos viewed under OR and RD conditions and comparing the results is also useful for generalizing and evaluating the impression of optical flow generated by a third-person 3DCG video game. We report the results of an experiment in which the videos of a flight simulation game with a camera following a drone-like avatar were evaluated subjectively.

## 2 SUBJECTIVE EVALUATION OF FLIGHT SIMULATION VIDEOS

#### 2.1 Video Stimuli

Figure 1 shows the scene of each video in the OR and RD conditions evaluated in this experiment, and Table 1 shows the motion patterns of the avatar and camera setup. The stimuli, 7-second videos, were generated using Unity (Ver. 2021.3.15f1).

Under OR conditions, as shown in Figure 1a, the background was a 3DCG space representing a forest. Also, an avatar was a drone model (VoodooPlay, 2017) and move forward at 12 m/s along a path in the forest. The avatar was positioned at a height of 1.5 m above the ground, and the camera's gazing point was 0.3 m above the avatar, with the camera's visual axis vector always directed toward this gazing point. The distance between the avatar and the camera was set to 3.0 m. When the camera was moving, the radius of motion was set between these two points. Thus, the camera position was controlled so that it was always on the spherical coordinates centered on the avatar. The initial coordinates of the camera were set higher than the avatar, and the camera was positioned so as to have a bird's-eye view of the avatar at the beginning of the video. The initial tilt angle was 18 degrees. As shown in Table 1, the motion patterns of the avatar and the camera were set to a total of seven patterns, combining the motion of the avatar moving straight ahead while oscillating and during the turning motion of the camera. When the avatar was oscillating, the range of motion amplitude was set to  $\pm 1.0$  m. When the camera swung, the range of motion was set to  $\pm 20$  degrees. The frequency of the avatar and camera oscillation was set to 3 oscillations per 7 seconds approximately 0.43 Hz. These motion patterns were selected with reference to the conditions found to be conducive to motion-sickness in related studies (Ujike et al., 2004; Lo & So, 2001; Lawther & Griffin, 1987).

Figure 1b shows the same frame as Figure 1a converted to the RD condition. In this still image, the 3D information perceived under the OR condition is not apparent, but when these dots move as in the OR condition (i.e., the same optical flow is generated on the screen), 3D information such as the shape of the avatar and the path extending back is perceived from the dots' movements through motion parallax. In the RD condition, the density of dots was controlled so as to be uniform across the entire screen, and more than 10,000 dots were drawn in a single frame.





a. Original (OR Condition)

b. Random Dot Kinematogram (RD Condition)

Figure 1. Video Stimuli

No.	Avatar (Drone)	Camera (Viewpoint)			
1	Moving straight ahead	None			
2	Horizontal meandering	Yawing			
3	Vertical meandering	Pitching			
4	Moving straight ahead	Rolling			
5	Horizontal meandering	Yawing + Rolling			
6	Vertical meandering	Pitching + Rolling			
7	Horizontal meandering + Vertical meandering	Yawing + Pitching + Rolling			

#### Table 1. Avatars and Camera Motion Patterns

#### 2.2 Evaluation Procedure

A total of 17 participants, 10 males and 7 females in their 20s, were included in this experiment. The seven motion patterns in Table 1 were evaluated using Sheffe's analysis of variance (ANOVA) on paired comparison (Nakaya's variation). Thus, the participants watched two video stimuli with different motion patterns and then performed 21 trials to compare their impressions. These evaluation trials were conducted under the OR and RD conditions, respectively. To account for order effects and counterbalance, the participants were divided into two groups: one group evaluated 21 trials in the OR condition first, and the other group evaluated 21 trials in the RD condition first. The order in which the motion patterns were presented was randomized for each participant in each condition. Figure 2 shows the procedure of this experiment.

The evaluation terms used for the paired comparison were "dynamic movements (HAKURYOKU-NO-ARU UGOKI)," "easy viewable movements (KANSHOU-SHIYASUI UGOKI)," and

"motion-sickness movements (YOISOU-NA UGOKI)." For examples, the participants were asked "Which the two movements did you think was the dynamic movement." The order in which the questions were presented was randomized, and the final question was, "Which of the two movements did you think was the better movement "overall (SOUGOUTEKI-NI YOI)?" The participants were asked to answer the above four questions and, for examples, the choices of the answers was in the followings: (1) The video I saw first had more "dynamic movement," (2) If I had to choose, the video I saw first had more "dynamic movement," (3) I can't choose one (about the same), (4) If I had to choose, the video I saw later had more "dynamic movement," and (5) The video I saw later had more "dynamic movement."

Video stimuli were displayed on an LCD monitor (CG2700-X, EIZO). The maximum luminance of the screen was calibrated at 200 cd/m², the frame rate was 60 fps, the resolution was 4K-UHD (16:9, 3840 x 2160 px), and the screen size was 0.518 x 0.292 m. The viewing distance was approximately 0.9 m, which is three times the height *H* of the screen. A D₆₅ light source (Z-209PRO-6500K, Yamada Shomei Lighting Co., Ltd.) was used for illumination. Figure 3 shows the environment of this experiment.



Figure 2. The experimental Procedure of the Paired Comparisons



Figure 3. The Experimental Environment

#### 3 RESULTS AND DISCUSSION

Figure 4 shows the subjective evaluation scores obtained by the paired comparison method. The error bars in the figures represent the yardstick  $Y_{0.05}$ . Figure 5 shows scatter plots of the scores obtained under the OR and RD conditions.



Figure 4. Scores obtained by the paired comparison method



Figure 5. Scatter plots of scores obtained in the OR and RD conditions

The leftmost panel of Figure 4a shows significant differences between  $OR_1$  and  $OR_{\{2, 3, 4, 5, 6, 7\}}$ ,  $OR_2$  and  $OR_{\{1, 3, 5, 6, 7\}}$ ,  $OR_3$  and  $OR_{\{1, 2, 4, 5, 6, 7\}}$ ,  $OR_4$  and  $OR_{\{1, 3, 5, 6, 7\}}$ ,  $OR_5$  and  $OR_{\{1, 2, 3, 4, 7\}}$ ,  $OR_6$  and  $OR_{\{1, 2, 3, 4\}}$ ,  $OR_7$  and  $OR_{\{1, 2, 3, 4, 5\}}$ , and the leftmost panel of Figure 4b shows significant differences between RD₁ and RD_{2, 3, 4, 5, 6, 7}, RD₂ and RD_{1, 5, 6, 7}, RD₃ and RD_{1, 5, 6, 7}, RD₄ and RD_{1, 5, 6, 7}, RD₅ and RD_{{1, 2, 3, 4}, RD₆ and RD_{{1, 2, 3, 4}, and RD₇ and RD_{1, 2, 3, 4, 5}. Therefore, the impression of "dynamic" that were impressed with the movements of the avatar and camera rated under the RD condition seem somewhat more ambiguous than those under the OR condition, but their ratings tend to be in general agreement. When the scatter plots of the scores are plotted, a very strong correlation is observed in Q1 ("dynamic") with r = 0.983 (t = 11.8, df = 5, p < 0.001),

as shown in the leftmost panel of Figure 5. These trends were also observed in Q2 ("easy viewable"), and Q3 ("motion-sickness") with correlation coefficients of r = 0.987 (t = 14.7, df = 5, p < 0.001), and r = 0.990 (t = 15.5, df = 5, p < 0.001), respectively.

However, for Q4 ("overall"), there was no significant correlation between the OR and RD conditions, as shown in the rightmost panel of Figure 5 (r = 0.676, t = 2.05, df = 5, p > 0.05). This may be because about half of the participants in this experiment preferred dynamic movements with a certain degree of allowance for motion-sickness, while the other half preferred movements that were easier to watch, and no significant differences were shown in the overall impressions under both OR and RD conditions, as shown in the rightmost two panels of Figures 4. In other words, if there is no difference in the overall impression under the RD condition.

#### 4 CONCLUSION

This study evaluated the dynamic features of optical flow generated by a third-person flight simulation game under the OR and RD conditions and verify whether these results were correlated. The results showed a strong positive correlation between impressions of "dynamic," "easy viewable," and "motion-sickness" (r > 0.98) between the two conditions. Thus, the impressions expressed by the dynamic control of the avatar and camera is a reproducible affective value that does not depend on differences in content, such as the appearance of the avatar or background objects. In other words, the seven motion patterns evaluated in this experiment may retain their motion ratings when applied to driving simulation and adventure action games.

Future research includes examining whether similar correlations can be observed under wide-field-of-view conditions and in virtual reality (VR) games using head-mounted displays (HMDs).

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# Assessing Personality Traits and Career Inclinations in MBTI Game Development Design

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## ABSTRACT

In modern education and career planning, many students face confusion when choosing their future career paths, sometimes even selecting the wrong field due to a lack of understanding of their personality traits. This study proposes an innovative solution to address this dilemma by developing and designing an MBTI game to assess personality traits and career inclinations. MBTI (Myers-Briggs Type Indicator) is a well-known psychological test aimed at analyzing an individual's psychological type. This study integrates the principles of MBTI into game design to create an interactive gaming environment where users naturally discover their personality traits during gameplay. Decisions and choices made in the game will reflect users' behavioral tendencies and thought patterns, thereby aiding in analyzing their most suitable career types. The design of the MBTI game not only provides personalized career guidance but also adds enjoyment to students' exploration of themselves and understanding of future career directions. Through this approach, students can make future career choices with more confidence and wisdom, identifying their career paths earlier. In conclusion, this innovative gaming application not only expands the practicality of MBTI game development and design but also pioneers new realms in education and career planning, providing students with a fun and effective tool for self-exploration and career planning.

## Keywords: MBTI games, career planning, digital game learning

## 1. RESEARCH BACKGROUND AND MOTIVATION

In today's life, whether in the academic stage or as working professionals, it's common to hear people regretting their initial choices of "choosing the wrong major, entering the wrong field," realizing too late that they are already behind from the starting line. To "find direction," the first step is to understand oneself and engage in profound "self-exploration" (Yusof et al., 2020; Istiyono et al., 2021). Numerous personality tests and career aptitude tests have emerged online to assist with this endeavor. Among the most representative and recently popular

worldwide is the Myers-Briggs Type Indicator (MBTI), which has developed into one of the globally renowned personality assessment tools (Briggs, 1976). In recent years, it has been extensively applied in schools and workplaces, aiding individuals in uncovering their personality potential and improving interpersonal relationships (King & Mason, 2020). By integrating the principles of MBTI into game design, a gaming environment that allows for scenario and dialogue interactions is created, enabling users to progressively analyze their personality traits while playing the game. This game design not only allows users to experience a sense of achievement in the game (Chu & Hung, 2015) but also facilitates the exploration of their behavioral tendencies and thought patterns through gameplay, which can then be applied in analytical contexts such as academic advancement and job seeking, assisting individuals in making directed choices for their future development. Therefore, the purpose of this study is to develop and design a game system that integrates MBTI principles, providing a comprehensive testing experience and analyzing test results to offer suitable career advice to test takers.

## 2. LITERATURE REVIEW

## 2.1 Personality theory

The emergence of personality theories aims to describe the traits of individuals in individualistic societies, traits that may not be considered crucial in collective societies (Cervone & Pervin, 2022). Generally, Western personality theories assume the existence of an underlying personality structure composed of structures and processes that explain and predict behavior. The main differences between these theories lie in the qualities of these structures and the processes occurring within them (Cervone & Pervin, 2022; Schultz et al., 2009). All Western personality theories posit that these internal constructs initially develop from past experiences of individuals with their social environment but later become internalized as factors guiding behavior, almost independent of the environment. Thus, consistent behavior across different situations and timeframes is determined by internal factors rather than current external factors. According to these theories, social factors influence consistent behavior only through representations of internal structures formed during development. Psychoanalytic theory assumes the existence of structures such as the id, ego, and superego (Compton, 1981), with conflicts between these structures being primary processes. Defense mechanisms regulate the psychological content between consciousness, subconsciousness, and unconsciousness. According to the mainstream perspective of psychodynamic theory, unconscious processes not only explain human behavior but also impel it, exerting a decisive influence on it. For object relations theory, processes such as individuation and splitting are major processes that can occur, affecting the formation of personality or self (Ertemel & Çaylak, 2021).

## 2.2 Myers-Briggs personality Type Indicator (MBTI)

The usage of the Myers-Briggs Type Indicator (MBTI) as a personality assessment is explored. Based on Carl Jung's theory, the test utilizes four letters (such as ENTJ, ISFP, etc) to describe specific types of individuals (King & Mason, 2020). The article discusses three distinct aspects of MBTI, including its foundation on Jung's intricate theory, its design measuring types rather than continuous scales, and its widespread use in explaining individual traits. However, limitations of MBTI are also noted, such as the recontextualization of original concepts, the lack of bimodal distributions for preferences, and the frequent failure in research to confirm the economic viability of theories or measures. Additionally, various studies examining the relationship between MBTI and other personality factor models, such as the Big Five Factor Model, are mentioned. Scholars have pointed out correspondences between MBTI indices and the Big Five dimensions, where EI corresponds to Extraversion, SN to Openness, TF to Agreeableness, and JP to Conscientiousness. Relationships between MBTI and Big Five personality traits, especially cases related to EI (Extraversion) and TF (Thinking-Feeling), are highlighted (Furnham, 2022). Studies indicate positive correlations between EI and Extraversion, TF and Openness, and TF and Agreeableness. Furthermore, the article mentions the correlation between MBTI and dark side traits. Nevertheless, it emphasizes supporters of MBTI insisting on its non-clinical nature, stating that MBTI scores are not intended to measure pathology (Dwairy, 2022). However, research and discussion still persist regarding whether specific psychological pathologies exist among different MBTI types.

## 2.3 Digital game learning

Digital game-based learning is a method of education and learning conducted through gaming. It combines educational objectives and game design to make the learning process more engaging and enjoyable (Prensky, 2003). Through games, students can explore various topics interactively and learn through trial and error. Digital game-based learning can be applied in many different fields, including mathematics, science, language learning, etc., and can be customized according to students' age and proficiency levels (Hung et al., 2018). Through the competitiveness, immediate feedback, and challenge of gaming, digital game-based learning outcomes. According to scholars, digital game-based learning is defined as a process that tightly integrates educational content with computer games, which can also refer to educational game that integrates instructional content and gaming features, allowing players to continuously assess, execute, and receive system feedback during challenges to achieve specific learning goals (Ke, 2016). In summary, digital game-based learning achieves learning outcomes through digital game-based learning elements.

## 2.4 Flow experience

Flow experience is a psychological concept proposed by Csikszentmihalyi (1975). This state describes individuals being fully immersed and focused, enhancing efficiency and creativity while forgetting external distractions. Research suggests that regularly and consistently entering a flow state can enhance overall happiness and quality of life (Csikszentmihalyi, 2000). Today, flow has become an important research direction in positive psychology. Studies indicate that certain conditions facilitate easier entry into a flow state, including having a strong interest in the activity, possessing relevant skills to control the activity, engaging in activities with a moderate level of challenge (approximately exceeding current ability by 10%), providing regular feedback and rewards (Kiili, 2005; Kiili, 2006; Chien et al., 2024), and having clear goals with known steps to achieve them. When these conditions are met, it becomes easier for individuals to enter a flow state during their activities. In this study, we integrate Kiili's (2005) flow experience model as a framework to support our research, aiming to help students achieve better flow experiences and learning outcomes.

## 3. SYSTEM ARCHITECTURE

RPG Maker is a role-playing game creation tool developed by Enterbrain, a Japanese company, in 1992, which enables the integration of curriculum knowledge into RPG game creation. This study developed a game system that integrates MBTI (Myers-Briggs Type Indicator) personality traits and dual-level testing, aiming to assist students in analyzing future career orientations based on their personality traits and providing learning content for career planning courses, enabling students to understand their personality traits and plan their future career directions in advance. This curriculum design is a collaborative effort between the research team and course instructors, with instructors ensuring a high level of consistency between game content and school curriculum for optimal learning outcomes.

As shown in Figure 1, our system consists of the MBTI personality trait analysis and career orientation module, which will play a crucial role in students' learning and career planning. Firstly, the MBTI personality trait analysis is one of the core components of this system. MBTI is a widely validated assessment tool that identifies individuals' preferences on four dimensions: Extraversion vs. Introversion, Sensing vs. Intuition, Thinking vs. Feeling, and Judging vs. Perceiving, which generate 16 different personality types, each reflecting unique characteristics in information processing, decision-making, and interaction. Through this analysis, students can gain a deeper understanding of their personality traits, which has profound implications for their personal growth and future career planning.

Secondly, the career orientation module provides personalized career recommendations based on students' MBTI analysis results. This module combines a rich career database, recommending suitable career directions based on students' personality traits and aptitudes. For example, for students who excel in problem-solving and prefer independent work, we may suggest considering careers in research or technology-related fields; while for those who excel in communication and enjoy collaboration, careers in education, social work, or management-related fields may be recommended. Such personalized recommendations help students make wiser decisions in career choices and prepare for their future careers.

The game design module plays a critical role in this system. It is responsible for storing and managing learning materials, including text, images, and personality trait analysis results. This module also records completed tasks, unfinished tasks, collected resources, and test results of students. These data help us track students' learning progress and provide necessary support and guidance. Students can gradually understand their personality traits through various levels of gameplay. Each level is carefully designed to provide relevant knowledge and advice to test students' personality traits. For example, in one level, students may need to complete a series of tasks to test their coping strategies under pressure; in another level, they may need to solve complex problems to assess their analytical and decision-making abilities. In this way, students can gain a deeper understanding of their strengths and areas for improvement. Additionally, these levels are designed in the form of game challenges, making the learning process more engaging and challenging. After completing each level, students receive immediate feedback on their performance and progress. This immediate feedback not only stimulates students' interest in learning but also helps them continuously improve in their learning.

In conclusion, this system provides students with a comprehensive learning and career planning tool by integrating MBTI personality trait analysis and career orientation modules. It not only helps students understand their personality traits but also provides personalized career recommendations, enabling them to better plan their future careers.



Figure 1. Game flow chart

## 4. CHARACTER DESIGN

The MBTI (Myers-Briggs Type Indicator) is a tool used to assess personality traits, categorizing individuals into 16 different personality types based on four dimensions. This study has preliminarily designed character personas representing different styles based on these personality traits. The design of these characters considers the four key dimensions of the MBTI: Extraversion vs. Introversion, Sensing vs. Intuition, Thinking vs. Feeling, and Judging vs. Perceiving. In this manner, each character can embody a specific personality type, facilitating a deeper understanding of various personality traits and providing visual references for subsequent applications and research. These character designs can be utilized in various fields such as education, psychological counseling, and personal development to help individuals better understand themselves and others. As shown in the figure below, this study presents the initial demonstration of these characters designed based on MBTI personality traits.



Figure 3. Character design diagram of ENFJ (extroversion, intuition, emotion, judgment) personality traits

## 5. SCENE DESIGN

The game design for the MBTI personality trait analysis and career orientation module in this study is divided into 5 levels, each featuring different scenarios. Initially, the game lobby is designed as the interior of a castle. Students must interact with NPCs to complete various stage-based character tasks. After completing the tasks in each stage, students progress to the second level, which is set in a classroom scene. Students must then complete the tasks in this level, and so on.



Figure 4. The first level is the scene design of the game lobby



Figure 5. The second level is the scene design of the classroom

## 6. CONCLUSIONS AND RECOMMENDATUONS

This study combines MBTI personality trait analysis with a dual-level test to develop a game system for career planning. The system aims to help students understand their personality traits and plan their future career paths early. Through this system, students can gradually explore their personality traits during gameplay and receive personalized career advice. The following are the main conclusions and expected outcomes of this study:

Firstly, the MBTI (Myers-Briggs Type Indicator) personality trait analysis is a widely validated assessment tool that identifies an individual's preferences across four dimensions: Extroversion vs. Introversion, Sensing vs. Intuition, Thinking vs. Feeling, and Judging vs. Perceiving. These preference combinations generate 16 different personality types, each reflecting unique

characteristics in information processing, decision-making, and interactions. Through this analysis, students can gain deeper insights into their personality traits, which has profound implications for their personal growth and future career planning.

Secondly, the career orientation module provides personalized career advice based on the students' MBTI analysis results. This module integrates a comprehensive career database to recommend suitable career paths according to the student's personality traits and abilities. For example, students who excel in analysis and problem-solving and prefer independent work might be advised to consider careers in research or technology. Conversely, students who are good at communication and enjoy collaboration might be advised to pursue careers in education, social work, or management. This personalized advice helps students make more informed career choices and prepares them for their future professional lives.

The game design module plays a crucial role in this system. It is responsible for storing and managing learning materials, including texts, images, and personality trait analysis results. This module also records the tasks students have completed, the tasks pending, resources collected, and test results. These data help us track students' learning progress and provide necessary support and guidance. Students can gradually understand their personality traits through various levels, each carefully designed to provide relevant knowledge and suggestions to test their traits. For instance, on one level, students might need to complete a series of tasks to test their coping mechanisms under stress; on another, they might need to solve complex problems to assess their analytical and decision-making abilities. In this way, students can gain deeper insights into their strengths and areas for improvement. Additionally, these levels are designed as game challenges, making the learning process more engaging and challenging. After completing each level, students receive immediate feedback to understand their performance and progress. This real-time feedback not only stimulates their interest in learning but also helps them continuously improve.

In summary, the system developed in this study combines MBTI personality trait analysis with a career orientation module to provide students with a comprehensive learning and career planning tool. It not only helps students understand their personality traits but also offers personalized career advice, enabling them to better plan their future careers. This innovative game system expands the application scope of MBTI analysis and pioneers new methods in education and career planning, offering students an engaging and effective tool for self-exploration and career planning.

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## HOW DOES PERSONALITY INFLUENCE YOUR CONSUMPTION HABITS? APPLYING WEARABLE EYE-TRACKING TO EXPLORE THE

CONSUMER'S VISUAL PERCEPTION BETWEEN PRODUCT PERSONALITY AND CONSUMER PERSONALITY TRAITS

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## ABSTRACT

This paper explores how different personality types perceive product personality in the way of hedonic and utilitarian consumption. The study shows that psychometric marketing has become a popular topic among Generation Z, highlighting the importance of brand and product personality in marketing strategies. Using the Myers-Briggs Type Indicator (MBTI) and head-mounted eye-tracking experiments, the research finds that personality influences consumer preferences for product appearance, marketing text, and purchase decisions. Results indicate that in hedonic contexts, Feeling and Perceiving (FP) type of personality focus on aesthetics and emotions, whereas Thinking and Judgment (TJ) type of personality prioritize functionality and structural design. In utilitarian contexts, TJ personalities tend to make quick decisions, while FP personalities are more influenced by the context, contemplating the rationality and functionality of the product. The fluency of marketing text impacts consumer attention, but the final decision is still determined by the product's inherent characteristics. These findings provide empirical support for industrial design, brand design, and marketing strategies, helping the public understand how different personalities influence consumer behavior towards products and brand personalities in the global market, and examining both current and potential customers.

*Keywords:* Personality Trait, Thinking and Feeling, Judging and Perceiving, Consumer Behavior, Eye-Tracking, Product Personality, Brand Personality

## 1. INTRODUCTION

Psychological tests are a marketing tool with endless imaginative potential. Starting around 2018, various psychological test marketing campaigns have swept across different social media

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platforms. The primary audience for this type of marketing is the younger Generation Z, which refers to individuals born in 1995 and later. This generation is also known as the mobile generation, increasingly conducting their social lives through smartphones, tablets, and other smart devices. This shift has also changed their perception of time and space in consumption habits. Young people in Generation Z often use the results of psychological tests as a basis for everyday conversations, making friends, and initiating topics (Mustafa Özkan & Betül Solmaz, 2017). Psychometric marketing is also known as User-Generated Content (UCG) marketing. In UCG marketing, internet users play a central role as both producers and consumers of content(Mendes-Filho & Tan, 2009). Integrating UCG marketing into test-based marketing involves centering advertisements around psychometric tests and using marketing tools to encourage users to spontaneously generate and share content, creating a viral effect. This marketing approach not only achieves brand promotion but also attracts potential customers through semi-customized product marketing. This underscores the significant role of personality in brand and product marketing. According to previous research, the features and functionalities of a new product are critical factors in consumers' willingness to adopt it, indicating that consumers prefer products that align with their personalities (Rogers, 1983). Consumers' perceptions of a brand and its personality influence their perception of the congruence between their identity and the company's identity. This behavioral pattern, known as Consumer-Company Identification (CCI), is characterized as proactive, selective, and voluntary by consumers, significantly impacting brand and product loyalty (Sen, 2003). In other words, consumption is not merely about the need for a product but also about expressing the consumer's identity through the purchase.

Considering the current lack of academic activity in the field of the relationship between personality and product personality, it is evidently necessary to conduct research on this issue. This study investigates consumers' judgments of brand personality and product appearance from the perspective of personality differences, validating the relationship between personality, product, and brand personality in consumer behavior. In summary, this paper aims to help the public better understand how different personalities influence consumer judgments of product and brand personality in the global market, examining current and potential customers, and providing guidance for product design and marketing management strategies.

Therefore, the main objectives of this study include:

1. Understanding how different personalities perceive product personality and influence consumer behavior.

2. Determining whether mismatched marketing text and product personality affect the purchasing decisions of consumers with different personalities.

3. Investigating whether different contexts, hedonic or utilitarian, influence consumer judgment.

These are the three main sections of this paper. First, we discuss the theoretical background and previous research in the field. Second, we present our findings on brand personality, product personality, and personality differences, discussing these results in the context of existing theories. Based on this foundation, we conducted experiments using wearable eye-tracking devices. Third, we present the experimental results to verify our hypotheses. Finally, we provide a general discussion of the research findings, addressing the study's limitations and suggesting directions for future research.

#### 2. LITERATURE REVIEW

#### 2.1 Brand and Product Personality

In fact, there are more paths to demonstrate the importance of personality, product personality, and brand marketing. Brand personality is a set of characteristics related to human traits that help design the "brand image," including logo colors, fonts, website design, business card design, etc. Aaker (1997) introduced a model categorizing brand personality into five anthropomorphic dimensions: Sincerity, Excitement, Competence, Sophistication, and Ruggedness. This anthropomorphism helps attract target consumers(Nagpal et al., 2023). Later, scholars developed the product personality scale, indicating that product appearance can also have personality traits. Mugge et al. (2009) used Aaker (1997) 42-item scale to assess the relationship between brand personality and product personality. Monga and Lau-Gesk (2007)used a 43-item scale to measure seven design aspects: simplicity, harmony, balance, unity, dynamism, timeliness/fashion, and novelty. They confirmed that overall product style measurements reflect different design levels and proposed a 22-item product personality scale based on cars, they are cheerful, open, relaxed, pretty, easy-going, cute, idiosyncratic, provocative, interesting, lively, dominant, obtrusive, childish, untidy, silly, boring, aloof, serious, honest and modest.

#### 2.2 MBTI Personality

Previous studies have confirmed that consumers with different personality types exhibit varying purchasing behaviors and visual tracking patterns, with personality differences also affecting their judgments of appearances. Personality analysis that explores consumer decision-making behavior often uses the MBTI (Myers-Briggs Type Indicator) based on Carl Jung's theory of psychological types. Jung's work, "Psychological Types," is the theoretical foundation of the MBTI. Isabel Briggs Myers and her mother, Katharine Cook Briggs, believed Jung's work was too complex for the general public, so they attempted to simplify his cognitive functions for easier understanding (Carlson, 1985). The MBTI is a forced-choice, self-report personality assessment tool that measures how individuals interact with the world: Extraversion (E) vs. Introversion (I); how they perceive and learn: Sensing (S) vs. Intuition (N); how they make decisions: Thinking (T) vs. Feeling (F); and their preferred lifestyle: Judging (J) vs. Perceiving (P). These are the four dimensions of the MBTI. According to dynamic psychology, MBTI personality assessment is dynamic; psychological types are not black-and-white but rather tendencies—both are innate and can be balanced.

## 2.3 Personality and Consumer Purchase Decision Process

This study investigates consumer behavior in judging and lifestyle patterns during consumption. According to the consumer decision-making process, personality types and consumption purposes influence both the evaluation and purchase stages. During the

evaluation stage, individuals assess alternatives based on their fundamental goals, motivations, and personalities. There are many different products on the market, and consumers have certain beliefs about various brands or items. This is highly correlated with the MBTI dimensions of decision-making: Thinking (T) vs. Feeling (F), and preferred lifestyle: Judging (J) vs. Perceiving (P). Therefore, this study focuses on these two personality dimensions. Previous research indicates that consumers with a Thinking (T) personality tend to think about principles, purposes, and logic, and are more likely to be attracted to angular and straight appearances. In contrast, consumers with a Feeling (F) personality are more likely to have subjective awareness and emotions during consumption, and prefer irregular or rounded shapes (Wang, 2017). Consumers with a Judging (J) personality prefer a planned and purposeful lifestyle, while those with a Perceiving (P) personality are more flexible and mood-driven.

#### 2.4 Hedonic and Utilitarian Consumption and Personality

The lifestyle patterns of different personalities are strongly correlated with hedonic and utilitarian consumption habits. Past research shows clear distinctions between hedonic and utilitarian consumption habits, which serve as a reminder to merchants to sell their products in different ways. Hedonic consumers are more concerned with their thoughts, feelings, and the enjoyment of shopping, whereas utilitarian consumers prioritize shopping efficiency and may rely on trusted opinions to achieve their goals more quickly (Parker & Tritter, 2006). This corresponds to our understanding of personality dimensions, as illustrated in the following table:

Feeling (F) / Perceiving (P)	Hedonic	Thinking(T)/ Judgmental (J)	Utilitarian
Imagine	Fantasy	Rationality	Cognition
On the street	Not profit	Plan	Mission
Empathy	Experience	Purpose	Functionality
Emotion	Emotion	Logic	Rationality

 Table 1. The commonalities between hedonistic utilitarianism and personality traits

## 2.5 The Impact of Marketing Text

Previous research indicates that when consumers perceive high fluency in marketing text, they are more likely to have a high purchase intention. However, during the consumption process, there can be discrepancies between the perceived product personality by designers and users (Creusen & Schoormans, 2004). These mismatches can affect how primary users of different personality types evaluate a product or brand. Such evaluations are not always negative; mismatches between brand personality and product personality can create memorable marketing effects. Research has found that persuasion is more effective under negative framing than positive framing, which enhances purchase intentions when the persuasive effect is strengthened (Jaud & Melnyk, 2020). To ensure the alignment of expected product personality with brand personality, it is crucial for designers and marketers to pursue specific product personalities during the design process(Mugge et al., 2009).

#### 3. METHOD

#### 3.1 Participants

The study involved a total of 8 participants. Given the measurement method using Tobii Glasses 3 wearable eye-tracking devices, participants were selected according to Tobii's guidelines. The selection criteria included participants with myopia not exceeding 800 degrees, and those with myopia were required to wear contact lenses. Since the study is directly related to judgments about product appearance, non-art or design participants were excluded to avoid biases, as those with systematic education and training in art or design might have different aesthetic perceptions. Participants were pre-screened for their MBTI personality types, including 2 INFPs, 3 INTJs, and 3 ENFPs. All participants were between the ages of 14 and 34. In the first phase of the experiment, participants registered and completed an MBTI test, submitting screenshots as part of the selection process, with a lottery draw as an incentive. In the second phase, after completing the eye-tracking experiment, participants received gift vouchers.

#### 3.2 Stimuli

Regarding product personality, cars are most used as stimulus products (Malhotra, 1988). However, previous research has indicated that everyday products we use also have significant meaning(Kleine et al., 1993). For this experiment, considering hygiene and flexibility, pens were used as stimuli. Pens also fit into three categories of products that meet consumer needs: Utilitarian Goods, Symbolic Goods, and Hedonic Goods (Park et al., 1986). Firstly, the stimuli samples were randomly collected. In the second stage, three experts were invited to define and classify the product personalities of the stimuli through the focus group method. The focus group method, originating from therapy and marketing but used by social scientists for over half a century (Morgan, 1996), involves collective interviews in a relatively informal atmosphere to encourage discussion on specific topics, enabling potential issues to achieve consensus as a research method (Robson et al., 2001). This method is relatively objective and widely used in relevant fields for distinguishing experimental stimuli samples. In the process of defining product personalities, adjectives from the product personality scale were used as the basis for definition. Finally, a total of 24 stimuli products were selected, grouped into three sets based on material, color, and attribute averages, with one group consisting of eight pens. The stimuli are shown in Figure 1.



#### Figure 1. All Stimuli

#### 3.3 Experimental Design

Participants will be divided into two groups: the Hedonic Group and the Utilitarian Group. Hedonic Group Scenario: Participants will imagine themselves in a stationery store selecting a pen they would like to gift to themselves as a present. The stationery store is known for its consistent quality, and all pens write equally well, without differences in writing performance. Participants are not constrained by cost considerations. After browsing, they can touch the pens but are not allowed to try writing with them. They will then select a pen to take out of the store. Utilitarian Group Scenario: Participants will select a pen for daily use, considering it a necessary purchase. All other aspects of the scenario are the same as for the Hedonic Group. After entering their respective scenarios, participants will go through three rounds of testing. First Round: Eight pens are displayed. Second Round: In addition to the pens, there are personality description cards. Third Round: Personality description cards are presented again, but this time, descriptions of three stimuli samples do not match their actual definitions. After making their selections, participants will engage in structured interviews using retrospective thinking aloud and ORID questioning methods.

#### 3.4 Procedure

The study is structured into three phases. In the first phase, participants will complete the MBTI assessment to ensure their personality types align with the experimental requirements. The second phase involves a pen selection experiment conducted in three rounds, where eye-tracking will measure participants' gaze patterns. The first round presents eight pens. The second round includes pens and personality description cards. In the final round, personality description cards contain descriptions that do not match the actual definitions of three stimulus samples. In the final phase, a semi-structured interview, approximately ten minutes in duration, will be conducted. This interview will use a retrospective approach to confirm participants' thoughts during the experiment and their daily consumption habits.

#### 3.5 Measurements

In this study, measurements were conducted using the Tobii Pro Glasses 3. These glasses are similar in weight and form to traditional eyeglasses (77 grams) but are equipped with multiple sensors and cameras to perform eye-tracking while allowing free movement of the head. The HDMI cable transmits sensor output from the glasses to the host computer, utilizing video for eye-tracking during operations. The system processes corneal reflections generated by infrared illuminators placed on the glasses (8 per eye) to infer eye direction with an accuracy of 0.6 degrees. Tobii Pro Glasses 3 are equipped with rechargeable batteries, capable of recording for up to 105 minutes per battery. The glasses transmit multiple digital media packets wirelessly to applications via Real-Time Streaming Protocol (RTSP) (Nasrabadi & Alonso, 2022).

## 4. **RESULTS**

The participants in this study include 7 individuals, comprising 2 INFP, 3 INTJ, and 2 ENFP. They come from various professional backgrounds such as Chinese, psychology, economics,

business management, physical therapy, urban planning, and mechanical engineering. All participants are of Eastern origin and belong to the Generation Z demographic.

## 4.1 Hedonic and utilitarian influences on different consumer personalities

Based on the semi-structured interviews, it was found that all participants believed the product personalities they chose were similar to their own. For example, thermal imaging revealed that in the hedonic context of G2 and G3, individuals with TJ personalities preferred "calm" pens, which directly correlates with their personality type. During the selection process, participants also indicated making certain associations. In hedonic states, TJ types were more likely to link items to their own pens or lecture work fields, whereas FP types were more prone to associating based on preference, liking, or color. Thermal imaging revealed a common trait in all hedonic contexts: FP types emphasized the appearance, texture, and color of stimuli, while TJ types focused more on the mechanical design, such as springs, buttons, and pen caps. This supports the hypothesis that FP types tend to seek hedonic shopping experiences, while TJ types focus more on utility. In utilitarian contexts, FP personalities tended to observe the structural design and functional performance of samples, suggesting they are more susceptible to emotional empathy and environmental influence. In contrast, TJ types showed a decrease in the number of fixations, with TTFF decreasing from 5 in hedonic contexts to 1 in utilitarian contexts. Time to first fixation (TTFF) and first fixation duration (FFD) with Tobii Pro Glasses 3 confirmed these findings. For TJ personalities in G1 utilitarian contexts, the average TTFF was 9.45 seconds and FFD was 0.52 seconds, compared to 13.95 seconds and 0.45 seconds respectively in hedonic contexts, indicating quicker fixation on target samples and reduced browsing time.



Table 2. G1 Time to first fixation and first fixation duration of Interested products

#### Figure 2. G1 participant's eye tracker wearable

#### 4.2 The impact of marketing text on different consumer personalities

Based on the wearable analysis, in the descriptive card conditions of G2 under both hedonic and utilitarian contexts, TJ personalities show a significantly greater interest in the explanatory cards compared to FP personalities. The First Fixation Duration (FFD) reveals that in the hedonic context of G2, TJ personalities have an average FFD of 0.49 seconds compared to FP personalities with an FFD of 0.24 seconds. In the utilitarian condition, TJ personalities have an average FFD of 0.16 seconds compared to FP personalities with an FFD of 0.06 seconds, indicating a longer initial gaze duration for TJ personalities, suggesting that informational content on the cards is important to them, prompting them to spend more time to understand and assist in judgment. In contrast, FP personalities in the hedonic state are more concerned with the appearance of the product and make decisions based on their subjective will. It is suggested that explanatory cards can provide TJ personalities with guidance to make more efficient judgments. This is consistent with previous literature suggesting that TJ personalities are more likely to listen to others' recommendations to increase their purchasing efficiency. In the utilitarian contexts of G2 and G3, TJ personalities are notably focused only on the form and mechanism of the pen, which differs significantly from FP personalities. Conversely, FP personalities are more concerned with the descriptive explanatory cards of the pen in the utilitarian context, which may be related to their desire to understand the objective definition of the pen to align with the utilitarian context.





Based on the wearable analysis from the experimental design of G3, which involved defining three pens with definitions of opposite words, TJ personalities did not show significant interest in descriptions in the utilitarian consumption state. However, in the hedonic consumption state, they showed a high level of attention to inconsistent terms and samples. This suggests a non-targeted consumption task that allows them time to consider the reasonableness of the process, indicating that this marketing approach will increase the attention of TJ personalities in the hedonic state. In contrast, for FP personalities, it was quite different. In the utilitarian state, FP personalities are more likely to be influenced by situational considerations of the sample and judgment methods, thus showing higher attention to the samples and terms. Among all participants, 57.1% ultimately chose pens with opposite terms, but semi-structured interviews revealed that the main reason for the choice was not the terms themselves. The focus was on the feelings and personality the product gave to the participants. However, it cannot be denied that products with opposite terms do indeed attract consumers' curiosity. The wearable analysis

revealed that non-fluent text descriptions clearly attracted more participants' attention than fluent text descriptions. Regarding the mismatched word cards in G3, regardless of personality type, participants tended to rationalize the connection between the descriptions on the cards and the product's character. This may strongly correlate with the differences in cognitive fluidity mentioned across cultures between East and West. In this study, all participants were Easterners, who generally have a greater acceptance of cognitive disfluency and may even attempt to rationalize erroneous cognition.



Figure 3. G2 participant's eye tracker wearable



#### 5. CONCLUSION AND DISCUSSION

In summary, the results indicate that different shopping purposes and contexts influence the judgments of different personalities. Negative descriptive framing indeed captures consumers' attention, but it is not the key factor in their purchasing decisions; the product itself remains crucial. Specifically, this study found a significant correlation between product personality and consumer individual personality, particularly in the visual attention displayed by FP (Feeling-Perceiving) and TJ (Thinking-Judging) types. In a hedonic context, FP personalities tend to focus more on the appearance and sensory attributes of the product, such as color and texture, while TJ personalities focus more on the structural design and functional details, such as springs and push buttons. In a utilitarian context, FP personalities are more influenced by environmental settings and spend more time on descriptive texts to make more rational judgments, whereas TJ personalities quickly focus on target samples, reducing browsing time. These findings suggest that different personality traits have significant differences in visual perception and attention allocation, which has important implications for product design and marketing strategies. More empirical research is needed to further understand the relationship between product personality and consumer personality choices.

This study has several limitations. Specifically, it was conducted on a sample of students, predominantly female, and focused on pens as the sample product, which may lead to slight differences in attention to stationery in everyday life and during the selection process. Additionally, this research prioritized user-friendliness for participants, using the Neris Type Explorer[®] model for personality assessment, which is a model generated based on the Big Five and MBTI frameworks. While widely used and demonstrating stable internal consistency and reliability through Confirmatory Factor Analysis (CFA), the results theoretically support a multidimensional model accurately describing broad personality types, but it is a non-traditional MBTI model, which could benefit from further validation in future research.

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# WHO BRINGS EMOTIONAL VALUE TO THE BANK?

## A STUDY ON THE VISUAL PERCEPTION OF MASCOT ON BANK PAYMENT CARDS USING WEARABLE EYE-TRACKING DEVICES.

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## ABSTRACT

Payment cards serve as frequent transaction mediums handled by consumers, involving personal financial privacy considerations that prompt users to be emotionally cautious. How can the visual presentation on the card's front effectively communicate with consumers? In recent years, mascots have become increasingly prevalent in bank marketing strategies, eliciting emotional responses from consumers. Adorable brand mascots can evoke feelings of relaxation and happiness, even capturing the interest of those previously unengaged, thereby creating opportunities for companies to connect with consumers in their daily lives. This study employs wearable eye-tracking devices to conduct scientific experiments in visual cognition, aiming to understand the impact of mascot imagery in financial application design (specifically, the visual design of payment cards) on consumer behavior.

Keywords: mascot, eye tracking, payment card, emotional value, communication design

## 1. INTRODUCTION

Payment cards, as an essential tool for consumer transactions, have seen a global increase of nearly 1 billion cards in circulation over the past two years. In the next five years, the number of circulating payment cards is expected to further increase by 3.28 billion (Statista & Report, 2024). When consumers take out a payment card, the first thing they do is identify the issuing bank by the card's design. At this point, the visual design of the card starts to communicate the card's function, usage, and social significance. The visual design of a credit card serves as a visual cue to attract consumers and persuade them to use the card, playing a crucial role in influencing consumer reactions (Crilly et al., 2004).

In credit card visual design, designing strategies focused on themes or brands can effectively enhance customer brand experiences and leave a lasting impression on consumers (Kim & Kim, 2020). In Eastern social environments and businesses, mascots are often seen in the marketing

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and banking industries. As a brand ambassador (Wattanacharoensil et al., 2021), a mascot helps consumers understand the brand's business scope and corporate appeal through its appearance and behavior. The consistency between the mascot's image and the consumer's self-image, along with the emotional value it generates, also enhances the consumer's willingness to purchase the product (Chen et al., 2022). Therefore, cute mascots offer consumers diverse emotional appeals and values. When applied to the visual communication medium of payment cards, how do consumers perceive them? This study employs wearable eye-tracking devices to explore the visual application of mascots on bank payment cards. By analyzing consumer visual interest areas using eye-tracking metrics, we aim to understand consumers' attention distribution on payment card designs and evaluate the potential of mascots in bank marketing applications.

#### 2. LITERATURE REVIEW

#### 2.1 Utilitarian and Hedonic Value

How do consumers decide to purchase a product or service? Consumer purchasing decisions and engagement in service consumption are primarily guided by two factors: (1) utilitarian attributes, which involve functional or instrumental usability, and (2) hedonic attributes, which provide sensory emotional satisfaction (Batra & Ahtola, 1991).

In the process of banking financial services, whether these services can meet consumer needs has a direct or indirect impact on consumer satisfaction and trust. This, in turn, affects consumer loyalty to the brand and their usage behavior(Jebarajakirthy & Shankar, 2021). In banking services, whether online or physical, consumers exhibit clear utilitarian needs. For example, using credit cards for shopping, making online payments, and checking account balances are basic and essential utilitarian service needs that must be satisfied.

People often purchase products or obtain services not only for their functionality but also to evoke different emotional meanings through hedonic service engagement. This allows consumers to have more emotional experiences with the product or service (Hirschman & Holbrook, 1982). Such hedonic service consumption can also drive user engagement behaviors and enhance the intention to use the service (Hepola et al., 2020).

## 2.2 Communication Design

Through the use of different visual languages, it guides consumers and brands in their communication. People recognize that communication should be designed as an object, making communication a tool to create entertainment and information (Aakhus, 2007). Companies use visual communication to create their own value, and customers also use visual communication to obtain the value they want in their minds (Finne & Grönroos, 2017). Therefore, visual communication design attracts consumers' attention, playing an important and indispensable role in this endless marketing strategy. In Eastern cultures, the marketing application of mascots has attracted public attention and established corporate image through visual communication design methods (Soltani et al., 2018). By establishing associations in consumers' minds, it makes

consumers feel that they have not only purchased physical products or services, but also gained other intangible benefits.

#### 2.3 Emotional Value of Mascots

In Japan, mascots are described as characters with a relaxed personality (yuru-kyara), bringing emotional healing and a sense of satisfaction to busy modern lives. These mascots, with their cute elements, evoke positive emotional states in people (Ikeda et al., 2020; Soltani et al., 2018). In studies of visual cognition in mobile banking apps, it has been found that when East Asian users see mascots on the initial screen upon launching the app, they feel more relaxed and less bored. These feelings of relaxation and engagement increase user acceptance and intention to use (Huang & Chiu, 2024). Moreover, using mascots in local culture for brand promotion is an executable marketing strategy. These cute mascots convey specific images of cities and businesses, potentially prompting target audiences to take action or respond and capturing the attention of those who may otherwise lack interest, thereby enhancing positive emotions(Xu et al., 2022).

## 2.4 Eye-Tracking Studies in Marketing Communication

Using wearable eye-tracking devices in experiments allows for a closer simulation of real-life user behavior, giving participants greater flexibility (such as head movement) and more natural social interactions (like conversing and making eye contact with marketing personnel) in the experimental setting (Chanijani et al., 2016; Hessels et al., 2022). This approach holds significant potential and possibilities for understanding actual user behavior. In consumer behavior research related to marketing communication, the "areas of interest" from the consumer's perspective can be analyzed to understand the attention and feasibility of visual elements in marketing communication design(Li et al., 2014). By utilizing eye-tracking data to assess the emotional value of visual communication design, it becomes possible to see how these kawaii mascots are viewed and noticed by consumers(Laohakangvalvit et al., 2019). This eye-tracking data accurately provides businesses and researchers with valuable references for how design can be used to communicate with consumers.

In summary, mascots significantly bring positive emotional value (healing) and emotional relaxation to consumers in the marketing field. In highly utilitarian banking services, can mascots similarly attract consumer attention and bring emotional value? Using eye-tracking experiments, this research will explore how mascots influence consumers in the visual design of financial payment cards by analyzing consumers' visual interest areas.

#### 3. METHOD

#### 3.1 Participants

This study recruited a total of 13 participants, consisting of 6 males and 7 females, with an average age of 24.7 years. To ensure participants were not familiar with the visual design of payment cards, they were excluded if they had accounts or payment cards from specified banks. Additionally, to minimize data inaccuracies from eye-tracking devices, all participants were required to have normal vision or corrected vision using contact lenses.

#### 3.2 Materials

This study selected a credit card from Cathay United Bank, one of Taiwan's major commercial banks, as the primary visual stimulus. The reason for choosing this brand's credit card as the visual stimulus is its minimalist design in the visual identity system and credit card design. The color scheme predominantly uses non-colors, which helps minimize users' color preferences in visual design.

In addition to Cathay United Bank's original credit card, the study introduced Cathay United Bank's mascot, Ah-Fa, a round and yellow auspicious character, replacing the original credit card design. This simulation involved integrating the mascot's image into the visual design of the credit card, creating an additional sample with a mascot image. Both versions of the credit card designs were presented against a solid black background for participants to choose from.

#### 3.3 Equipment

The experiment utilized Tobii Glass 3, a wearable eye-tracking device, to collect data. The device's built-in sensors captured participants' visual data to analyze their areas of interest (AOIs) on the visual stimuli. Data analysis was conducted using Tobii Pro Lab, which provides visual data visualization and allows researchers to examine participants' gaze patterns and attention levels, particularly focusing on the mascot's impact.

#### 3.4 Procedure

Participants were briefed on the safety of the eye-tracking device and then fitted with Tobii Glass 3, followed by a calibration procedure using a calibration card. After calibration, participants were given a scenario: "After leaving a shopping mall, you see a bank's marketing personnel outside the supermarket offering attractive credit card deals. You decide to sit down and apply for a card." Participants then interacted with the marketing personnel to process the credit card application while wearing the eye-tracking device throughout the experiment.

During the experiment, participants were provided with documentation for credit card application review. The marketing personnel presented participants with a reference image of two styles of credit cards: one with a symbol pattern and the other featuring the mascot. Participants were informed that both cards offered identical benefits, differing only in visual design. After making their selection, participants indicated their choice on the documentation, signed it, and concluded the experiment.

## 3.5 Measurement

This study aims to conduct a quantitative analysis of the visual design on payment cards by utilizing eye-tracking metrics based on Areas of Interest (AOI). Specifically, it will apply three key indicators: (a) Attention Ratio, which reflects the distribution of user attention and the amount of time participants spend fixating on the target object (AOI); (b) Effective Attention Ratio, which measures the concentration of participants on different screen contents during visits, focusing on the proportion of fixation time on the target object (AOI); and (c) Revisit Ratio, indicating the percentage of interested individuals who revisit the target object (AOI), considering instances where users' gaze returns to an area after leaving it. These metrics will

provide a deeper understanding of how participants interact with the visual design of payment cards, particularly regarding attention allocation, concentration levels, and revisiting behaviors towards specific AOIs.

## 4. RESULT

## 4.1 Eye Tracking Visualization Analysis

In the heatmaps, participants were observed to focus more on reading and scrutinizing text when viewing payment cards with a minimalist design. Conversely, symbol pattern specially designed in the center of the card received less attention. For cards featuring mascots, the heatmaps revealed that participants' gaze was significantly concentrated, primarily on the mascot itself. From these heatmaps, three trends can be identified: (1) Minimalist style payment cards lead to more dispersed attention among participants. (2) Credit cards with mascots enhance visual focus among participants. (3) Due to the ease of facial recognition, participants tend not to overly focus on the mascot's face but rather on understanding the accessories and the relationship with the mascot's surroundings.



Figure 1. Heat maps



Figure 2. The AOI of the material

## 4.2 Eye-Tracking Metrics

#### 4.2.1 Attention Ratio

The distribution of attention on payment cards reveals that mascot images attract more consumer attention compared to symbol pattern. Additionally, accessories such as coins and the mascot's hat, while occupying a smaller proportion of the screen, also capture some participants' attention.



Figure 3. The Attention ratio in AOI

#### 4.2.2 Effective Attention Ratio

The effective attention ratio towards mascots is only 1.5% higher for participants compared to cards primarily featuring symbol pattern. However, cards where mascots are prominently featured show a significantly higher effective attention ratio of 6.3% compared to those primarily featuring symbol pattern. This trend highlights that including mascots in the visual design of payment cards enhances participants' focus on these cards, thereby increasing consumer viewing time.



Figure 4. The Effective Attention ratio in AOI

#### 4.2.3 Revisit Rate

The revisit rate indicates consumers' interest in visual areas. Participants revisit the mascot area at a high rate of 80%, compared to a revisit ratio of 37.5% for bank symbol patterns. This demonstrates significantly higher interest among participants in mascots, leading to frequent revisiting behaviors.



Figure 5. The Revisit Rate in AOI

#### 5. CONCLUSION AND DISCUSSION

Based on the data analysis of visual interest areas obtained through eye-tracking technology, it is evident that mascots hold higher visual appeal among Eastern participants when presented on the front of payment cards. Particularly noteworthy from the revisit ratio data is that mascots significantly enhance participants' interest, leading to frequent revisits. This behavior can greatly assist brands in shaping their image and promoting corporate identity.

Increasing visibility can attract consumers' attention, thereby creating commercial opportunities for businesses to engage in visual communication design. Regarding effective attention ratios, although simplistic payment cards may show lower attention compared to mascot-based cards, it does not imply that simplistic designs are less attention-worthy. The front design of payment cards serves as a versatile medium for marketing communication. It does not significantly impact transaction processes, as critical transaction information (such as card numbers and CVC codes) is typically located on the card's back.

Therefore, the visual presentation on the front of payment cards serves as a pivotal point for designers and marketers to effectively communicate with consumers. Offering various themed card visuals can enhance consumer satisfaction and freshness. For Eastern consumers, the inclusion of mascots proves to be a suitable medium, serving as brand ambassadors in banking marketing. Beyond the mascots themselves, aligning visual presentations with different themes, accessories, or attire can not only clarify marketing purposes but also evoke positive emotions, bringing delight and enjoyment to consumers.

This study acknowledges several limitations in its experimental design. Firstly, each consumer has their own preferences regarding mascot images, and different banks promote vastly different mascot images. These differences could potentially influence consumers' preferences and perceptions of the mascots used. The current findings are based on the visual design of the front face of bank payment cards, without exploring the relationship between the front and back designs or testing utility-related service functions of the banks. Secondly, this research focuses exclusively on bank payment cards, lacking exploration into different application designs within the banking industry. Future studies could delve into various application designs to provide a broader understanding. Lastly, this study was conducted within the context of Eastern culture. Whether mascot applications are suitable for Western consumers in terms of communication design remains uncertain. Future research aims to understand cross-cultural differences in mascot applications.

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# DEVELOPMENT OF THE PROPOSED METHOD FOR EXTRACTION OF COMBINATION OF TOPIC TRANSITION

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## ABSTRACT

People have a great interest in good communication, as communication skills have become a very important competence in modern society. There are many systems for the facilitated communication between users by providing topics. In related research, systems have been proposed to support communication by recommending topics that are highly relevant to the content of the conversation. In addition, previous systems that aiming for natural conversation by representing topic transition are used to respond to conversations, but not to recommend the next topic. Furthermore, the topic presentation system needs to be able to extract topics that would be spoken about next to the current topic, rather than short periods of topic transition such as conversational responses. In this study, a new method is proposed for extracting topic transition from users' past conversation data. Using the proposed method, it is possible to provide support that considers topics related to proper nouns and topics that users are more likely to talk. It is therefore expected to lead to smooth communication. Specifically, an algorithm for extracting combinations of topic transition (CTT patterns) was constructed and evaluation experiments were conducted using a conversational corpus. The results show that the proposed method can provide new topics that could not be presented before.

Keywords: Topic Transition, Computer-Mediated Communication, Communication Support

## 1. INTRODUCTION

Communication is one of the important means of connecting people. In recent years, communication skills have become a topic of more attention in society. A lot of research has been conducted on communication (Borish et al., 2014, Ou and Hsu, 2020). In view of these considerations, numerous systems have been proposed with the aim of facilitating communication between individuals through the presentation of topics (Kimura and Maruyama, 2017, Dongli et al., 2010). It is essential to transition to natural topics to enhance user conversations within these systems. One example of a topic transition method involves

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representing a specific topic using word embeddings and then transitioning to a topic with a high cosine similarity to it (Tang et al., 2019). Furthermore, topic transition methods based on knowledge graphs (KG) have also been proposed (Chaudhuri et al., 2021). The topic transition is defined as "short-term topic transition". Short-term topic transition refers to transition where utterances are temporally proximate, e.g., predicting the next utterance based on the current utterance. In this topic transition, the topic is expected to be followed by a topic that is highly relevant to the topic presently being discussed. For instance, after discussing the topic of "pets", the conversation may transition to "dogs", "cats", and other closely related topics.

On the other hand, topic transition that is discussed after the current topic has concluded are defined as "long-term topic transition". For example, after the topic of "animals" is discussed, the conversation may shift to "sports". In human-system communication, expressing short-term topic transition is crucial for the system to respond to human utterances. However, in a topic presentation system, it is not necessary to predict the next utterance to respond to the current one. It is more important to anticipate the topic of conversation that will follow the current topic. For instance, assuming that the "dog" topic is derived from the "pet" topic, in the context of a conversation between a human and a system, the system can respond to a human uttering the word "pet" by generating the word "dog". By contrast, in a topic presentation system, the conversation proceeds without awaiting a response from the system. The user is likely to have already discussed "dogs" within the topic of "pets," and the system does not effectively support the conversation even if it presents "dogs" to the user. Therefore, in a topic presentation system, the extraction of long-term topic transition is important.

In this study, we propose a method for extracting long-term topic transition from conversational data with the aim of topic extraction for topic presentation systems. This method enables the extraction of both short-term and long-term topic transition from conversational data. If the conversation data comprises the user's historical conversations, it is hypothesized that the method can extract topic transition that aligns with the user's characteristics, such as frequently discussed topics.

#### 2. RELATED WORKS

There are related works on topic extraction methods for communication support. The system that provides topics related to the contents of the conversation without making the user feel awkward, was proposed by Kimura and Maruyama (2017). In this related study, topics are extracted using the TF-IDF method, fetches some news articles from a Web service and shows their headlines to the users. The system that extracts topics from the Web texts according to the vectors that user's latest interest was proposed by Dongli et al. (2010). Although these methods extract topics from web texts, and do not consider topic transition.

Here are some related studies on methods for representing topic transition in below. Tang et al. (2019) represent topics by word embedding, use cosine similarity as a measure of closeness between topics. A method for extracting topics using knowledge graphs (KG) was proposed by Chaudhuri et al. (2021). A KG represents information as a triple. Triple means a data structure

that stores information in a KG as <subject, relation, object>. For example, the knowledge that "Tokyo is the capital of Japan" is represented as < Tokyo,capital city,Japan > (Chaudhuri et al., 2021). However, these methods were proposed as chatting systems and can only extract short term topic transition.

In this study, a new method using sequential pattern mining is proposed to extract "combinations of topic transition" (This is called CTT pattern in this paper.) from conversational data. Since conversational data is time series data, it is possible to extract CTT patterns from conversational data by using sequential pattern mining. In addition, even if the same keywords are used, the different CTT patterns are extracted by changing the conversational data as input. For example, if the CTT patterns ['football', 'travel'] are extracted in the conversational data of a speaker A, different CTT patterns are extracted in the conversational data of a speaker B, such as ['football', 'basketball']. By this proposed method, it is expected to specify CTT patterns considering the user features using past conversational data of user.

## 3. METHOD

Figure 1 shows the outline of the proposed method for extracting CTT patterns from conversational data. Input data is conversational data and preprocessing such as removing unnecessary words and extracting nouns is performed in STEP1. In STEP2, frequent patterns are extracted using sequential pattern mining method. These steps are described in detail below.





## 5.1 STEP1: Preprocessing

In STEP1, morphological analysis is performed on the conversational data, and nouns are extracted from the data. MeCab (MeCab, n.d.) was used for morphological analysis, and UniDic was used as the dictionary for analysis. From the extracted nouns, nouns (common. adjectival) and nouns (common. adverbial) were removed. This is an expression in Japanese grammar. Nouns (common. adjectival) are nouns, e.g. ("adjectival verb" – "-na" or "-daro"). Nouns (common.adverbial) are nouns of time, e.g., "today", "present" as well. These keywords were removed because the meaning is changed depending on the text. In addition, some keywords were removed as stopword using the Japanese stopword list provided by SlothLib (Ohshima et al., 2007). Keywords whose meaning cannot be understood by itself or that appear frequently in all sentences are regarded as stopwords, e.g., "Honma(really)", "Toki(when)".

#### 5.2 STEP2: Sequential Pattern Mining

From the words extracted in STEP1, frequent CTT patterns are extracted by using Episode Mining using Memory Anchor (EMMA), a Sequential Pattern Mining (Huang and Chang, 2008). Figure 2 shows the flow of patterns extraction by EMMA. In this case, CTT patterns with two or more occurrences are extracted. First, all nouns that occur and the utterances in which that nouns occur are found to extract episodes from the conversation data. If only nouns with two or more occurrences are retained, [a,b] and [a,c] with less than two occurrences are deleted. The results are shown in the table in Figure 2(1). In the table, "Episode" represents the extracted episode, "Sup" represents the number of occurrences, and "Bound-list" represents the utterances that occur as [first occurrence position, last occurrence position].

Next, consecutive episodes are found. Figure 3 shows the procedure for searching episode. First, all the episodes that appear after "a" are searched. In Figure 3, combinations that appear two or more times are indicated by solid lines. Thus, combinations that appear two or more times were saved as new episodes. However, episodes with less than two occurrences, such as the episode in which "c" comes after "a", are deleted. In Figure 3, these combinations are shown by the dotted line. Figure 2(2) shows the episodes that have been processed above steps. This process is executed recursively. The search is continued in the same manner as above, and only those episodes with two or more occurrences are left, as shown in Figure 2(3). Finally, the CTT pattern is extracted. In addition, the episode is extracted from the following utterance in this example. The interval between utterances to search for episodes varies depending on the length of the conversational data.



Figure 2. Outline of episode extraction in EMMA



Figure 3. The procedure for searching episodes

#### 4. **EXPERIMENTS**

#### 4.1 Summary

The objective of this experiment was to ascertain whether CTT patterns could be employed to extract topics for use in a topic presentation system. For example, the performance evaluation is based on whether the CTT patterns was able to extract relevant topics for proper nouns. Therefore, CTT patterns were extracted from a Japanese Topic-Oriented Conversation Corpus (J-TOCC), which compiles data on conversations between college students who are close to each other (Nakamata et al., 2021).

#### 4.2 Input : Conversation data on the topic of food

We used a conversation corpus of recorded and transcribed one-on-one conversations about "food" between close college students as our conversation data. CCT patterns are extracted from the conversation data. This corpus is five minutes conversation between 120 pairs of college students, collected between 2018 and 2019, that was transcribed. There are two reasons for using this corpus. The first reason is that the topics of "food" are common in everyday conversation, and therefore, it was considered a valid target for analysis. The second reason is that the data were easy to handle for research purposes because the topics and conversation lengths were controlled.

#### 4.3 Output: CTT patterns

The output of this experiments are CTT patterns that are proposed to extract combinations of topic transition. This section details the procedure for outputting CTT patterns. First, the interval between utterances in each conversation data was determined. The average number of utterances in the conversation data was 97 sentences. Therefore, the interval between utterances to be searched was set to 50 sentences, approximately half of the total number of utterances. Next, CTT patterns were extracted for short term topic transition from 1 to 20 sentences between utterances, and for long term topic transition from 21 to 50 sentences between utterances. In addition, when keywords were extracted, the same words were sometimes found in succession, for example, ['ramen', 'ramen']. If the CTT pattern for these same keywords is extracted, it is not possible to recommend the pattern as a conversation topic. Thus, the extracted this pattern was eliminated.

#### 5. THE RESULTS & DISCUSSION

CTT patterns with two or more occurrences were extracted in 110 conversation data on the topic "food". In the short-term topic transition, 319 CTT patterns were extracted. Table 1 shows some of the extracted CTT patterns (translated from Japanese to English). In the long-term topic transition, 418 CTT patterns were extracted. Table 2 shows some of the extracted CTT patterns (translated from Japanese to English). The "word" indicates the CTT pattern, and the "count" indicates the number of occurrences of the CTT pattern. A commonality between the two tables is the extraction of numerous CTT patterns, each consisting of approximately two to three words. The minimum value of "count" is two times. The maximum value of "count" is 3.33 for the short-term and 11 for the long-term. Besides, the mean value of "count" is 3.33 for the short-term and long terms were extracted. On the other hand, these tables show that CTT patterns that only appeared on one side or the other.

Table 3 shows the actual conversational data from which ['Pickled Ume', 'Udon', 'Curry Udon'] were extracted. The "ID" indicates the position of appearance of utterance, the "Speaker" indicates the speaker of the utterance, the "Utterance" indicates the utterance. Table 3 shows that the position of the topic "Pickled Ume" and the position of "Curry Udon" are far apart in terms of "ID". Accordingly, it was thought to be possible to extract long term topic transition.

word	count
['Cooking', 'Eating Out']	9
['Cuisine', 'Salmon']	3
['Sushi', 'Sushiro']	2
['Sushi', 'Tuna']	3
['Vegetables', 'Chinese Cabbage']	2
['Fish', 'Meat']	3
['Salmon', 'Meat']	2
['Udon', 'Curry Udon']	3
['Ohagi', 'Daifuku', 'Snack']	2
['Osho', 'Ramen']	2

Table 1	Part of the CTT	nattern extracted in	a short-term	(translated from la	nanese to English)
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 Table 2. Part of the CTT pattern extracted in a long-term (translated from Japanese to English)

word	count
['Cooking', 'Sushi']	4
['Sushi', 'Cooking']	2
['Sushi', 'Tuna']	2
['Eating Out', 'Cooking']	3
['Vegetables', 'Sushi']	2
['Vegetables', 'Salmon']	2
['Vegetables', 'Shrimp']	2
['Vegetables', 'Meat']	2
['Pickled Ume', 'Udon', 'Curry Udon']	2
['Abura Soba', 'Tsukiji']	2

ID	Speaker	Utterance
62	E-103-1M	Yes, that's why I never choose plums, even if they put them at a buffet or something.
63	E-103-2M	I would definitely choose. I take about five or six plums. (E-103-1M: Seriously?) Pickled Ume, yes, pickled Ume.
99	E-103-1M	Well, let's see, what is it that you like Let's see what your favorite dish is.
100	E-103-2M	Curry Udon.
101	E-103-1M	Curry Udon. Curry, Curry Soba, not curry soba or something?

Table 3. Conversational data (translated from Japanese to English)

#### 5.1 Short-term topic transition

CTT patterns were extracted that seemed to be highly related to each other, such as ['Sushi','Sushiro'], ['Vegetable','Chinese Cabbage']. This result is thought to be because the sentences were extracted from sentences with close timing of utterance. Thus, natural topic transitions were extracted by this method.

#### 5.2 Long-term topic transition

CTT patterns were extracted that seemed to be highly related to each other, such as ['sushi','Tuna']. By contrast, CTT patterns were extracted that seem to be less related to each other, such as ['Vegetable','Salmon'] and ['Pickled Ume','Udon','Curry Udon']. Table 3 shows that the position of the topic "Pickled Ume" and the position of "Curry Udon" are far apart in terms of "ID". Accordingly, it was thought to be possible to extract long term topic transition. In addition, CTT pattern named ['Abura Soba','Tsukiji'] was extracted. "Abura Soba" is a type of ramen without soup. "Tsukiji" is the name of a place in Tokyo. "Tsukiji" is not famous for its "Abura Soba", and the relationship between the two is not strong. It is difficult to express that topic transition using other methods. The CTT pattern was possible to extract topic transition corresponding to proper nouns.

## 6. CONCLUSIONS

In this study, we developed a method for extracting topic transition from conversational data using sequential pattern mining for providing topics in a topic presentation system. In the experiments, the conversational corpus was used to extract conversational patterns. In the results of the experiments, both short-term and long-term topic transition could be extracted. The extraction of short-term topic transition resulted in the extraction of CTT patterns between highly related topics. It was confirmed that it is possible to extract topic transition

corresponding to proper nouns. Accordingly, it was suggested that CTT patterns could be used for topic presentation in the topic presentation system.

However, the conversation data used in the experiment was based on a fixed conversation time. Actual conversations differ in the timing of topic transitions influenced by the conversational situation and the conversationalist. Examination of thresholds for topic transition term based on conversation data is needed to be addressed in future studies. Since more conversational data needs to be incorporated, use a large corpus of conversational data, or collect conversational data through experimentation. The selection of this collected conversational data provides a foundation for future research to explore a diverse array of languages and contexts. It is also necessary to conduct a quantitative evaluation of the extraction of CTT patterns. Although it is difficult to quantitatively capture the validity of topic transition, it is possible to evaluate the method used in topic presentation systems by creating a metric for extracting topic transition. In the future, it will be verified whether the CTT patterns extracted by this method can be used in a topic presentation system to support.

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THE IMPACT OF FLAT AND SKEUOMORPHIC DESIGNS ON PHYSICAL INTERFACE PREFERENCES ACROSS DIFFERENT AGE GROUPS: APPLYING WEARABLE EYE-TRACKING TO EXPLORE VISUAL PERCEPTION BETWEEN DIGITAL NATIVES AND DIGITAL IMMIGRANTS' PREFERENCES IN HOME APPLIANCES

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## ABSTRACT

Smart home technology has matured significantly with the development of the Internet of Things (IoT), becoming an integral part of contemporary family life. However, current discussions often focus on technical functionalities and usability, neglecting its impact on emotional connections within families. This study investigates the applicability and visual perception of two design styles which includes flat design and skeuomorphic design. In addition, this study explores the two groups difference between digital natives and digital immigrants in the operation of home appliance controllers. Through wearable eye-tracking equipment and semi-structured interviews, we found that digital natives prefer flat design for its operational consistency and intuitiveness, while digital immigrants favor skeuomorphic design for its realistic feedback and sense of reassurance. These findings not only provide valuable insights for design optimization but also emphasize the importance of balancing technological innovation with emotional experience in smart home design to foster emotional connections and user satisfaction among family members.

Keywords: Smart Home, Interface Design, Digital Natives, Digital Immigrants, Eye-tracking

## 1. INTRODUCTION

At the 1998 World Economic Forum, Kevin Ashton first introduced the concept of the Internet of Things (IoT), which extends connectivity not only between people but also to all objects (Madakam & Tripathi, 2015). This concept transcends traditional internet boundaries, enabling automation and intelligence, thereby enhancing efficiency and convenience. As technology has matured, IoT has become integrated into daily life, widely applied in industries such as manufacturing, retail, and healthcare, particularly in residential environments. Since 2015, IoT technology has seen widespread adoption in both new and existing buildings, leading

to increased attention on Smart Homes (Frank, 2024). This growth is supported by corporate showcases at events like CES and robust communication protocols such as WiFi, Bluetooth, Zigbee, Thread, and Matter, which cater to diverse household needs, enhancing convenience. Data from CES 2023 highlighted Smart Home as the most significant IoT application, with steadily increasing market acceptance (see Fig.1).



Figure 1. Smart Home leads the IoT market, with nearly a 20% lead over the second position. Image redrawn from this study.

However, scholarly discussions on smart homes often emphasize technological advantages such as device interoperability (Lutolf, 1992), internal technical quality (Harper, 2006), and remote monitoring capabilities (Balta-Ozkan; Davidson et al., 2013). This technology-centric approach often overshadows the "home" concept's significance—home not only as a convenient living space but also as a place of comfort, security, and family bonding. Exploring the applicability of design styles in smart home technology can complement technology with aesthetics, enhancing the living environment's beauty and ambiance while meeting emotional needs. Therefore, this study examines flat and skeuomorphic design styles, analyzing their suitability and perceptual effects on digital immigrants and digital natives. The results offer new perspectives for integrating technology and emotional values in smart home environments, redefining the balance between "Smart" and "Home" for greater harmony.

#### 2. LITERATURE REVIEW

#### 2.1 Concepts of Interface Design

#### 2.1.1 Skeuomorphic Design

Skeuomorphism, originating from archaeologist Henry Colley March, refers to the design strategy of injecting the appearance, shape, or function of old objects or concepts into new objects (March, 1890). Early applications included ship-shaped pottery net textures, Ford T-series cars borrowing from carriage design, and the folder graphics in the 1973 Xerox Alto computer user interface. This metaphorical design strategy leverages users' familiarity with old objects or concepts, making new objects easier to understand and use. Skeuomorphic design

extends beyond mimicking appearance to functional imitation, providing 3D visual affordances that enhance understanding of purpose and operation, thus improving user experience.

## 2.1.2 Flat Design

Flat design originated with the 2010 Windows Phone 7 operating system, aiming to reduce visual fatigue and provide a cleaner interface (Burmistrov; Zlokazova et al., 2015). This design approach abandoned the previous complex 3D visual effects in favor of 2D visual signifiers, introducing a new visual style: devoid of added effects, simple elements, and focused on layout, making the interface look cleaner and livelier (Carrie, 2013). Such design simplifies rendering effects, enhances application productivity and efficiency, reduces battery consumption, and extends device battery life (Mu; Huang et al., 2022). Flat design improves user experience by offering a cleaner and smoother operation interface, reducing visual burden, and increasing user satisfaction.

#### 2.2 Generational Differences in the Digital Society

Since the internet's proliferation around 1985, the rapid rise of the digital society marked a generational divide. Marc Prensky defined those born before 1985 as digital immigrants and those born after as digital natives (Prensky, 2001). Digital immigrants grew up without digital exposure, relying on physical resources like books and notes for knowledge acquisition and transmission, cultivating habits of gradual problem-solving, patience, and perseverance. However, with the advent of the digital age, these individuals may feel apprehensive and unfamiliar with digital technology, often hesitant to completely abandon their previous behavioral patterns, deepening their disconnect from modern digital society (Prensky, 2001). In contrast, digital natives grew up in the digital age, familiar with digital technology as naturally as using their native language (Palfrey & Gasser, 2011). They adeptly handle multimedia demands on digital devices, developing efficient work habits. However, this fast-paced lifestyle often leads to multitasking and difficulty concentrating (Prensky, 2001).

#### 2.3 Wearable Eye-tracking Glasses

Traditional qualitative market research often faces challenges because participants may not fully express their true thoughts when describing user experiences, and their actual behavior may differ from their verbal accounts, leading to inaccurate survey results. Eye-tracking glasses address this issue by providing objective eye movement data that reflects participants' real behavior and visual attention distribution during product usage. Understanding the attractiveness and adaptability of physical interfaces is crucial in exploring smart home applications. Compared to screen-based eye-tracking devices, wearable eye-tracking glasses are more suitable as they allow easy gaze in 360-degree views across various environments, capturing dynamic gaze directions (Jongerius; Callemein et al., 2021). Thus, wearable eye-tracking glasses provide valuable tools for researchers to gain deeper insights into participants' behaviors and perceptions during interface operations.

## 3. METHOD

## 3.1 Participants

This study recruited 4 participants—2 digital natives (equal gender distribution,  $M_{age}$ =25.5) and 2 digital immigrants (equal gender distribution,  $M_{age}$ =45). All participants had a basic understanding of home appliance controllers, with visual acuity not exceeding 800 degrees.

## 3.2 Materials (Stimuli)

The experiment took place in the home appliance section of the HOLA large-scale household goods retail store, where participants operated two electric fans: one with a flat physical interface design and one with a skeuomorphic physical interface design (see Fig.2).





#### 3.3 Experimental Design

The study employed a cross-over design where each participant interacted with both the flat design and skeuomorphic design physical interfaces. The order of interface presentation was counterbalanced to mitigate sequence effects. The primary dependent variables included task completion time, accuracy, and participant satisfaction.

#### 3.4 Procedure

Each participant completed specified task scenarios (see Table 1). During the experiment, participants wore Tobii Pro Glasses 3 wearable eye-tracking glasses to collect eye movement data. After completing the tasks, participants engaged in retrospective thinking aloud, reviewing their behaviors and decisions during operation. Finally, semi-structured interviews were conducted to delve into participants' usage experiences and satisfaction.

Task	Description
Step 1	The weather is hot, so you start to turn on the electric fan.
Step 2	It's still too hot; you want to turn the fan speed to the maximum.
Step 3	After using the electric fan, you turn off the power.

#### Table 1. An example of a table

#### 3.5 Measurement

The measurement tools employed in this study include Eye tracker gaze for analyzing participants' gaze and operational behaviors. This includes their gaze location, duration of gaze, and sequence of gazes within the physical interface. Additionally, Advanced metrics' Attention Ratio will be used to delve deeper into participants' attention distribution. Semi-structured interviews will be conducted to gather qualitative data on participants' experiences, preferences, and satisfaction with the interface design.

#### 4. RESULTS

#### 4.1 Qualitative Interviews

Digital natives preferred the flat physical interface design, appreciating its operational consistency and intuitiveness. They found that different buttons could be operated with the same gestures, making them feel comfortable and facilitating smooth operation. Additionally, the visual aesthetics of flat design gave them a sense of sophistication, adding taste to their lives. In terms of interaction, they liked the tangible and intuitive tactile feedback provided by flat design, such as button feel and dynamic effects, which allowed them to clearly perceive their actions. In contrast, the feedback from skeuomorphic design was perceived as more ambiguous and abstract, potentially leading to confusion and dissatisfaction.

Digital immigrants, on the other hand, favored the skeuomorphic design of the physical interface because it closely mimicked real-world operation methods, such as pressing buttons with a clear sense of direction. The realistic feedback of skeuomorphic design, such as clicking sounds or tactile sensations, enriched their interaction experience and boosted their confidence in operating the system. This clarity enabled them to perceive whether the system correctly received their actions, providing a greater sense of security and reassurance.

#### 4.2 Heatmaps and Eye-tracking Data Analysis from Eye Trackers

During the analysis phase of the experiment, we defined Areas of Interest (AOIs) based on the operation of the two physical interface designs by participants, with switches (AOI 1) and fan speed were identified as the primary areas to be manipulated during the main tasks (see Fig. 3). In digital natives' operations, whether using flat design or skeuomorphic design, their visual focus in heatmaps concentrated on AOI 1 and AOI 2 (see Fig. 4). In the flat design physical interface, the attention ratio for AOI 1 was 12.86%, and for AOI 2, it was 11.34%. In contrast, in the skeuomorphic design physical interface, the attention ratio for AOI 1 was 12.86%, and for AOI 2, it was 10.21%, and for AOI 2, it was 30.82% (see Fig. 5). This indicates that digital natives could execute tasks clearly and complete operations when using these two home appliance controllers.


Figure 3. AOI of Flat design and Skeuomorphic design.



Figure 4. Heatmaps for Digital Natives.



Figure 5. Attention Ratio for Digital Natives.

However, when examining gaze plots, we found that digital natives achieved better scanning accuracy in executing task steps (first turning on the switch and then adjusting the fan speed) using the flat physical interface than the skeuomorphic design physical interface (see Fig. 6). This suggests that they could complete these visual task transitions more quickly and accurately on the flat physical interface. In contrast, in digital immigrants' operations, we found in heatmaps that the visual focus was too diffuse with the flat design physical interface compared to the skeuomorphic design physical interface (see Fig. 7). Therefore, the flat design physical interface brought more confusion for digital immigrants. They may need to spend more time

and effort to understand the functionality of each button individually, affecting operational efficiency and accuracy.



Figure 6. Gaze Plot for Digital Natives.



Figure 7. Heatmaps for Digital Natives Immigrant.

# 5. CONCLUSION AND DISCUSSION

After qualitative interviews and experimental results, we found that digital indigenous people prefer and are accustomed to the flat design style when using physical interfaces. This flat design provides a consistent operational experience and corresponds well with machine feedback, reducing their time spent thinking about how to operate. Such intuitive design characteristics help support digital indigenous people in maintaining high efficiency in work and daily life. At the same time, as members of the digital age, they do not wish to be disconnected from modern society; the streamlined thinking behind flat design makes them feel it is a symbol of high technology. Therefore, digital indigenous people can confidently and effectively manage various daily technological tools through flat design interfaces, staying synchronized with technological developments.

On the other hand, digital immigrants prefer skeuomorphic designs when operating physical interfaces. This design mimics real-world operation methods, providing realistic feedback that enriches their interaction experience and boosts their confidence in operating devices. Skeuomorphic interface elements offer tangible affordances, enabling them to gradually understand the logic of operations and clearly perceive whether the system correctly interprets their actions, thus feeling more grounded and reassured. This design style effectively helps digital immigrants avoid uncertainty, reduce anxiety during operation, and enhance comfort and satisfaction.

However, our study has some limitations. Firstly, our sample size was small, involving only four participants, which may affect the generalizability and representativeness of the results. Future research should increase the sample size and include participants from diverse backgrounds and age groups to obtain more comprehensive and accurate data. Additionally, our study scenario was limited to the operation of home appliance controllers and did not cover other application scenarios of smart homes. Future research should explore diverse applications of smart homes and analyze the suitability of different design styles in various application scenarios.

Therefore, in future research, we should carefully consider how to balance flat and skeuomorphic design styles in design to meet the needs of different users. We need to explore hybrid design solutions that allow interfaces to flexibly switch between or integrate flat and skeuomorphic elements based on user preferences and requirements, providing a better user experience. Furthermore, in smart home design, we should incorporate emotional design elements such as sound effects, tactile feedback, and visual effects to enhance emotional connections and satisfaction for users. Developing smart home devices adapted to different life scenarios will not only enhance convenience but also strengthen emotional communication and connection among family members.

Continuously conducting user behavior analysis and needs research, updating and optimizing design concepts and functional features based on technological developments and changes in user needs, will facilitate the design of inclusive interfaces and functions, promoting intergenerational understanding and use of technology. Through exploration of these design suggestions and research directions, future smart home designs will find a more harmonious balance between technology and emotional family values, achieving a truly intelligent and warm coexistence, and enhancing user quality of life and satisfaction. Smart home design should not only focus on technological innovation but also address humanistic needs, creating a genuinely warm smart living environment from the user's perspective. This will transform smart homes into bridges of emotional connection among family members, bringing new changes and improvements to future living environments.

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# FORMATIVE FEATURES AND SYMBOLISM OF DRAGON PATTERNS IN MIAO EMBROIDERY IN GUIZHOU PROVINCE

DESIGN ELEMENTS IN MYTHOLOGICAL BACKGROUNDS OF DECORATIVE EMBROIDERY PATTERNS

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# ABSTRACT

This study investigated and analyzed the dragon patterns found in the costumes of the Miao people living in Guizhou Province, China, with the aim of exploring the cultural meanings and origins of these richly decorative designs from the perspective of current designers. The authors classified the motifs used in Miao embroidery patterns based on their formative characteristics. The two important motifs are dragons: "Panlong" and "Miaolong." Panlong is depicted in a spiral, coiled form, whereas Miaolong is expressed in various forms and merges with other animals. In particular, Miaolong fuses the features of multiple animals, such as dragons, cattle, elephants, and birds, and these patterns play a crucial role in shaping the Miao's cultural identity.

Furthermore, the classification and analytical examination of Miao dragons have revealed that the elements of dragon forms in Miao culture are not merely decorative but also reflect cultural taboos and traditional values. For example, the absence of any combinations of cattle heads and bird bodies is derived from the cultural significance of Chi You (associated with cattle) and the Jiuyou bird in Miao mythology. To avoid mixing these symbolically significant animals and thus preserve their spiritual integrity, such combinations are avoided in motifs.

Through this research, it has been suggested that the representation of dragons by the Miao, while influenced by Han culture, has been determined with a unique cultural significance. The Miao have reflected on past traditions and myths in their decorative embroidery patterns over time, maintaining and expressing their cultural identity, while these function as essential elements in understanding contemporary Miao society and culture as a whole.

Keywords: Miao people, dragon patterns, Chinese culture, Design

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#### 1. BACKGROUND

The Miao people, who predominantly live in Guizhou Province, China, have fostered a diverse culture since ancient times. Their history dates back to the "Jiuli" and "Sanmiao" of the Yellow Emperor era. From the Xia, Shang, Qin, and Han dynasties to the present day, they have undergone numerous wars and migrations. These migrations aimed to avoid war, stretching from the middle and lower reaches of the Yellow River to the Yangtze and Huai River basins and further to the southwestern mountainous regions.

Successive feudal rulers' persecution and discriminatory policies significantly affected the Miao people, restricting their social and cultural development. Nevertheless, they continue to preserve their unique culture and traditions. Even through migration and political oppression, they have continuously integrated with the cultures of other ethnic groups, forming distinctive costumes and patterns.

Every twelve years, the Miaos hold a grand festival known as "Gusha Festival," which includes the dragon-dancing ceremony known as "Yinglong Qigu" as its initial ritual. During this ceremony, drums are worshipped while venerating the spirits of their ancestors. This custom stems from their religious belief that "all things have spirits."

Dragon patterns are commonly seen in contemporary Miao clothing, but their designs differ from those of the Han people. Compared to the Han dragons, based on the ancient "Nine Resemblances Theory," the Miao's unique dragons incorporate various animal features, combining the dragon art with cattle, dogs, and fish. These dragons hold meaning beyond mere decoration, each possessing a specific symbolic and cultural significance. Current literature has not yet concretely elucidated the rules and taboos associated with dragon design.

#### 2. OBJECTIVE

This research aims to detail the types and characteristics of dragon patterns used in the costumes of the Miao in Guizhou Province and to explore their cultural significance. Dragon patterns embroidered on Miao costumes lack unified production rules and exhibit variations in techniques and regions, necessitating classification. Based on image materials collected through literature research, the study focuses on the morphological characteristics of the dragon patterns and classifies them into two categories: "Panlong" (spiral dragons) and "Miaolong" (unique Miao dragons). Miaolong, in particular, is rich in form and often classified in combination with other animals. These animals were further classified based on the characteristics of their heads and bodies, and the cultural meaning of each pattern was interpreted. This research aims to clarify the influence of Miao culture and people in contemporary times and to understand how Miao patterns shape their sensibilities.

# 3. INVESTIGATION 1: THE DRAGONS OF THE MIAO AND THEIR CLASSIFICATION

In the overall design, Miao embroiderers rarely used straight lines; instead, they primarily employed flowing curves. Even when the head faces forward, the body may be depicted from the side, allowing free expression unbound by structural constraints. However, even with such transformations, the essential characteristics of the animals are accurately captured, such as the horns of an ox, the trunk of an elephant, the sinuous shape of a snake, the multiple legs of a centipede, and the face of a salamander. While maintaining these basic features, embroiderers add their personal aesthetic sense and make decorative modifications, such as adding scales to the body of a dragon, incorporating other ornamental designs, or altering colors.

#### 3.1 The Two Types of Dragons

There are broadly two types of dragons among the Miao: the "Panlong," which has a relatively unified form, and the "Miaolong," which merges with other animals. The shapes of these two types of dragons significantly differ from the traditional dragon forms of the Han Chinese. Panlong is typically depicted in a spiral shape, whereas Miaolong is more diverse, combining the features of other animals into unique and varied forms.

#### 4. INVESTIGATION 2: MIAOLONG FUSED WITH OTHER ANIMALS

Miaolong is commonly embroidered on various parts of Miao clothing, such as sleeves, shoulders, back, and waistbands. The "Hundred Birds Garment" features embroidery on the back of the upper garment. It is also used in hats, vests, silver crowns, and drum banners. This study analyzed Miaolong as the main sleeve pattern.

Head									
Dragon	Cattle	Elephant	Fish	Salamander	Lion	Sheep	Dog	Deer	
	S								
Body									2
Snakes	Cattle	Centipedes	Birds	Fish	Salamander	Silkworms	Qilin	Shrimp	Sheep
							97.0 1.1 1.1		

Table 1. The fused head and body parts of the Miao dragon

Seventeen types of dragon designs were created by fusing dragons with other animals. As shown in Table 1, nine animal types were used to create the heads: dragon, cattle, elephant, fish, salamander, lion, sheep, dog, and deer. The animals used to design the body include ten types: snakes, cattle, centipedes, birds, fish, salamanders, silkworms, qilin, shrimp, and sheep. Seven animal types are used to create tails, including fish, cattle, flowers, birds, circles, lions, and humans. Horns included those of deer, cattle, sheep, and curvy horns. Some curves appearing near the mouth represent whiskers, while others appear on the head.

#### 4.1 Differences in the Morphology of the Heads of Dragons and Cattle



Table 2. The fused dragon heads of the Miao dragon and the cattle-headed dragon

As shown in Table 2, the morphologies of dragon heads in Miaolong are generally similar. The head is depicted using curved lines with a protruding part on top of the head, a wide-open mouth, and an embroidered tongue. The curved lines represent the horns, and the protruding parts of the mouth are used to express whiskers.

The morphology of the cattle-headed dragon gives a more ferocious impression than a regular dragon head. The shape of the tongue is depicted similarly, with fangs drawn in the open mouth and cattle horns placed on top of the head instead of curved lines.

#### 4.2 Differences in the Morphology of the Bodies of Snakes and Centipedes

The centipede body uses lines and comma-shaped forms on its sides to represent the legs, and the body is spiral shaped. It is worth noting that there are forms in which two heads share one body or two symmetrical pairs are embroidered on the sleeves. Among these, a dragon head sharing a centipede body has two different morphologies. One had a split tail with a flower in the center, and the other had an unsplit tail with eight tentacle-like decorations around it.

A snake's body is usually S-shaped, with lines around it and three lines at the tail, making it appear more peaceful than a centipede's body.

# 5. INVESTIGATION 3: COMBINATIONS OF ANIMALS USED IN PATTERNS AND THEIR MEANINGS

This investigation details the combinations of different animal bodies with the heads of dragons, cattle, humans, and dogs and their symbolic meanings.

As shown in Table 3 below, it is worth noting that even with the same snake body, the meaning varies drastically depending on the head.

These animal combinations are deeply rooted in their respective cultures and legends, each with a specific symbolic meaning. This suggests that combinations of animals are not merely decorative but serve as cultural symbols.

Head	Torso	Quantity	Meaning		
	Snake	25	Small dragon: a dragon still in the growth phase		
Dragon	Centipede	2	Earth dragon: Daughter of the Phoenix, symbolizes the Miao		
Dragon	Fish	1	Maple leaf that fell into the water and transformed		
	Bird	11	Birds are represented as symbols of male reproductive organs		
Cattle	Snake	10	Water Dragon: According to "Yulongge," the 24 types of dragons are each divided into 12 water dragons and 12 early dragons, which are managed by humans, respectively.		
			Pangu: The allied tribes became the three Miao clans, and the Miao worship him as an ancestor god.		
	Riding a Snake	7	Legend of the Dragon Boat Festival		
Dog	Snake	2	Pangu: Ancestor of the Miao		

Table 3. Combinations of Animals Used in Patterns and Their Meanings

# 6. DISCUSSION 1: CLASSIFICATION OF MIAO DRAGONS AND THEIR CULTURAL SIGNIFICANCE

There are two main types of dragons in Miao culture. One is the "Panlong" (Coiled Dragon), and the other is the "Miaolong" (Miao Dragon) that merges with other animals.

#### 6.1 The Cultural Background and Symbolism of the "Panlong"

The "Panlong" (Coiled Dragon) is a form of dragon that is heavily influenced by the Han Chinese. Its design is very similar to archaeological artifacts from the Shang Dynasty and the mid-Western Zhou Dynasty, which were used by royalty in the past. Specifically, examples include the "Coiled Dragon Pattern Plate" and "Dragon Fish Pattern Plate" from the Shang Dynasty and the "Coiled Snake Ornament" from the mid-Western Zhou Dynasty (Cheng, 2015). These shapes are described in the "Fangyan: Volume Twelve" as "a dragon that is coiled in a circular form, not ascending to the heavens" (Shang, 2017). Therefore, in Miao culture, the "Panlong" is positioned as a dragon that does not ascend to the heavens, reflecting the cultural influence of the Han Chinese.

#### 6.2 The Cultural Uniqueness and Fusion of the "Miaolong"

The "Miaolong" (Miao Dragon) merges with other animals, a unique characteristic of the Miao. The Miaos recognize the Miaolong as their own dragon. This fusion is deeply rooted in the Miao culture and beliefs.

#### 6.3 The Cultural Uniqueness and Fusion of the "Miaolong"

Miao culture has a cultural taboo regarding combining the symbols of ox (Chiyou) and bird (Jiyu Bird). The ox is associated with Chiyou, the ancestral god of the Miao, whereas birds, especially the Jiyu Bird, are considered ancestors of the Miao. These symbols each hold significant positions but are never combined.

The background to this taboo includes the following mythological and cultural reasons. Chiyou led the ancient tribal alliance of Jiuli and, after being defeated by the Yellow Emperor, was said to have transformed into a maple tree (Editorial Committee of the Continuation of the Four Treasuries, 1995). It is believed that the Jiyu Bird was born from this maple tree, which deeply connects these symbols to Miao mythology (Suzuki, 2015). However, Chiyou is regarded as the ancestor of life, while the Jiyu Bird is seen as a benefactor, and their roles are never interchanged.

Because of this mythological background, mixing the symbols of the ox (Chiyou) and the bird (Jiyu Bird) is considered culturally inappropriate, as it disrupts the balance. This cultural taboo is reflected in Miao embroidery, highlighting the importance and continuation of cultural symbols.

The classification of dragons in Miao culture and their associated cultural significance reflects their history, mythology, and cultural exchange with the Han Chinese. These elements played a crucial role in shaping the Miao's cultural identity.

# 7. DISCUSSION 2: CONSIDERATION OF ANIMAL COMBINATIONS AND THEIR SYMBOLISM

The design expression methods used by the Miao people may be related to the fact that women primarily handle Miao embroidery. These women favor soft curves in their creations, and because the Miao reside in mountainous areas with limited access to public education, they rarely have opportunities to learn artistic educational methods such as sketching or skills like perspective. Consequently, Miao patterns exhibit more free and bold abstraction, generously reflecting embroiderers' imaginations.

# 7.1 Evolution and Transformation of the Miaolong

Miao women believe that anything capable of transforming into a dragon must have already attained divine status. Many dragon forms found in Miao embroidery retain the original features of the animals from which they originated. According to the legend, the transformation process was interrupted by chance events, leaving insufficient time for "cultivation," resulting in a lack of vital energy. Consequently, it is difficult for these beings to fully transform into a typical dragon form (Yang, 1992).

In Miao culture, the abilities and statuses of dragons vary according to their evolution and transformation. Notably, dragons with ox heads are considered to have higher status than those with ordinary dragon heads. This is because dragons with oxheads are believed to be more powerful and sacred. Therefore, in Miao embroidery, dragons with ox heads are depicted as

more ferocious and majestic than ordinary dragons. The form of the dragon symbolizes its status and abilities, reflecting the culture and beliefs of the Miao.

In Miao culture, dragons are not merely mythical creatures but play an important role as embodiments of spiritual power.

#### 7.2 Dragon Patterns Reflecting Worldview and Daily Life

As a mountain-dwelling ethnic group in China, the Miao have developed a unique sensibility and rich expressiveness in their designs based on their geographical environment and historical background. In particular, the complex and diverse designs seen in the dragon patterns are deeply rooted in their worldviews and daily lives.

Their designs reflect a strong awareness of harmony with nature and the belief that all elements of the natural world possess souls. For example, dragons embroidered on Miao clothing are not merely decorative but represent the forces of nature and spirits, symbolizing their spirituality and beliefs. The parts of the animals combined in Miaolong are closely related to their everyday lives; for instance, snakes, centipedes, birds, and fish are commonly observed in their daily surroundings. By incorporating these animals, their designs connect with their culture and imbue them with various symbolic meanings. These designs are closely linked to their daily lives, with each pattern conveying specific meanings or stories.

The embroidery techniques and patterns of the Miao have been passed down through generations and serve as a means of preserving and conveying the community's history and traditions. This continuity of design strengthens their cultural identity and remains a crucial element in maintaining a unique culture despite external influences.

# 8. DISCUSSION 3: IMPACT ON MODERN DESIGN AND FUTURE PROSPECTS

The influence of Miao dragon patterns in contemporary design serves as a bridge that connects cultural traditions and innovation. Dragon patterns, with their unique formative characteristics and deep cultural meanings, have become a source of creative inspiration for many modern designers.

The Miao dragon patterns exhibit skillful simplifications and stylizations of their motifs. In particular, owing to the constraints of embroidery, designs are highly abstract, emphasizing essential features. The use of repetition and symmetry creates visual rhythm and harmony, providing consistency across the entire costume. These graphic elements transcend mere decoration, visually reinforcing Miao cultural identity.

Moreover, the specific classification of Miaolong clarifies how traditional Miao dragon patterns can be utilized as design elements. For instance, the unique shapes formed by the fusion of Miaolong with other animals offer new design motifs and themes. Complex traditional Miao dragon patterns can be abstracted into simple, symbolic forms in modern graphic design while retaining the meanings the Miao wish to express, paying attention to taboos in pattern combinations. This allows designers to incorporate these complex and beautiful patterns into their work, weaving cultural significance and symbolism into their designs. Using Miao dragon patterns serves as a means of preserving and introducing their history and traditional culture to the world. By applying these patterns to contemporary products, modern designers can play a crucial role in respecting Miao traditions while conveying their allure to new generations and diverse cultures.

# 9. CONCLUSION

Miao designs emphasize abstraction over figurative representation. In general Han culture, the dragon is a symbol of power, and common people are not allowed to use dragon patterns on their clothing. However, in Miao culture, it is permissible for women to embroider dragons in their garments, making the Miao dragon appear more approachable and familiar than the Han dragon.

This study demonstrates that the dragon patterns found in the costumes of the Miao people residing in Guizhou Province, China, are not merely decorative but deeply reflect their cultural identity. The representation of dragons among the Miao reveals unique cultural meanings despite being influenced by Han culture. The "Panlong" of the Miao is depicted as a dragon that does not ascend to heaven, reflecting the cultural influence of the Han, yet it is not entirely accepted. On the other hand, the "Miaolong" reflects the unique myths and traditions of the Miao and integrates various animal elements, playing an important role in their cultural identity.

The avoidance of combining cattle (Chi You) with birds (Jiuyou) stems from their profound cultural and mythological significance. These animals hold crucial positions in Miao mythology and mixing their symbolic meanings dilutes their spiritual significance. Thus, the Miao maintain their cultural identity by reflecting on past traditions and myths in contemporary times, preserving their unique cultural expression.

This research proves that the representation of dragons in the Miao tradition goes beyond mere decoration or aesthetics and reflects deep cultural foundations and traditional values. These representations serve as a means for the Miao to establish and maintain their identity; thus it is essential to understand their cultural meanings in order to comprehend Miao society and culture as a whole. By understanding and classifying these combinations, it is possible to accurately assess the rich cultural heritage of the Miao. Traditional Miao patterns can be applied in modern contexts, enabling the transmission of Miao culture in a contemporary design while respecting traditions. Furthermore, Miao pattern designs can be integrated into modern designs without employing the traditional perspective techniques used in general drawing methods. Instead, they utilize flat and bold stylization, preserving the formative characteristics of the depicted animals and offering a new graphic that combines harmony and re-abstraction.

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# PROPOSAL OF ORGANIZATIONAL DESIGN OF "INJECTING INTENT" FOR BOTTOM-UP BASED PURPOSE-DRIVEN MANAGEMENT CULTIVATING A SENSE OF UNITY AND ENHANCING VISIONARY KANSEI FROM THE BUSINESS UNIT

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#### ABSTRACT

In contemporary corporate management, enhancing employee engagement is critically important. This study aims to introduce and evaluate the effectiveness of a practical approach that strengthens departmental cohesion and revitalizes purpose-driven management through the "unity of mind" based on project-specific vision statements within each department. By incorporating new intentions into the existing corporate management philosophy, we strive to deepen employees' connection with the company's guiding principles and enhance their engagement by sharing its purpose. This study proposes the design of organizational systems that revitalize purpose-driven management. First, we build a system where project team members within departments formulate their own team vision, promoting more proactive and autonomous task engagement. Next, we develop a system that revitalizes the existing corporate purpose into current value through project activities within departments, and makes this recognized by the executive level.

*Keywords:* Purpose-driven management, Engagement, Visionary Kansei, Departmental Visionary Partner (DVP)

# 1. INTRODUCTION

Purpose-driven management refers to an approach where a company places social responsibility and purpose at the core of its management strategy. This has become a crucial element in the modern business environment, with many Japanese companies focusing in this direction. However, many Japanese companies are still exploring concrete methods to achieve purpose-driven management. Generally, companies publish their philosophies and purposes on their websites, but these are not always fully understood and shared among employees. This gap presents a significant challenge for companies.

In business, it is assumed that companies are established with defined management philosophies, purposes, and reasons for existence. However, these are often not well understood by employees. The dissemination of management philosophy within an organization has been a longstanding issue and remains a new challenge. Today, it is not enough for a company's purpose to be solely profit-driven; it must also gain empathy from both customers and employees. The reason for this shift is that the value of goods and services has moved from functional value to semantic value, questioning the existential significance of companies that create semantic value. However, the traditional top-down approach has limitations in promoting the purpose and improving employee engagement. This is because today is the "era of respecting individuals," and

**KEER 2024** | 10TH INTERNATIONAL CONFERENCE ON KANSEI FOR SUSTAINABILITY AND INNOVATION 2024 without respecting employees, it is difficult to achieve engagement, and consequently, Purposedriven Management. Peter Senge pointed out in his book "The Fifth Discipline" published over 30 years ago that the top-down approach does not resonate with employees.

Therefore, it is necessary to consider methods other than the top-down approach, specifically the bottom-up approach. Japanese companies have a track record of promoting business using the bottom-up approach during the period of rapid growth after World War II. A famous example of the bottom-up approach is the "Amoeba Management" by Kyocera's founder, Kazuo Inamori. Recently, Inamori's successful restructuring of Japan Airlines (JAL) is also known as a success story. The JAL restructuring case is not only an example of management improvement but also a successful case of enhancing employee engagement. The JAL restructuring was achieved by clarifying each employee's personal perspective of "how they want to be," fostering empathy among employees, and eliciting creative ideas for business restructuring. The JAL restructuring case emphasized the "unity of mind" among frontline employees, leading to improved employee engagement.

# 2. PURPOSE OF THE STUDY

This study focuses on the issue that a company's philosophy and purpose are not effectively communicated to frontline employees. The lack of shared vision between management and employees underlies this problem. This gap is particularly pronounced in environments such as new business development departments, where creativity and innovation are essential. Companies need to find ways to understand the values and individual purposes of frontline employees and integrate them into the company's philosophy. The purpose of this study is to propose a bottom-up based purpose management approach and to demonstrate that for the company philosophy to penetrate, it is important for employees to actively and dynamically make sense of the purpose through their activities on the ground. To verify the effectiveness, the study will use the following methods. In a project-based learning (PBL) format in a graduate course, teams will create business plans. After the PBL session, each team will evaluate their own activities, and the instructor will provide a relative evaluation of each team's "unity of mind." This will clarify the impact on team performance and engagement.

# 3. INSIGHTFUL PRECEDENTS

#### 3.1 Microsoft and Sony Cases

In addition to Kyocera and JAL, there are other recent examples of insightful internal corporate reforms related to purpose-driven management and engagement, such as the cases of Microsoft and Sony. Microsoft's CEO, Satya Nadella, has emphasized a management style that prioritizes empathy and kindness, referring to himself as the "Chief Empathy Officer." It is crucial for a company's business strategy and model to reflect its purpose in some form. Similarly, former Sony CEO Kazuo Hirai expressed the value Sony aims for with the word "Kando (Emotional involvement)". Hirai visited Sony offices and factories worldwide, holding town hall meetings to help employees understand the direction Sony should take.

# **3.2** Emotional Domains

As the pace of generative AI evolution accelerates, it has become clear that there are areas beyond generative AI's reach. These include empathy, relationships, physical sensations, and aesthetic sensibilities, which are part of human cognition—referred to as the "emotional **KEER 2024** | 10TH INTERNATIONAL CONFERENCE ON KANSEI FOR SUSTAINABILITY AND INNOVATION 2024 domain." Employee engagement is inherently linked to these personal emotional domains. In an era where generative AI usage in business is becoming commonplace, the importance of the emotional domain is increasing.

With technological advancements, companies must practice "purpose-driven management." Managers need to recognize the importance of human sense-making and knowledge creation activities that cannot be replaced by generative AI. These activities mainly occur within project teams in each business unit. The kansei, emotions and thoughts of employees within these project teams act as "sensors" for the company and should be effectively utilized as management data. If this is overlooked, the feasibility of achieving company-wide purpose-driven management is compromised.

# 3.3 Insights from the Efforts of Two Global CEOs and Peter Senge's Suggestions

Future business leaders must embody the "emotional cohesion" of their teams and business units. In this study, this concept is referred to as "Visionary Kansei." This principle highlights the importance of understanding the emotional and cognitive aspects of employees and aligning them with the organization's broader goals and objectives.

This study focuses on the issue that a company's philosophy and purpose are not effectively communicated to frontline employees. The lack of shared vision between management and employees underlies this problem. This gap is particularly pronounced in environments such as new business development departments, where creativity and innovation are essential. Companies need to find ways to understand the values and individual purposes of frontline employees and integrate them into the company's philosophy.

# 4. APPROACH TO THE PROPOSED SOLUTIONS

# 4.1 PROPOSAL OF SOLUTIONS TO CHALLENGES

This study proposes an approach to "injecting intent" into on-site projects to align them with the company's philosophy and purpose. This allows employees to connect their sense of values with the company's goals, resulting in deeper engagement. It is crucial to build a shared vision within project teams. Specifically, leveraging sense-making theory, employees should create and internalize team vision statements through their own sense of values.

Next, it is recommended to periodically review and update the team vision statements during project activities. This ensures the statements reflect the current emotions of team members. Additionally, as the project progresses, it is important to encourage employees to relate and interpret the company's philosophy through the team vision statements. In previous research, each team's self-evaluation using rubrics was a subjective assessment of understanding the SECI model, self-understanding, member understanding, and agreement with the team vision statement based on the SECI model. In this study, we conducted a QCA (Qualitative Comparative Analysis) on the "cohesiveness" of each team. There are two types of evaluation methods: evaluation by team members and evaluation by faculty. The faculty combines the average score of each team's self-evaluation with the evaluation score based on the faculty's observation of each team's activities, and then performs a relative evaluation of each team using QCA.

Step 1: Team members perform self-evaluation (5-point scale) by ICE Rublic.

**KEER 2024** | 10TH INTERNATIONAL CONFERENCE ON KANSEI FOR SUSTAINABILITY AND INNOVATION 2024 The average score of the member evaluations becomes the team score.

Step 2: The faculty performs a relative evaluation of each team by QCA.

# 4.2 Appointment of "Divisional Visionary Partners" in Business Units

Considering the physical and psychological distance between project sites and management, it is proposed to appoint "Divisional Visionary Partners (DVP)" within business units. The role of DVP promotes communication between project sites and management, enabling employees to actively contribute to the company's purpose through their kansei, experience and knowledge. The appointment of DVPs should ideally be from within the business unit for the following reasons. First, they have a deep understanding of the business unit's activities. Second, they are wellacquainted with the members of each project, facilitating communication and extracting honest feedback. Furthermore, the role of DVPs serves as a training ground for future executive candidates. Through their experience in communicating with management, understanding, and relaying information to both management and on-site staff, they can develop into potential executive candidates.

# 4.3 Roles of DVPs

The role of DVPs was proposed to manage the "unity of mind" within business units.

The roles of DVPs include:

• Engagement Advisor: Reporting the status of projects within the business unit to management and department leaders, and providing advice on engagement.

• Monitoring Team Vision and Kansei: Understanding the purposes, visions, emotions and goals of each project within the business unit, ensuring they align with the projects, and taking actions to enhance engagement.

• Enhancing Unity of Mind: Monitoring and comparatively evaluating the "unity of mind" within each project in the business unit. If negative factors are identified, providing opportunities for dialogue with team members to discuss and implement countermeasures.

• Organizational Development: Reporting any issues within organizational activities in the business unit to the business unit head, and formulating and implementing strategies to improve the outcomes of each project.



Figure1. The Role of DVP in the Business unit

#### 4.4 ICE Rubric as a Self-Evaluation Method for Team Members

To develop methods for nurturing team vision within each project in the business unit, practical applications were simulated in project-based learning (PBL) activities at the graduate level, as demonstrated in papers presented by the author at ISASE 2021 and IJAE 2022. Furthermore, after the PBL sessions, a rubric was used to allow team members to self-evaluate the achievement of their business plans and activities based on the team vision. While the rubric is suitable for self-evaluation of achievement levels, it is not appropriate for the relative evaluation of PBL activities by team members or instructors.

In the ISASE 2021 study, the author developed a qualitative ICE rubric as shown in Table 1. ICE stands for Ideas, Connections, and Extensions. ICE is a learning method, and the ICE rubric is an evaluation method. The integration of learning and evaluation in the ICE rubric offers the advantage of making learning and assessment "visible." The purpose of this ICE rubric is for project members to qualitatively self-evaluate their understanding and achievement of various items related to the project activities process.

If a DVP wants to provide appropriate guidance based on the learning progress of team members, the ICE rubric is useful. This is because the ICE rubric can clearly identify where and how team members stumbled in each area, as well as the reasons behind it.

Evaluation Items	Level1	Level2	Level3
Understanding of SECI model	Understand an overview of SECI model	Understand SECI model as it applies to PBL activities	Understand the cycle of SECI model in PBL activities
Understanding of "Socialization"	Understanding the meaning of "Socialization"	Realize through the experience of "Socialization"	Realize more through PBL activities
Understanding of Self- awareness	Understanding of The importance of Sense of values	Understand the changing sense of values of self	Understand universal sense of values
Understanding of selection of value words of self	I just marked the value words that Intuitively ring a bell	Consider the meaning of the relevance of the selected value words	Convince yourself to think about the implications of the value words you choose
Understanding of value statement development	Imagine what the selected value words remind you of	Explore value statement consistency while trying to connect the value words	Revise value statement to make it more convincing
Understand and respect other's sense of values	I was able to get a vague impression of another person's personality	I have some understanding of member's personality	Understand members' personalities and collaborate with them rather well
Create the team vision statement	Write down what each person has in common while interacting with each other	Write down the common elements of each person and connect them to form one sentence	Based on the tentative statement, make sure everyone agrees on the vision statement

Table1. ICE Rubric for deepening Sense-making in PBL

# 4.5 QCA (Qualitative Comparative Analysis) as a Method of Relative Evaluation

The role of the DVP is to monitor and enhance the level of "unity of mind" and cohesion among multiple teams within the business unit, and to evaluate the achievement levels of each project.

Therefore, in this PBL, QCA (Qualitative Comparative Analysis) will be used for the relative evaluation of teams, simulating the role that instructors should play in place of the DVP. Qualitative Comparative Analysis (QCA) is a method that identifies sufficient and necessary conditions for a certain 'outcome' through the extraction of commonalities in conditional configurations. It is said that QCA represents a middle ground between quantitative and qualitative research, mitigating the challenges of both. Furthermore, QCA is applicable to relatively small samples, and is suitable for N=5 to 50. However, in PBL in the study, a comparative evaluation of 6 teams is planned. It should be noted that QCA does not identify the mechanisms that produce the results, but is rather a technique for extracting the conditions that lead to those results. Table 2 presents the constituent factors for DVP to comparatively evaluate the 'Heart unity' of each project team using QCA. As constituent factors, the following eight elements are assumed in the study.

	Constituent Factors of QCA
1.	Understanding and respecting values
	among members
2.	Agreement and passion for the team
	vision statement
3.	Psychological safety
4.	Communication level (degree of
	communication within the team)
5.	Synchronicity and alignment between the
	team vision statement and project
	activities
6	Project progress

Table2. Constituent Factors of QCA for monitoring by DVP

# 5. THE RESULTS OF PBL SESSION IN LECTURE

# 5.1 Each Team's Self-evaluation by Participating students

The author utilized the above ICE Rublic in the PBL session of Entrepreneurship at Tokyo University of Agriculture and Technology in February in 2024. Participating students are briefed in advance on the SECI Model, Self-Awareness and the purpose of creating team vision statement before participating in the work. As Table3 shows, the author asked the students the self-assessment after the completion of PBL session.

#### Table3. Result of self-assessment on gaining deeper understanding

Evaluation of items	Unchanged	Level1 to Level2	Level2 to Level3	Level1 to Level3	Progress Ratio
Understanding of SECI Model	0%	80%		20%	100%
Understanding of Socialization	40%	20%		40%	60%
Understading of Self-awareness	0%	20%	20%	60%	100%
Understanding of selection of value words	0%	20%	40%	40%	100%
Understanding of Value Statement Development	0%	20%	40%	40%	100%
Understanding of others values	0%	20%	20%	60%	100%
Create Team Vision statement	0%		20%	80%	100%

of Team Vision Statement and Sense-making

The results showed that the understanding of self-awareness and sense-making deepened in each evaluation item before and after the project work. The improvement rate in understanding for each evaluation item, except for "Socialization," reached 100% before and after the start of the PBL. The proportion of understanding of the team vision statement that improved from level

1 to level 3 is 80%. These self-evaluation results from each team indicate a high degree of collective sense-making within the teams.

# 5.2 Comparative evaluation of PBL teams by instructor

Based on the components in Table 2, the author conducted a comparative evaluation of each team's activities in the PBL sessions of the graduate course. The results of this evaluation were processed (converted to 0s and 1s) to be readable by the QCA tool. These analysis results are presented in Figure3. fsQCA targets the analysis of a complete truth table that shows the combination patterns of causal conditions and outcomes. This truth table is created based on the results of fsQCA and the analyst's judgment. While the software tools partially assist in the process, the final determination of values (1 or 0) in the "Results" column is made by the analyst. Therefore, the results reflect the analyst's subjective judgment and are converted into values (0 and 1) to be readable by the QCA tool.

Figure 3 displays the intermediate solutions of the analysis results. The coverage and consistency of each solution are as follows:

Solution Coverage: 0.857143

Solution Consistency: 1

These solutions indicate how the combination of each factor forms a "sense of unity." All solutions have high coverage and consistency, demonstrating that these factors function effectively. Based on the fsQCA analysis results of this study, it was confirmed that certain factors are important for forming a "sense of unity" in project activities. The intermediate solutions identified several patterns in which these factors combine to form a "sense of unity." Particularly, assuming the presence of all factors, the high coverage and consistency suggest that these factors function effectively.

URV	VS	PS	CL	SA	PP	*TRUTH TABLE ANALYSIS*
1	1	1	1	0	0	***********
1	1	1	1	1	1	File: C:/Users/takah/Desktop/QCAData/truthtablewith 6variablesv2.csv Model: Regults = f(IDV_VC_PS_CL_SA_PD)
1	1	1	1	1	0	Algorithm: Quine-McCluskey
0	0	0	0	0	0	COMPLEX SOLUTION frequency cutoff: 1
1	0	0	0	0	0	consistency cutoff: 1
0	1	0	0	0	0	coverage coverage consistency
1	1	0	0	0	0	URV*VS*PS*CL*SA 0.285714 0.142857 1 URV*VS*PS*CL*PP 0.285714 0.142857 1
0	0	1	0	0	0	URV*VS*P5*SA*PP 0.285714 0.142857 1 URV*VS*CL*SA*PP 0.285714 0.142857 1
1	0	1	0	0	0	URV*PS*CL*SA*PP 0.285714 0.142857 1 solution coverage: 0.857143
0	1	1	0	0	0	solution consistency: 1
1	1	1	0	0	0	*****
0	0	0	1	0	0	*TRUTH TABLE ANALYSIS*
1	0	0	1	0	0	File: C:/Users/takah/Desktop/QCAData/truthtablewith 6variablesv2.csv
0	1	0	1	0	0	Model: Results = f(URV, VS, PS, CL, SA, PP) Algorithm: Quine-McCluskey
1	1	0	1	0	0	PARSIMONIOUS SOLUTION
0	0	1	1	0	0	frequency cutoff: 1 consistency cutoff: 1
1	0	1	1	0	0	raw unique coverage coverage consistency
0	1	1	1	0	0	URV*VS*PS*CL*SA 0.285714 0.142857 1
0	0	0	0	1	0	URV*VS*PS*CL*PP 0.285714 0.142857 1 URV*VS*PS*SA*PP 0.285714 0.142857 1

Figure2. Complete Truth Table and Analysis result of fsQCA

*TRUTH TABLE ANALYSIS* C:/Users/takah/Desktop/QCAData/truthtablewith 6variablesv2.csv File: Model: Results = f(URV, VS, PS, CL, SA, PP) Algorithm: Quine-McCluskey INTERMEDIATE SOLUTION frequency cutoff: 1
consistency cutoff: 1 Assumptions: URV (present) VS (present) PS (present) CL (present) SA (present) PP (present) raw unique coverage coverage consistency URV*VS*PS*CL*SA 0.285714 0.142857 URV*VS*PS*CL*PP 0.285714 0.142857 URV*VS*PS*SA*PP 0.285714 0.142857 1 URV*VS*CL*SA*PP 0.285714 0.142857 URV*PS*CL*SA*PP 0.285714 0.142857 1 solution coverage: 0.857143 solution consistency: 1



#### 6. CONCLUSIONS

This study proposes a bottom-up purpose-driven management approach to enhance team cohesion and employee engagement within corporate departments, rather than adhering to traditional top-down purpose-driven management approaches. However, it should be noted that this approach is based on the implementation results of PBL in graduate school lectures, and it is difficult to conclude that employees can engage deeply with the company's management philosophy and share its purpose to work more proactively and autonomously.

From the PBL implementation results, the following key conclusions were partially derived. First, by clearly defining and regularly reviewing and updating their vision, project teams can enhance their cohesion and purpose-driven orientation. If this is practiced within a company, it is expected that employees will be able to connect their individual values with the company's purpose, promoting deeper engagement.

Second, conceptually, appointing a "Visionary Partner (DVP)" within business units to facilitate communication between project sites and management, and utilizing on-site experiences and knowledge is essential. However, this was not verified in the PBL of graduate school lectures. The DVP reports the on-site situation to the management and provides advice to enhance engagement. Additionally, the DVP plays an important role in developing future executive candidates and acts as a bridge between management and the field.

Furthermore, combining ICE rubrics and QCA (Qualitative Comparative Analysis) introduced a method to qualitatively and quantitatively evaluate and compare the "mental cohesion" of project teams. This evaluation method allows for the visualization of each team's activity outcomes and cohesion, enabling effective feedback. This allows team members to reflect on their activities, identify areas for improvement, and increase the success rate of projects. The significance of this study lies in providing specific methods based on a bottom-up approach, different from the traditional ones, to realize purpose-driven management in companies. It

respects the values and opinions of each employee, aiming for the permeation of the management philosophy and the enhancement of engagement. Implementing it within a company is not easy. Although this sounds ideal, it requires a commitment to and execution of a shift in awareness by management, as well as the delegation of authority to each business unit. However, as an initiative to pursue a purpose across the company and achieve sustainable growth, it is well worth attempting.

Future challenges include further verifying how the role and activities of the DVP function in an actual corporate environment. Additionally, it is important to apply the evaluation methods of ICE rubrics and QCA to actual corporate business units to confirm their generalizability and effectiveness.

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# RESEARCH ON THE DEVELOPMENT OF AUDIO GAMES AND VISUAL STIMULI IN AUDIO GAMES

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# ABSTRACT

Audio games, which can be played using only auditory information without any visual cues, have been primarily developed by creators with visual impairments. These games offer a unique gaming experience not only to visually impaired individuals but also to sighted people. However, the number of existing audio games is still small, making it challenging to fully understand their potential. In this study, we first created an audio game to understand its characteristics and held an exhibition. Feedback from visitor surveys and observations at the exhibition suggested that incorporating decorative visual information could help balance concentration and reduce stress for sighted players. Therefore, a preliminary experiment was conducted to investigate whether different types of display screens affect players' experiences.

Keywords: Audio game, Inclusive design

# 1. INTRODUCTION

In the gaming field, where content is often produced with a focus on visual information, on the other hand, games designed with the premise of being played through auditory information have also evolved, primarily driven by game developers with visual impairments.

These games, called audio games, are attracting attention as a new experience that allows players to concentrate only on auditory information, enabling a wide range of people, including those with visual impairments, to enjoy them. Audio games contribute to the expansion of gaming culture. However, as a new field, the number of games currently announced as audio games is relatively small, and those that require proprietary controllers can only be played in limited times and spaces, such as event venues. Therefore, it is difficult to grasp the reality of audio games. In this research, we aim to understand audio games and create new audio game content. We will also discuss the potential for further development in this area.

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# 2. CHARACTERISTICS OF AUDIO GAMES SEEN FROM PRECEDENT EXAMPLES

For visually impaired individuals to play games, there are information summary sites such as "Game Accessibility Information Summary Site" and "Audio.game.net" that can be referenced when choosing games. The former introduces existing video games with excellent accessibility that can also be played by visually impaired people. By browsing this website, it becomes clear that there are not many video games that can be played without using vision at all. The latter features more than 500 audio games designed to be played solely with sound. These games are created with the premise of being played with auditory information only, making them extremely difficult for people without disabilities. In response to this issue, Matsuo (2016) developed a barrier-free game that can be played by both people with and without disabilities in a similar manner.

Audio games have primarily been developed to improve the accessibility of video games. In other words, their design has remained limited to serving as an alternative means of conveying information, failing to fully capitalize on the unique entertainment value of audio games. This research aims to explore the potential for new entertainment experiences by maximizing the inherent appeal of audio games. We will create game designs specialized for auditory experiences and use them to consider the characteristics and the future development of audio games.

The design of audio games either remains as an alternative to visual information or has become quite difficult for people without disabilities, such as those unfamiliar with the format, to play. This research aims to maximize the inherent appeal of playing with auditory information alone and to design games that are also easy for people without disabilities to play. Additionally, we would like to use this to consider the characteristics and further development of audio games.

# 3. AUDIO GAME EXAMPLE FOR DEVELOPMENT

In this chapter, we want to extract themes that are well-suited for audio games from existing works to create new audio games. Considering the appeal of audio games and focusing on iOS applications that are easy for people without disabilities to play, we looked at the following two examples:

#### 3.1 Blind Drive

Players drive a car in reverse while blindfolded. By carefully listening to the sounds of approaching cars from the front, players must steer to avoid colliding with them.

#### 3.2 A Blind Legend

Players become a blind knight and, relying on sound, swing their sword to defeat enemies in this action/adventure game.

# 3.3 Theme Selection

By playing these existing games, we felt that the fun lies in "creating spatial awareness in one's mind" and "distinguishing different sounds," making these well-suited themes for audio games.

# 4. PROTOTYPE DEVELOPMENT

To objectively examine how audio games are perceived and what features they have, we developed prototype games and held an exhibition. When creating the prototypes, we based them on the two themes that emerged in Chapter 3:

# 4.1 Sonar in the A.

The player is trapped in a pitch-black maze. The maze takes the shape of one of the 26 letters of the alphabet. Relying on sound to perceive the location of the walls, the player explores the maze with the goal of guessing which letter shape it forms. This work focuses on "creating spatial awareness in one's mind."



Figure 1. Screen of Sonar in the A.

# 4.2 Play REC!

After listening to a sample sound, the player recreates that sound using nearby objects. For example, if the sample is a soft cloth being tapped with a wooden stick, the player might tap a tissue or their own clothing with a pen. The similarity between the sample and recreated sounds is calculated, with the aim of scoring higher points. This work focuses on "distinguishing different sounds."



Figure 2. Screen of Play REC!

By developing and exhibiting these prototypes, we aimed to gain objective insights into the perception and characteristics of audio games.

#### 5. EXBITION





Figure 3. The scene at the exhibition

We exhibited the two works, Sonar in the A., and Play Rec! Many of the visitors were students from the University of Tsukuba, and after playing, they filled out comment sheets. Comments like "It was fun and challenging to create imagery using only sound" and "There was enjoyment in discerning subtle differences in sounds" indicated that players experienced the intended appeal we had envisioned when selecting the themes. Comments such as "My senses were sharpened," "Having only sound made me use my brain more," and "I was focused" suggest that audio games provided a fresh experience for those without disabilities.

On the other hand, there were also negative comments like "Without any visual information, it was difficult to understand at first" and "Understanding the rules was hard." This reveals that for people accustomed to relying on vision, having some supplementary or decorative visual information for non-gameplay elements like the opening screen or rule explanations would be beneficial. Additionally, we found that audio games require short-term memory skills, so complex game systems are more likely to cause confusion compared to video games.

At the exhibition, more people preferred Play Rec! over Sonar in the A. Possible reasons for this include Play Rec! providing some visual aid by using physical objects, and that high listening ability was not strictly necessary for gameplay progression.

#### 6. EXPERIMENT

From observing visitors at the exhibition and conducting case studies, we found that the absence of screen information could cause anxiety. Therefore, we conducted a simple experiment to determine what type of screen display could reduce this anxiety while allowing players to concentrate on the audio during gameplay.

#### 6.1 Procedure

Six university students were asked to play our self-made audio game "Sonar in the A". Three stages were prepared, and the display shown was changed for each stage. Considering the influence of color, three types of displays were used: a solid dark screen, a monochrome video, and a monochrome still image.



Figure 4. Display Images (Left: Dark, Center: Video, Right: Still Image)

# 6.2 Evaluation

After playing each of the three stages, the participants were asked to respond to a survey. To assess immersion and comfort levels, a Japanese version of the survey was created, referring to items from Yamamoto (2021) and Brockmyer (2009). The rating was on a 5-point scale from "1. Disagree" to "5. Agree."

Additionally, to obtain objective data, brainwave measurements were conducted using EEG (electroencephalography) alongside the survey.

Survey Items	Number	Question Content					
De sie hefe werdtie e	1	Participant Number					
Basic Information	2	About Your Gaming Habits					
	3	Feel disconnected from your surrounding environment					
	4	Gameplay time felt long					
	5	Could concentrate on distinguishing sounds					
During Comparison	6	Felt it was difficult					
During Gameplay	7	Felt irritated					
	8	Felt bored					
	9	Felt anxious					
	10	Felt a sense of oppression					
After Comenlay	11	Felt a sense of satisfaction					
After Gameplay	12	Felt exhausted					

#### Table 1. About the Survey Items

#### 6.3 Result

No.	Stage No.	di	sconnec	ted	с	oncentra	ite		irritated			anxious		o	ppressio	n
		Dark	Video	lmage	Dark	Video	Image	Dark	Video	Image	Dark	Video	Image	Dark	Video	Image
	1	3			3			1			2			2		
1	2		2			L			1			3			2	
	3			2			5			1			2			1
	1	2			2			2			2			2		
2	2			2			2			2			4			2
	3		2			2			2			2			2	
	1		5			1			3			4			4	
3	2	3			4			1			2			5		
	3			3			4			4			2			3
	1		3			5			2			4			2	
4	2			4			4			2			2			2
	3	4			4			3			4			4		
	1			1			5			1			1			1
5	2	2			5			1			1			1		
	3		1			2			1			2			1	
	1			3			2			4			3			3
6	2		2			2			2			2			1	
	3	4			3			4			3			1		

Table 2. Values for Each Item



Figure 5. Comparison of Average Values for Each Item

The average of each survey item was taken and the differences according to the type of display were compared. Particular attention was given to items where the difference in average values was 0.5 or more.

Regarding the sense of being isolated from the surroundings, the average value for videos was lower than the average values for the other two screens. (Others > Video) Looking at the breakdown, 4 out of 6 people rated the video lower than the completely dark screen. When comparing still images to videos, 3 out of 6 people gave a lower rating to the video.

In the question about concentration on sound, the average value for still images was higher than the average value for videos. (Still images > Video) Looking at the breakdown, 2 out of 6 people rated the still images higher than the video. When asked for their impressions after playing the game, those who rated still images higher than videos mentioned that their thoughts were distracted by the movement within the video.

For the question about frustration during gameplay, the average value for still images was higher than the average value for videos. (Still images > Video) Looking at the breakdown, 2 out of 6 people rated the still images higher than the video.

Regarding anxiety, the average value for videos was higher than the other two. (Video > Others) Compared to the completely dark screen, 3 out of 6 people gave higher ratings to the video, and compared to still images, 4 out of 6 people gave higher ratings to the video. However, in their impressions after playing, 4 out of 6 people answered that they liked the video the most, and among them, 3 had rated the video as more anxiety-inducing than the completely dark screen or still images in the survey.

Regarding the sense of oppression, the average value for the completely dark screen was higher than the other two. (Dark > Others) Compared to still images, 3 out of 6 people, and compared to videos, 2 out of 6 people gave higher ratings to the completely dark screen.

#### 6.4 Discussion

Regarding the question about the sense of being isolated from the surroundings, 4 out of 6 people rated the video lower than the completely dark screen. it is unclear whether the results indicate a decrease in immersion or a reduction in feelings of loneliness or uneasiness. A more detailed evaluation of the survey is necessary for this experiment.

In the question about concentration on sound, the average value for still images was higher than the average value for videos. Considering the breakdown, the number of people who rated it higher was less than half, suggesting that the large variance in these two responses affected the average value. Impressions after gameplay suggested that the type of screen might affect concentration on sound during gameplay.

On the other hand, regarding the question about frustration during gameplay, the average value for still images was higher than that for videos. Given that the number of people who rated it higher was less than half, the large variance in these two responses likely influenced the average value. In terms of frustration, factors other than the differences in the display screen, such as the game stage, might also be influential. Stage 1 of the game is the easiest, while Stage 3 is relatively difficult. Therefore, Stage 1 might lead to stress from unfamiliar controls, and Stage 3 might lead to stress from increased difficulty, which could elevate the ratings.

Considering the game stages played by the two people who rated still images higher than videos, one played Stage 1 and the other played Stage 3 of the still images. It is possible that the stressful stage led to a higher level of frustration with the still images.

Regarding the question about anxiety, the average value for videos was higher than the other two, but in impressions after gameplay, 4 out of 6 people answered that they preferred the video the most. This suggests that anxiety can be broadly divided into "anxiety about the game system" and "anxiety felt as a part of the presentation." The increased anxiety from the video likely pertains to the latter, with no strong impact on the former, which is why many people rated the video as the most preferable. Additionally, the evaluation of "anxiety about a completely dark screen" was not high. This is believed to be due to the careful explanation of how to play the game before the experiment. At the exhibition, I could not thoroughly explain how to play the game, so players needed to actively understand the game. In this experiment, the clear and careful explanation of how to play might have reduced "anxiety about the game system," leading to higher ratings.

Regarding the sense of oppression, the average value for the completely dark screen was higher than the other two. It is possible that the black color, being very intense, caused a sense of oppression, but the number of respondents is small, so no definitive conclusion can be drawn.

# 7. CONCLUSION

At the exhibition using a self-made audio game, it was shown that audio games, a genre developed primarily by and for visually impaired individuals, can provide a fresh gaming experience to sighted people as well. While audio games have their own unique appeal, the lack of visual information often makes it difficult to understand the rules and gameplay. Therefore, a preliminary experiment was conducted based on the hypothesis that incorporating supplementary or decorative visual information during gameplay could reduce the anxiety and stress felt by sighted players. The survey results suggested that the gameplay screen might influence concentration on sound.

# 8. LIMITATIONS AND FUTURE WORKS

The preliminary experiment had a small number of participants, so the results cannot be considered universal. In the future, we aim to analyze the degree of concentration on sound and stress levels using the brainwaves measured during the preliminary experiment, focusing on the types of screens presented. Additionally, despite many participants expressing a preference for videos in their post-play impressions, there were also comments about the distracting nature of video movement. Therefore, we want to revise our experimental methods to determine which types of videos are most effective during gameplay.

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# EFFECTS OF VISUAL AND AUDITORY STIMULI ON SILENCES DURING MULTI-PERSON COMMUNICATION TO PROMOTE SPEECH

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# ABSTRACT

In online communication, the presentation of stimuli effective for promoting speech has been explored. This study focuses on elements within conversation, such as the duration of silences, and proposes methods for presenting visual and auditory stimuli, examining their effectiveness. The results showed that visual stimuli, using a "noticeable flicker" that blinks twice within 800ms at a frequency of 2.5Hz, enhanced visibility and were effective when presented in response to individual silences. For auditory stimuli, short alarms were found to be suitable for actively encouraging speech, while ambient sounds such as cafe noises were found to be suitable for passively creating a conversational environment.

Keywords: online communication, silences, visual and auditory stimuli

# 1. INTRODUCTION

In recent years, in the wake of the remote culture brought about by COVID-19, there has been an increase in online communication at school and at work. The advantages of online communication include not having to secure a specific location, no need to worry about the physical state of participants, and the ability to present all materials onscreen.

In this context, situations where group discussions are conducted solely via audio have also increased. In such circumstances, it becomes difficult to discern responses, hindering conversation progress, and often leading to the 'facilitator' feeling stressed about needing to manage the balance of speaking turns without visible progress (Yomiuri Shimbun Education Network, 2020).

In a previous study by David et al., 2017, a table device that indicates the frequency of speech in a meeting room was used to facilitate conversation. Furthermore, research by Tasaka et al., 2021, investigated the impact of background noise on communication and reported that employing ambient sounds promotes communication. Thus, this study focuses on online

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discussions and proposes that presenting appropriate stimuli to online speech elements could potentially enhance conversation in online settings.

This research investigates the relationship between various elements within group conversations online, such as speech frequency, direction of speech, and the duration of silences, and the speakers' impact on the conversation. Based on the findings, this study aims to propose visual and auditory stimuli designed to promote speech and to verify their effectiveness.

# 2. EXPERIMENT 1: THE RELATIONSHIP BETWEEN SILENT ELEMENTS IN CONVERSATION AND SPEAKER IMPRESSION EVALUATION

#### 2.1 Overview of the experiment

The purpose of this experiment was to investigate the relationship between various elements in conversation, such as speech frequency, directionality of speech, silence duration and frequency, and the impact of the speaker on the conversation, based on online group discussions among three groups.

Eleven university students, both male and female, were selected as subjects and randomly divided into three groups of three to four each (A, B, C): Group A consisted of four members, three of whom were acquaintances; Group B consisted of three members, two of whom were acquaintances; Group C consisted of four members, none of whom were acquaintances.

With the subjects' consent, they were asked to engage in approximately 10 minutes of conversation using only microphones, without cameras, on three prepared topics. After each conversation, subjects rated their experience on a four-point scale based on five questions: "vivacity of the conversation," "depth of content," "impression of the conversation," "frequency of silent moments," and "balance of conversation."

The three topics were selected based on a preliminary survey conducted among university students about topics for initial meetings under academic and school-related circumstances. They included "University life during the coronavirus pandemic," "How to spend holidays," and "Favorite prefectures."

To capture data on speech frequency and directionality during conversations, a web application called Hylable (Figure 1, Hylable Inc.) was used to graph the group conversations in real-time, allowing for online tracking of progress and recording and analysis of the conversations.

Additionally, a program was created using Python to automatically output the duration of silences by importing conversation data. For the analysis, the split_on_silence module from the pydub audio library was used to detect and split silent intervals in the audio. The criterion set was to split the audio if the volume dropped below -57 dBFS for more than 1500ms, with a grace period of 600ms. dBFS refers to the scale of volume handled in computers, with 0 dBFS being the maximum volume level.



Figure 1. Hylable call screen

#### 2.2 Results and discussion

Table 1 shows the number of silences and the proportion of each speaker's speech output in the conversation. When comparing these, it was found that in groups like Group A and Group C, where one person's share of speech output dominates much of the conversation, the number of silences decreases. This suggests that silences occur due to changes in speakers.

Group A	Number of silences	Silonco duration(s)	Percentage of speech output					
Group A			A1	A2	A3	A4		
1st	26	26.98	37%	19%	27%	17%		
2nd	19	18.94	16%	48%	23%	13%		
3rd	30	25.31	35%	22%	15%	28%		
Croup P	Number of eileness	Silonoo duration(a)	Percentage of speech output					
Group в	Number of sherices	Silence duration(s)	B1	B2	B3			
1st	21	21.44	44%	34%	22%			
2nd	20	24.98	31%	39%	29%			
3rd	24	27.33	40%	34%	25%			
Group C	Number of silences	Silonce duration(s)	Percentage of speech output					
Group C			C1	C2	C3	C4		
1st	29	41.63	21%	16%	13%	51%		
2nd	33	40.09	23%	24%	14%	39%		
3rd	17	25.36	16%	29%	39%	16%		

Table 1. Comparison of the number of silences and each speaker's speech output

Comparing groups, in Group A, a decrease in the number of silences correlates with a high percentage of speech output by one individual. However, in Group C, while the first conversation shows one individual accounting for 51% of the speech output with 29 silences, by the third conversation, this drops to 39% with 17 silences, showing no correlation. Considering the relationships within the group discussed in the previous section, in Group A, where relationships are already established, changes in speakers directly reflect the reduced silences. In Group C, being strangers initially, silences measured are not solely due to speaker changes. As the conversations continue, improvements in speech frequency and vivacity are observed, and it is speculated that silences increasingly reflect changes in speakers.

# 3. EXPERIMENT 2: PRESENTATION OF STIMULI FOR SPEECH PROMOTION AND ITS EFFECTS

#### 3.1 Overview of the experiment

This experiment aims to investigate effective stimuli for encouraging speech and activating conversation by utilizing the relationship between "conversation vivacity" and "silence duration" identified in Experiment 1.

The subjects consisted of fifteen university students in their twenties, both male and female, who were randomly divided into five groups of three people each, labeled Groups A to E. Each subject was assigned a separate room and PC, and they connected to the online meeting web application Hylable while wearing Elecom headsets (HS-HP28UBK). The experimenter, in a different room, remotely accessed the subjects' PCs to check the operation of the program and give instructions.

The topics of conversation were set to four subjects that are easy to discuss among peers and involve low levels of self-disclosure: "Research topics at university," "Hometown," "Stress relief methods," and "Values concerning ways of working." Subjects were asked to converse for 10 minutes on each topic, divided into two 5-minute halves, and they provided evaluations regarding the stimuli presented online during the conversation.

Additionally, during the conversation, visual and auditory stimuli were presented to the subjects in one pattern each for the first and second halves, totaling eight different stimulus patterns.

# 3.2 Settings for stimuli during conversation

**Visual stimuli:** Prior research (David et al., 2017, Tobitani et al., 2012) has reported that even with a constant cycle, a higher frequency leads to better visibility in "noticeable" blinking patterns. In this experiment, lights were set up to change the blinking speed, using these elements. Two types of visual stimuli were prepared: a "normal blink" that blinks once in 800ms at 1.25Hz, and a "noticeable blink" that blinks twice at 2.5Hz.

**Auditory stimuli:** Prior research by Tasaka et al., 2021, reported that adding background noise during online conversations can consistently enhance communication, including ease of speaking and transitions between topics. In this experiment, ambient sounds such as "cafe noises" were used, and more active stimuli were prepared, including "alarms (short tones)."

**Method of presenting stimuli:** In this experiment, to investigate whether the prepared stimuli affect the "activation of conversation" and to find effective methods of presentation, a combination of visual and auditory stimuli and presentation methods was used, presenting a total of eight patterns of stimuli to the subjects (Table 2). The experimental setup is shown in Figure 2.

Stimulus	s type	Stimulus	Trigger		
	Patterns 1	Noticeable blink	Group's overall silence duration		
Vicual etimuli	Patterns 2	Normal blink	Group's overall silence duration		
Visual sumuli	Patterns 3	Noticeable blink	Group's overall silence duration		
	Patterns 4	Noticeable blink	Each speaker's silence duration		
	Patterns 1	Cafe noises	Group's overall silence duration		
Aduio stimuli	Patterns 2	Alarm	Group's overall silence duration		
Audio Sumuli	Patterns 3	Cafe noises	Group's overall silence duration		
	Patterns 4	Cafe noises	Always play		

Table 2. Each stimulus and its trigger



Figure 2. Experiment showing the presentation of visual stimuli

#### 3.3 Results and discussion: Evaluation of visual stimuli

**Patterns 1 and 2:** To examine the impact of the visual stimuli used in Patterns 1 and 2, the number of responses was tallied, the average ratings were calculated, and a t-test was performed for significance testing.

In response to the question "What does the flashing light mean?", most subjects responded that it indicated "evaluation of the conversation environment" and "quantification of silence." Furthermore, subjects who selected "evaluation of the conversation environment" also responded to "quantification of silence" and "induction of tension" as multiple-choice answers. From this, it can be inferred that subjects perceive the blinking as having a functional role triggered by "quantification of silence" based on the "evaluation of the conversation environment," as well as a psychological role in "induction of tension."

The average ratings for "visibility of the light" are shown in Figure 3. After calculating the average ratings and performing a t-test, a significant difference was found between patterns (t(14)=3.40, p<.05). This confirms that the visibility was significantly enhanced by using the "noticeable blink" at 2.5Hz in Pattern 1.

**Patterns 3 and 4:** In response to the question "Do you understand the purpose of the stimulus?", the subjects often chose the option "promoting speech," although it was not specified whether this was aimed at individuals or the group as a whole. Subjects who chose "random" excluded options related to "promoting speech." This indicates that while it was
difficult to understand the directionality of the stimulus, whether it was targeted at individuals or the entire group, the intent to promote speech was somewhat communicated.

The average rating results for the "appropriateness of the light stimulus" are shown in Figure 4. After calculating the average ratings and conducting a t-test, a significant difference was observed between the patterns in terms of "appropriateness" (t(14)=3.05, p<.05). The average rating was higher for Pattern 4 than for Pattern 3, and the significant difference suggests that presenting the stimulus in response to individual silence rather than overall group silence was more impactful and thus more appropriate.





#### 3.4 Results and discussion: Evaluation of auditory stimuli

**Patterns 1 and 2:** To examine the impact of the auditory stimuli used in Patterns 1 and 2, the number of responses was tallied, average ratings were calculated, and a significance test was conducted.

In the question about the "role of sound," Pattern 1, which presented cafe noises, was answered mostly in the order of "representation of the conversation environment," "background music," and "prompting of speech." Pattern 2, which presented an alarm, received most responses for "system sounds" and "prompting of speech."

In the question about the "positive effects of sound," excluding "none in particular," the responses were most frequently in the order of "promotion of speech" and "enhancement of engagement."

From this, it can be inferred that the subjects felt a psychological impact in terms of "promotion of speech," and the presentation of auditory stimuli is considered effective for "prompting speech." Particularly, although cafe noises are inherently ambient sounds, the fact that subjects also responded with "prompting of speech" in addition to environment sounds and background music aligns with the results of previous research on the impact of ambient sounds on communication [4].

After calculating the average ratings and performing a t-test, significant differences were found between patterns, particularly regarding the oppressiveness and annoyance of the sounds (t(13)=2.53, p<.05). From this, it can be confirmed that during conversation, cafe noises

were perceived as significantly more oppressive and annoying compared to the alarm. In other aspects, Pattern 2 was evaluated as more positive in terms of impression.

From these results, it is considered that using an alarm as an auditory stimulus can make participants recognize its role in promoting conversation and naturally enhance the effectiveness of promotion during the conversation.



Figure 5. Average ratings for "oppressiveness" on audio stimuli (left) Figure 6. Average ratings for "annoyance" on audio stimuli (right)

**Patterns 3 and 4:** In the question "Do you understand the purpose of the stimulus?", responses in both patterns frequently mentioned "overall amount of speech in the conversation." In Pattern 2, "notification of time passage" was equally responded to.

In the question about the "positive impact of sound," excluding "none in particular," Pattern 3, which presented the stimulus during overall silence times, received many responses for "promotion of speech," whereas Pattern 4, which presented the stimulus continuously, received many responses for "enhancement of engagement in conversation" and "creation of a conducive conversation environment".

From this, while participants found it difficult to distinguish whether the stimulus was directed towards the whole conversation or individual speakers, they perceived the auditory stimuli as having an effect in promoting speech. Moreover, consistently presenting cafe noises as a stimulus is thought to provide a passive effect in enhancing the conversation environment.

Average ratings for "oppressiveness" and "annoyance" of auditory stimuli were calculated, and a t-test was performed, resulting in no significant differences found between the items. Moreover, evaluations for Pattern 4 consistently exceeded those for Pattern 3.

From these results, it can be inferred that presenting stimuli in response to overall silence in the conversation actively promotes speech, whereas continuous stimuli provide passive benefits such as creating a conducive conversation environment and enhancing engagement in the conversation.

#### 4. CONCLUSION

In this study, the first phase investigated the relationship between elements during conversation and the impact of speakers based on online group discussions. The findings

revealed that combining speech frequency and directionality allows for more accurate determination of conversation liveliness, and short silences can reflect elements such as speaker changes, thereby predicting the balance of speech.

In the second phase, focusing on the relationship between conversation liveliness and silence duration identified in the first phase, effective visual and auditory stimuli to promote speech were investigated. Results showed that visual stimuli, using a "noticeable flicker" that blinks twice within 800ms at a frequency of 2.5Hz, enhanced visibility and were effective when presented in response to individual silences. For auditory stimuli, short alarms were found to be suitable for actively encouraging speech, while ambient sounds such as cafe noises were found to be suitable for passively creating a conversational environment.

This study successfully demonstrated the effectiveness of visual and auditory stimuli by focusing on silences, but it also suggested that auditory stimuli used to promote speech could be annoying for actively participating speakers, indicating that the stimuli employed may not always facilitate smooth communication. Therefore, future research should explore combinations with other conversational elements to propose stimuli that could more effectively activate conversations.

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# PROSTHETIC LEG COVER DESIGN BASED ON KANSEI EVALUATION THROUGH SHAPE ABSTRACTION: DERIVING SHAPE GUIDELINES ACCORDING TO CLOTHING STYLES

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# ABSTRACT

This paper proposes an approach to improve the design of prosthetic leg covers in Japan by leveraging kansei evaluation. One of the main challenges in the current state of kansei evaluation is that as the number of models to be evaluated increases, the burden on subjects increases as well, which makes it difficult to conduct wide exploration of design. Therefore, it is necessary to limit the number of models to a feasible number for experiments. However, the selection of the testing models often relies on the intuition of the examiner rather than an objective method. This paper addresses this issue by creating abstract shape models of prosthetic leg covers and conducting kansei evaluations. As a result, shaping guidelines for prosthetic leg cover in respect to clothing style could be obtained. Therefore, shape abstraction was revealed to be useful in designing complex shape in feasible number of tests.

*Keywords:* kansei evaluation, shape abstraction, parametric design, prosthetic leg, fashion styles

# BACKGROUND OF THE STUDY

# 1.1 Challenges of Prostheses

The primary purpose of using prostheses in Japan is to supplement the functions of limbs. As a result, there is a strong cultural tendency to hide prostheses due to the limited range of design options available. Emphasis is placed on concealing the missing limb and making the appearance closer to the real limb. This negative impression on prostheses may hinder a patient from amputation, which leads to issues such as the enlargement of the amputation site and further movement restrictions (Takada , 1991).

In Japan, the cost of prostheses is covered by health insurance, disability certificates, or workers' compensation insurance, as long as it is made of basic low-cost parts. Common

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prosthetic leg exteriors are made of polyurethane sponge material, which is low-cost but lacks durability. Higher-quality plastic and carbon exteriors are more durable but are often not covered by the insurances.

To obtain an aesthetically appealing prosthesis, a patient has to purchase a whole prosthesis without insurances, which is a significant financial burden on users.

#### **1.2** Challenges in Kansei Evaluation

In the current state of kansei evaluation, when the number of models to be evaluated increases, the time and the burden on examinees also increase, making it impossible to execute when the number of models is large. Therefore, it is necessary to limit the number of models to a feasible number for experiments, but it is challenging to objectively reduce the number of models, often relying on the intuition of the examiner.

#### **RELATED WORKS**

#### **1.3** Related Works in the Prosthetics

A number of related research have addressed the design of prosthetic limbs and orthotics. Yoshikawa et al. proposed a lightweight and low-cost opposing three-finger prosthetic hand that takes functionality and design into consideration. In this proposal, they cite issues regarding the appearance, weight, and cost of current prosthetic hands for work. As a solution, they propose a lightweight and low-cost prosthetic hand with a sophisticated appearance as a tool (Yoshikawa et al., 2013). Yamanaka et al. cite the lack of refinement as a product in sports prosthetic leg and have examined the usefulness of the design (Yamanaka et al., 2010). In these studies, the aesthetics as a stand-alone product and its compatibility with the body have been verified. Nevertheless, since the majority of prosthetic leg users utilize their prostheses for the purpose of engaging in daily activities, it is necessary to consider the compatibility of the prostheses with fashion.

#### **1.4** Related Works in the Kansei Engineering

There are many related design studies using kansei evaluation.

Kansei evaluation has been used in research on the design of cameras, hair dryers, mobile phones, cosmetic containers, and other products (Guo, Liu, Liu, Wang, & Wang, 2014; Kinoshita, Inoue, Sakai, 2008; Liu, & Yang, 2022; Suto, Okita, Kino, Uozumi & Kubo, 2010). In the case of discrete kansei evaluations, it is difficult to identify trends. On the other hand, when continuous evaluation is used, the number of parameters is so large that it is impossible to check all of them. Therefore, it is necessary to select from a myriad of parameters. In this case, the influence of parameters that are not parameterized cannot be seen. Also, since the parameters are extracted from existing products, the degree of design freedom is low.

#### PURPOSE OF THIS STUDY

To address the challenges related to prosthetic legs in Japan, it is necessary to change the impressions of individuals and society towards prosthetic legs to a positive one. As it is currently difficult to fundamentally change the functions of prosthetic legs and the insurance system, this paper aims to solve the issues through exterior design, namely prosthetic leg covers. Prosthetic leg exteriors are perceived by prosthetic leg users as part of their body and clothing. Preferences for clothing styles vary among individuals, making it difficult to verbalize and extract the features of preferred shapes. As it is a sort of brand-new design that has no conventional reference, the degree of freedom is quite high, resulting in an uncountable number of parameters. Therefore, it is important to control the number of parameters to be tested in kansei evaluation. This paper proposes a design process incorporating abstraction of shape. By abstracting and reducing the parameters of the prosthetic leg exterior models, this paper aims to make kansei evaluation feasible. As the shape is abstracted, the resultants obtained through the kansei evaluation should not be a designed shape itself but guidelines for suitable prosthetic leg cover shapes for each clothing style.

#### APPROACH

To reduce the number of kansei evaluation to be feasible, kansei design process incorporating shape abstraction is proposed. Kansei evaluations are conducted on abstract shape models. As a result, shaping guidelines are to be obtained. Following the resultant guidelines, actual shape is designed. The design process is shown in Figure 1.

This approach is applied to the prosthetic leg covers that are the subject of this paper. First, abstract shape model of prosthetic leg covers is designed. kansei evaluations are conducted with each clothing style. Through these evaluations, shaping guidelines for prosthetic leg cover suitable for each clothing style are to be obtained.



Figure 4 Kansei design process incorporating shape abstraction

### APPLICATION OF PROPOSED PROCESS TO DESIGN OF PROSTHETIC LEG COVER

The proposed method is applied to the design of prosthetic leg cover. This section illustrates the use of the proposed method. The detail of proposed method is explained with the applied case. Before applying the proposed method, clothing styles were classified regarding perception of Japanese people.

### 1.5 Overview of the Proposed Method

The proposed process is as follows. First, an abstract shape model is developed, and test models are manufactured. Second, kansei evaluations are conducted to obtain shaping guidelines. Last, a concrete design is synthesized. The following sections explains respective steps in detail.

#### 1.6 Categorization of Clothing Styles

Before applying the proposed process, clothing styles were categorized, as prosthetic leg covers should be designed to specific clothing styles. Clothing styles were determined through discussions among several individuals. The steps were as follows.

Photos of full-body coordination were collected from the Japan's major six women's fashion magazines. To eliminate arbitrariness, the second full-body photo in each section was selected. As a result, 74 photos were collected.

A workshop to determine clothing styles was conducted. Attendees of the workshop was male and female university students who have strong interest in fashion. Collected photos were categorized by means of KJ method. As a result, the photos were categorized into 6 styles: "Formal," "Cute," "Cool (Strict)," "Cool (Casual)," "Aoyama Style," and "Ginza Style" (Aoyama and Ginza are names of districts in Tokyo. Both known as fashion centers. In Japan, fashion styles are sometimes categorized by district names). As the prosthetic leg cover assumes the casual scenes as use cases, "Formal" was excluded. "Cool (Strict)" and "Cool (Casual)" were combined into one category, "Cool." As a result, a total of four categories were determined.

To use in kansei evaluation, representative coordination was determined to each category. The items were decided by a salesperson at a clothing store. Figure 2 shows the four-representative full-body coordination.



Figure 5 The four selected types of clothing

#### **1.7** Model development

As the prosthetic leg is tailored to each individual, the cover should be designed to each prosthetic leg. As for this paper, a woman who uses a prosthetic leg is a target user. To obtain the design conditions, the prosthetic leg worn by the woman was measured. The measured lengths became sizing conditions. Considering the space efficiency, cross-sectional shape was decided as a rounded square. As the prosthetic leg has certain width throughout the depth axis, the ellipse becomes too deep. The rounded square allows for a shorter depth compared to the ellipse. Considering the connection, the front part and back part are connected in discontinuous line. As a result, the abstract shape model was designed as shown in Figure 3. The abstract shape model changes its shape parametrically. The parameters that significantly change the overall size were chosen, which were section size at top/center/bottom. To control the visibility of the internal prosthetic leg, coverage ratio was also counted as a parameter.

To conduct kansei evaluations, abstract shape model needs be concreted and materialized. To reduce the number of models to be evaluations, L9 orthogonal array was applied. The L9 orthogonal array is a tool in the design of experiments, which allows for the efficient study of multiple factors with a minimal number of experiments. If the effects of 4 factors whose levels are 3 are to be studied, 81 models need to be tested. By applying the L9 orthogonal array, the number of the models to be tested can be reduced to 9. As shown in Figure 4, nine abstract shape models were developed by changing the parameters in accordance with the L9 orthogonal array. They were 3D-printed with PLA resin. This method allows for the systematic exploration of the effects of various design parameters on the outcome while significantly







Figure 7 Nine abstract shape models

reducing the experimental workload and resources required.

### 1.8 Kansei evaluation

#### 1.8.1 Evaluation Method

Kansei evaluation experiments were conducted. To evaluate the impression of the shape of the prosthetic leg cover in relation to clothing style, coordination of 9 test models and each representative coordination in 4 clothing styles were photographed. Impression of these photos were evaluated by 20 subjects (12 men and 8 women) aged 21 to 24. The steps are shown in Figure 5.

First, subjects saw the photos of torsos wearing each representative coordination in 4 clothing styles. They were asked to select the impression words from 14 pairs of adjectives related to the clothing (Step1)(Table 1). Suggested in Takamiya (2021). Adjectives related to color was excluded.



Step 1 Select the impression words by saw the photos of torsos.



Step 2 Ask if the impression changes from torso based on the selected impression words.

Figure 8 Steps of kansei evaluation



Saw the photos with the 9 abstract shape models and ask the same questions as in step 2.

А	Cool	Cute	Н	Functional Aesthetic	
В	Neat	Fluffy	I	Low Exposure High Exposu	
С	Masculine	Feminine	J	Relaxed	Elegant
D	Dark	Bright	К	Crude	Sophisticated
E	Calm	Bold	L	Everyday	Special
F	Plain	Eccentric	М	Childish	Mature
G	Pure	Sexy	N	Light & Cheerful	Gloomy

Table 6 14 pairs of adjectives

Second, subjects saw the photos of a woman wearing each representative coordination in 4 clothing styles (Step2). They were asked if the impressions changed from the torso based on the selected impression words.

Finally, subjects saw the photos of a woman put on 9 test models of prosthetic leg covers, in each representative coordination in 4 clothing styles (Step3). Again, they were asked if the impressions changed from the torso based on the selected impression words.

By comparing the results in the case of photos without prosthetic leg cover and those with the prosthetic leg covers, the influence of the torso and the woman on the impression was canceled.

#### 1.8.2 Impressions of Representative Coordination in 4 Clothing Styles

For each representative coordination in 4 clothing styles, the top five impression words that were commonly mentioned by the subjects were identified as listed in Table 2.

#### 1.8.3 Questionnaire Results of the Test Models

In this paper, the influence of the parameters in abstract shape model is discussed focusing on

	Cute	Cool	Aoyama Style	Ginza Style
1st	Feminine	Low Exposure	Feminine	Feminine
2nd	Everyday	Mature	Bright	Mature
3rd	Light & Cheerful	Elegant	Aesthetic	Low Exposure
4th	Relaxed	Neat	Cute	Elegant
5th	Cute	Cool	Elegant	Aesthetic

**Table 7** The top five impression words in 4 clothing styles



Figure 9 Effect of parameters on impressions in case of the Aoyama style

a clothing style, Aoyama style. How parameters influence the impressions is shown in Figure 6.

From the result shown in Fig.6 a), it was revealed that when the scaling factor of section A



Figure 10 Resultant design of prosthetic leg cover for Aoyama style

(bottom) is 2, "Aesthetic" impression would have less negative impact. As for other impressions, when the scaling factor is 1.5, negative impacts on impressions are rather small. From the result shown in Fig.6 b) and c), when the scaling factor of sections B (middle) and C (top) is 1, negative impacts are rather small. If the sections become larger, the original impressions of the clothing styles become weaker accordingly. From the result shown in Fig.6 d), the smaller coverage ratio tends to have fewer negative impacts on impressions except "Elegant" Impression.

Similar trends were observed in other clothing styles as the Aoyama style, while impression words showed different tendencies. For example, "Feminine," impression is kept when the section B (middle) and C (top) are small, and the section A (bottom) is large. This induces a flared shape that is narrow at the top and wider below the center.

## 1.9 Reflection in Specific Designs

Based on the results of the kansei evaluation, shaping guidelines were obtained. To summarize the shaping guidelines, flared shape and lower coverage ratio would not disturb the original impressions of the clothing styles, such as "aesthetic" impression. Following the guidelines, the concrete designs were synthesized. Figure 7 shows the designed prosthetic leg cover for Aoyama style.

#### DISCUSSION

#### 1.10 Considerations on Shape Abstraction and Kansei Evaluation-Based Design Process

This paper proposes a kansei design process incorporating abstraction of the shape of a product. As the number of parameters could be small, the kansei evaluation was feasible in terms of burden on subjects. Therefore, by the shape abstraction, it is possible to explorer the possible holistic shapes of a product while keeping the kansei evaluation feasible. However, method to abstract shape has not been discussed. As the design requirements and conditions entails abstract shape, there could be a method to obtain abstract shape from them in a

systematic process. Further, whether the tendency of impressions obtained for abstract model is still applicable to the concretized design has to be verified as well.

#### 1.11 Considerations on Differences in Shapes Enhancing Impressions by Clothing Styles

The study aimed to derive shapes that do not weaken the impressions of clothing styles. The study indicated that even with different clothing styles, similar tendencies were observed for the same impression.

### CONCLUSION

This paper proposes a kansei design process incorporating abstraction of the shape of a product. The proposed process was applied to a design of prosthetic leg cover. Thanks to the abstraction, it was possible to explorer the possible holistic shapes while maintaining models used in kansei evaluation in feasible number. Through this process, the shaping guidelines could be obtained for each clothing style though they were quite similar in each other. Following the guidelines, the concrete shapes were designed.

While the process proved effective, design of abstract shape model and selection of parameters involved a subjectivity of those implement the design. Thus, systematic process and more objective criteria needs to be addressed in future studies. Further, whether the tendency of impressions obtained for abstract model is still applicable to the concretized design has to be verified as well.

The outcomes of this study offer new perspectives in prosthetic leg cover design, potentially reducing the psychological burden on prosthesis users and contributing to positive societal impressions of prosthetics.

#### ACKNOWLEDGMENTS

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# DEVELOPMENT OF A MUSIC RECOMMENDATION METHOD CONSIDERING NOVELTY USING USER'S KANSEI

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# ABSTRACT

In recent years, each music subscription service is applied recommendation system to suggest music content that user might be preferred. The music content that matches user's preferences can be discovered by development of recommendations system. However, users also expect more satisfactory music recommendations such as unknown music that matches the user's preferences. Therefore, it is expected that the user experience when listening to music will be improved by devising a recommendation system. In this study, we develop a music recommendation method considered novelty based on user's Kansei information. The proposed method is achieved recommendation in accordance with the user's music preferences even for music immediately after release by feature extraction using mel-spectrogram and convolutional autoencoder. In the experiments, the proposed method was evaluated to be able to provide recommendation considered novelty for 10 males and females in their 20s. The results of the evaluation experiments showed that 69% of the recommended music were considered novelty recommendation for the users. Additionally, 66% of the recommended music were unexpected to the users, and the concept of unpredictability of recommendation is called serendipity. As a result of the experiments, the proposed method is able to recommend music with consideration of novelty and serendipity. This means that recommendations satisfying user's needs can be realized and contribute to improving the user experience when listening to music.

Keywords: recommendation system, convolutional autoencoder, Kansei engineering

# 1. INTRODUCTION

In recent years, music has become a more familiar part of people's lives by spreading of music subscription services such as Apple Music and Spotify. On the other hand, it is difficult for users to find the music they like because music saturates people's surroundings. This phenomenon is called "information overload," in which users are unable to identify the information that they want even though it is available for reference. To solve this problem, recommendation systems

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are adopted by each subscription service to suggest music content that users might be preferred. There are two main types of recommendation systems: content-based filtering and collaborative filtering. In content-based filtering, user preference information and content characteristics are expressed as a feature vector, and contents that are similar to the user's feature vector are recommended. In collaborative filtering, contents that are liked by many other users with similar preference to the user are recommended. Owned to these two methods have advantages and disadvantages in each other, each subscription service is used a recommendation method appropriate to the situation or combines the two methods to present content preferred by the user.

While some users are satisfied with the recommendation system in existing services, other users expect more satisfactory recommendation system than now one. This is because (1) there are many contents to be recommended, and it is hard for users to find from recommended contents they like, and (2) users want to know contents that they prefer among new and unknown. It is expected to improve the user experience when listening to music by solving these issues.

In this study, we develop a content-based music recommendation method considered novelty using the user's Kansei information. In more detail, mel-spectrogram, convolutional autoencoder (hereafter CAE), and clustering method are used to express user preference, and the proposed method achieve music recommendation considered novelty. The proposed method focuses specifically on new released music recommendations, and the proposed method is supposed to be combined with existing recommendation systems in the future. Thereby improving the user experience when listening to music using the proposed recommendation method. The evaluation experiments of the proposed method are executed by 10 males and females subjects in their 20s.

This paper is organized as follows. Section 2 introduced previous studies related to recommendation systems. Section 3 explains the implementation of the proposed method. Section 4 explains the evaluation experiments. Section 5 presents results and discussion of the experiments and Section 6 provides a summary of this study.

## 2. RELATED WORKS

#### 2.1 Music recommendation using mel-spectrogram and convolutional neural network

In recent years, there have been a number of studies combining mel-spectrograms and convolutional neural networks in music classification and recommendation tasks, such as the study of Yandre et al. (2017) and Yin (2023). Adiyansjah et al. (2019) proposed a music recommendation system based on the similarity of audio signals. The audio signal is converted to a mel-spectrogram, and the imaged audio representation is input to a convolutional recurrent neural network. Using this process, it is possible to extract features of music from images, and music that based on cosine similarity are recommended to users. The results of evaluation experiments showed that recommendations based on cosine similarity considered

music genres are preferred by the user more than recommendations based on only cosine similarity.

Several previous studies have shown that neural networks are an effective method for the task of extracting music features from mel-spectrograms. However, a convolutional neural network is basically a supervised learning, there is a possibility that music immediately after release is faced with a cold start problem where no supervised data exists. The cold start problem means that new items are difficult to predict, classify, etc. by machine learning because they do not have the necessary information for recommendation, such as user ratings. To avoid this problem, it is necessary to extract features of music by unsupervised learning. In addition, a method such as this previous study that require measuring cosine similarity between music in recommendation is required a brute force calculation between the music to be recommended and the music owned by the user. Furthermore, different cosine similarity thresholds must be investigated and determined for each user. The limitations of expressing users' musical preferences in terms of cosine similarity are also concerning.

#### 2.2 Music recommendation using Spotify music feature

Spotify allows the use of unique music features analyzed by Spotify via API (Spotify for Developers, n.d.). Sota et al. (2023) developed "Music by Feeling," a music recommendation application that enables users to recommend music that match their feeling when listening to music. In this application, music that is close to the user's emotion from the music plotted on the two-dimensional graph is recommended by changing the emotion value parameter. In the user evaluation experiments, there was a discrepancy between the recommended music by the application and the user's emotions. However, recommendations that were close to user's emotions have been enabled by user feedback to the application.

This previous research achieved music recommendation that is close to the user's emotions by inputting the emotion value, they avoided information overload. However, this music recommendation application depends on music features provided by Spotify, therefore, it is impossible for other music subscription services to provide music recommendations. The proposed method should aim to be independent of any particular service because the objective of the proposed recommendation method is to coexist with other music recommendation systems in the future.

#### 2.3 Recommendation system considering novelty

Ogawa et al. (2009) proposed a recommendation system considered novelty to solve the problem that high accuracy of the recommendation system leads to user dissatisfaction. A novelty was defined as "percentage of items that a user had not heard of before but became interested in after being recommended" in this research. A co-evaluation relationship is expressed as a network, such as "users who evaluate item A also evaluate item B". Then items with similar preferences are grouped as topics by clustering. This previous research achieved a recommendation system considered novelty by selecting items so that the topics become diverse. In comparison experiments with conventional collaborative filtering conducted on 20 university students, this method was shown to provide higher novelty recommendations than

conventional collaborative filtering. This research differs from our proposed study in field and methodology, but the objective of providing recommendations considered novelty is consistent. Therefore, the evaluation experiments of the proposed method will be conducted with reference to the experimental methods of this previous research.

## 3. PROPOSED METHOD

#### 3.1 Concept

In this study, we develop a music recommendation method considered novelty based on user's Kansei information made by music that users usually listening. Referring to related studies, in the proposed method, features are extracted directly from the music data using unsupervised learning. Therefore, the proposed method is able to generate features from music immediately after release and avoid the cold start problem. In addition, even if the user does not have a clear understanding of his or her music preference, it is possible to make recommendations that consider his or her preferences. Furthermore, users listen to new music successively and there are trends in the music they listen, hence users' music preferences change over time. Based on applying an example of identifying user needs by cluster analysis (Shaari, N., & Wahab, S. A. 2010), the proposed method will achieve recommendations that can respond to changes in user preferences using clustering.

Fig. 1 shows a procedure of the proposed method. In step 1, the music data is converted to a mel-spectrogram. In step 2, CAE is trained by imaged music data. The proposed method is not used the entire CAE, but only the encoder part as a feature extractor. In step 3, the encoder part of the CAE learned in step 2 is used to cluster the music that the user usually listening, and then a feature map expressing the user's music preferences (hereafter Kansei map) is created. Lastly, all candidate music for recommendation is plotted within the Kansei map, and music mapped within a threshold is set for each cluster is recommended to the user. Each step is described in detail below.

#### 3.2 Data collection and conversion to a mel-spectrogram

First, the music data necessary to train CAE are collected. Using the Spotify API, a list of 170 artists is created based on a playlist compiled from the Japanese hit charts. Based on this list, up to 50 pieces of music per an artist are collected. Where the music data to be collected is a 30-seconds preview music data that can be collected via the Spotify API. Next, these music data are converted to mel-spectrograms using Librosa (Librosa, n.d.), a Python audio analysis library. The mel-spectrogram is a spectrogram with the horizontal axis representing time and the vertical axis representing frequency on the mel scale, and it is possible to represent the frequency characteristics of audio signals in a manner similar to human hearing. In creating the mel-spectrogram, each music data is sampled at 44.1 kHz, in total, 5987 images are created.



Figure 1. Procedure of the proposed method

#### 3.3 Feature extraction by CAE

Features are extracted from the mel-spectrogram created in subsection 3.2 using CAE. First, Autoencoder (hereafter AE) is described. AE is unsupervised learning with neural networks; AE is composed of two networks: an encoder, which represents the input data with fewer dimensions, and a decoder, which restores the values output by the encoder to the original input data. Because of this characteristic, AE has been used as a method for feature extraction and dimensionality reduction, but its use as a generative model has expanded in recent years. In the proposed method, CAE which is a type of AE and proficiency in extracting features from images is used. In normal AE, dense layers are used for encoder and decoder, but in CAE, convolutional layers and pooling layers are used. The implementation is in Keras (Keras, n.d.), a machine learning library in Python. The network structure of the CAE constructed is shown in Fig. 2. Note that the sigmoid function is used for the activation function of the convolutional layer only for the final layer, and the ReLU function for the other layers. The mel-spectrogram created in subsection 3.2 is split 8:2 between training and testing. These images are converted to grayscale as a pre-processing step before training, and then each pixel value in the image is normalized to be in the range 0 to 1. Additionally, the number of epochs is 50, adam is used as the optimization function, and the mean squared error (MSE) is used as the loss function.

#### 3.4 Clustering and threshold setting

Based on the image features extracted by CAE, clustering and threshold setting are executed. X-means is used for clustering in the proposed method (Pelleg, D., & Moore, A. W., 2000). X-means is an improved algorithm of K-means, in which the optimal number of clusters is automatically set by using K-means iterations and the division stopping criterion by Bayesian Information Criterion (BIC). First, the features extracted by CAE are dimensionally reduced to three dimensions by UMAP (McInnes et al., 2018). The reason for dimensionality reduction is



Figure 2. Structure of convolutional autoencoder

that using features with a large number of dimensions may result in a curse of dimensionality. Next, the dimensionality-reduced features are clustered using X-means. Then, the Mahalanobis distance

from the center of each cluster to all data belonging to that cluster is calculated, and the longest Mahalanobis distance in each cluster is set as the threshold for each cluster. Finally, feature extraction by CAE, dimensionality reduction, and clustering are applied to all candidate music of recommendation to the user. Then, music that Mahalanobis distance to the center of the belonged cluster less than the threshold value is recommended to the user. Note that a seed value for dimensionality reduction is not set in the UMAP, different feature vectors are created five times to recommendations matched to users, and also recommends music that have been recommended more than a majority of times. This is inspired by ensemble learning in machine learning.

#### 4. EXPERIMENTS

The evaluation experiments were conducted to verify that music recommendation by the proposed method was considered novelty for the user. Novelty in the study was defined by Ogawa et al. (2009) as "Percentage of items that a user had not heard of before but preferred after being recommended". The evaluation experiments were conducted on 10 male and female in their 20s. In the experiments, 80 pieces of new release music which were able to obtain preview sound files from Spotify's "New Music Wednesday playlist" (New Music Wednesday, n.d.) were used. First, subjects provided about 100 pieces of music that they usually listening. Next, based on the music data presented by the subjects, the music that each subject might be preferred from the New Music Wednesday playlist were recommended by the proposed method. Finally, a questionnaire was administered to the recommended music, and the effectiveness of the proposed method was evaluated based on the results. The questionnaire used in the evaluation experiments were asked to choose (1) whether they knew or not the music, (2) how match they liked the music, and (3) whether the music was unexpected or not for each of the recommended music, with two options for (1) and four options

for (2) and (3). In addition, free description responses were obtained from the subjects about what they noticed through the music recommendation and the experiments.



Figure 3. The result of novelty and serendipity

## 5. RESULTS AND DISCUSSION

The results of experiments are shown in Fig. 3. From the results of question 2, novelty was determined by the following equation:

As shown in Q2 of Fig. 3, in these evaluation experiments, 69% of the recommended music were considered novelty recommendations. The results showed that the aforementioned issues were resolved by recommending music matched to the user's preferences while overcoming the cold start problem. In addition, the subjects were surveyed to determine whether the recommended music were unexpected to them. The following formula was used to determine the unexpectedness of the recommended music based on the results of question 3:

Serendipity

 $r = \frac{Total number of items in the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of the top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the rating index of unexponent of top 2 on the ratio of unexponent of unexp$ 

As shown in Q3 of Fig. 3, in these evaluation experiments, 66% of the recommended music were unexpected for the user. In the evaluation index of the recommendation system, serendipity which adds unpredictability of recommended items to the concept of novelty has existed. Although an accurate quantitative evaluation of serendipity could not be performed in these evaluation experiments, the proposed method has the potential to provide unexpected recommendations that match user preferences. In addition, the following positive comments were obtained from the free description results.

 $\bullet$  "I was surprised to find that the music was to my favorite, even though I had never heard of the artist before."

- "The recommended music was similar to my preference."
- "It was unexpected that much of the music was of a tone I don't usually listen to."

These results suggests that the proposed method can be realized recommendation considering novelty and serendipity in terms of qualitative evaluation.

While the results were positive, in some case, the number of music recommended to the subjects was small depending on the subject's preference, although 80 pieces of music were targeted for recommendation. In order to more accurately validate the effectiveness of the proposed method, it is necessary to repeat the quantitative evaluation by conducting recommendations on several different playlists over a long period of time. Additionally, owned to this quantitative evaluation was simplified, we will conduct a more detailed quantitative evaluation experiment by applying a Kansei evaluation method as in Lokman, A. M. et al. (2022). On top of that, in these evaluation experiments, comparison experiments were not conducted between the proposed method and other recommendation algorithms. Therefore, in the future, comparative experiments should be conducted to show the advantage of the proposed method for music immediately after release.

Q1. Did you know the recommneded music?	<ol> <li>Yes, I knew.</li> <li>No, I did't know.</li> </ol>
Q2. Did the recommended music match your favorite?	<ol> <li>It was my favorite.</li> <li>If I had to choose, it was my favorite.</li> <li>If I had to choose, it was not my favorite.</li> <li>It was not my favorite.</li> </ol>
Q3. Were the recommended music unexpected?	<ol> <li>It was unexpected.</li> <li>If I had to choose, It was unexpected.</li> <li>If I had to choose, It was not unexpected.</li> <li>It was not unexpected.</li> </ol>

#### Table 1. Survey on preferences and unexpectedness for recommended music

## 6. CONCLUSION

In this study, we developed a music recommendation method considered novelty based on the user's Kansei information to improve the user experience when listening to music. The proposed method aims to music recommend that use of users' preferences even for music immediately after their release by extracting features directly from audio data. In the evaluation experiments, 10 males and females in their 20s were subjected to music recommendation by the proposed method, and a questionnaire was used to verify whether the recommendation was considered novelty. The results of the evaluation experiments showed that 69% of recommended music were considered novelty recommendations for the user. In addition, a questionnaire on unexpectedness of recommended items were showed that 66% of recommended music were unexpected to the user. The results of the evaluation experiments suggested that the proposed method was able to recommend with novelty and serendipity considered. In the future, the proposed method will be verified through comparison

experiments with other recommendation systems and recommendations for multiple playlists. What is more, the proposed method will be quantitatively evaluated in terms of novelty and serendipity, and we will aim to improve the user experience when listening to music.

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# A STUDY ON THE IDENTIFICATION OF ACCEPTABLE RANGES FOR WEARABLE SOUND WITH WEARER'S SENSE OF WEARABILITY AND SURROUNDING PEOPLE'S IMPRESSIONS

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## ABSTRACT

This study investigates the use of "auditory adornment," a type of fashion that decorates and enhances human motion and actions with wearable sounds. By digitizing wearable sounds, it is believed that the range and controllability of usable sounds can be amplified. The research aims to identify sound types that are comfortable for the wearer and not unpleasant for those around them. The study compares sounds based on two axes: pitch and clarity, to determine the appropriate range of pitch and clarity for wearable sounds. In this study, in addition to evaluating the sounds individually (Experiment 1), we prepared an evaluation experiment from the perspective of "seeing" the sound being worn (Experiment 2) and an evaluation experiment from the perspective of the person "wearing" the sound (Experiment 3). The experiment was conducted in July 2023 on a total of 30 Tsukuba University students. The experiment revealed three findings. Firstly, in terms of attractiveness, the combination of "Medium Fade and High Pitch (C3-G4)" consistently ranked first across all experiments, indicating it was the most appealing. Both wearers and observers found this combination favorable, suggesting it is suitable from all perspectives. Secondary, the multiple regression analysis revealed that pitch has a stronger impact on the evaluation of sound sources compared to fade strength. Lastly, the influence of fade strength on the sense of integration was found to be greater when the sounds were subjectively experienced by the wearer rather than objectively observed.

Keywords: wearable, soundscape, adornment, auralization

# **1** INTRODUCTION

## 1.1 Background

Traditional fashion has predominantly focused on visual and material designs. However, with technological advancements, augmented fashion utilizing light and video has gained attention. The fashion brand ANREALAGE proposes garments that extend beyond traditional fashion by utilizing AR, fiber optics, and photochromic materials (Morinaga, A&Z fashion of ANREALAGE,

2020). This trend is not limited to ANREALAGE; high-end brands such as Gucci, Hermes, and Louis Vuitton, along with tech giant Microsoft, are also contributing to this growing fusion of technology and fashion (Fashion Tech News, 2019). However, these innovations remain confined to visual expressions. There are examples of garments with auditory elements. For example, Machina's MIDI jacket by the Mexico-based collective Machina creates sound in response to the movements of the dancer wearing the jacket (Machina). SOUND FABRIC ORCHESTRA by Japanese fashion tech designer Olga is an installation work of soft, cloth-like speakers (O I g a, 2020). Both share the concept of incorporating sound into attire, but the idea of integrating sound into everyday fashion as a stylish accessory has not yet been thoroughly explored."

This study proposes the introduction of auditory embellishments into everyday fashion. By leveraging mechanisms where sound is produced in response to the wearer's movements, and through the digitalization of these sounds to diversify and control auditory outputs, the goal is to make auditory embellishments an accepted part of fashion that enhances the wearer's allure while being socially acceptable. There are existing studies that explore the characteristics of unpleasant sounds and those that are generally preferred (Shizuoka,2003).

Currently, there are no established criteria that define the characteristics of sounds that can be both enjoyed as a fashion statement and accepted by those in the surrounding environment.

### 1.2 Objective

Therefore, this study aims to create an experience wearing sounds that are synchronized with their motion, and to clarify how the impressions and effects on both the wearer and their surroundings change depending on the characteristics of these sounds. this study, the study seeks to establish criteria for the types of soundscapes that are effective when worn and acceptable to both the wearer and those around them. Through this research, it is possible to determine the range of sound that is effective when worn and the acceptable range of sound in the surroundings and in the person himself/herself as a single indicator. This is expected to contribute to the development of fashion expressions utilizing auditory information. This research investigates the characteristics of sound that are not only enjoyable and attractive to the wearer, but that are also not beyond the acceptable level of objective evaluation by surrounding people. Specifically, this study identifies appropriate sound characteristics for the wearer and their surrounding people, focusing on two factors: sound pitch and sound clarity. Regarding sound volume, previous studies have identified sound levels that are unpleasant for people (Kabuchan, 2021). Furthermore, there are previous studies exploring the psychological effects of listening to various types of sounds during tasks. In everyday life, we will investigate which sounds are preferable to wear as everyday attire (NISHIMOTO, 2023). In the context of fashion, there are significant benefits to integrating auditory elements into decorative designs. Visual decorations are mainly for the surrounding people who see the clothing, but if auditory information can be used as adornment, would allow the wearer to directly experience and perceive the embellishments. This approach enhances the subjective functionality of adornments, offering a novel dimension to personal attire and potentially leading to innovative fashion propositions.

## 2 MATERIAL AND METHOD

## 2.1 Sound

We created 9 sound sources by editing the same melody on the same synthesizer and setting 3 levels on 2 axes: "pitch" and "fade strength". Increasing the time for release and attack on the sound extends the fade at the beginning and end of the sound. For each of the three sound sources, three ranges were set up: "Weak Fade" with 0.05 seconds of attack and 0 seconds of release (Figure 1), "Medium Fade" with 1.00 seconds of attack and 1.05 seconds of release (Figure 2), and "Strong Fade" with 10.45 seconds of attack and 10.8 seconds of release (Figure 3). Each of the three levels of sound sources was assigned to three levels of pitch range: "High Pitch" from C3 to G4, "Medium Pitch" from C2 to G3, and "Low Pitch" from C1 to G2 (Figure 4). These nine sound sources are illustrated clearly in a figure (Figure 5). By creating different levels of pitch that can be easily distinguished by the human ear, a wide range of people can evaluate the sound regardless of their sense of pitch and hearing ability. The sound source data can be accessed and listened to via this link.



https://drive.google.com/drive/folders/1sLvcIOS_VYg6ZQ2pDkm0cGBu3Eskb0J9?usp=share_link

Figure 4. Range of pitch



Figure 5 9 sound sources for the experiment

#### 2.2 Video

We created a video for objective evaluation of individuals wearing sound while performing actions. Basic motion included standing up, squatting, rising, walking, turning around, raising hands, and waving hands, structured as a 17-second sequence transitioning from sitting in a chair to standing up, picking up an object, and running towards a call. In this study, the basic motions included standing up, squatting, rising, walking, turning around, raising hands, and waving hands were used as the movement elements for sound evaluation. The rationale behind this choice is that the wearable sound in this research is intended for everyday fashion use, rather than for shows or games. To develop auditory decorations that enhance common gestures rather than special actions, we conducted experiments using everyday movements to identify suitable sound characteristics. The video aimed for a neutral tone in clothing, background, and movements to minimize influence from visual cues. A section of the video is depicted below (Figure 6). The main footage consists of approximately 3 minutes showing the sequence repeated nine times.



Figure 6. A segment of the video used in the experiment

#### 2.3 Experiment

In this study, in addition to evaluating the sounds individually (Experiment 1), we prepared an evaluation experiment from the perspective of "seeing" the sound being worn (Experiment 2) and an evaluation experiment from the perspective of the person "wearing" the sound (Experiment 3).

The experiment was conducted in July 2023 on a total of 30 Tsukuba University students, 8 males and 22 females. In Experiment 1, participants listened to 9 sound sources and scored

each on a 100-point scale. In Experiment 2, the participants listened to the 9 sound sources and rated each on a 5-point scale in 5 question items. In Experiment 3, participants repeated the movements shown in the video 9 times with the 9 sound sources and rated each of the 9 movements on a 5-point scale in 5 questions. In Experiments 2 and 3, participants evaluated five axes: "attractive", "match", "negative", "positive", and "harmony with the person". All evaluations were conducted via paper questionnaires, and participants had unlimited time to respond. To mitigate the influence of the sequence of sound sources, half of the participants experienced the sound sources in ascending order, while the other half experienced them in descending order. In Experiment 3, the participants put the speakers in their pockets and performed prescribed movements with each sound source (Figure 7). The speaker was wirelessly linked to a PC and keyboard operated by the experimenter (author), who monitored the participants' movements and manually adjusted the sound output to match their actions without participant's knowledge.



Figure 7. A segment of the video used in the experiment

# 2.4 Hypotheses

• The results of Experiments 1, 2, and 3 show differences in the evaluation of the attractiveness of the sound source, indicating that a sound source that was highly rated on its own is not necessarily also highly rated when worn.

• The "Strong Fade" with a low degree of linkage to the wearer's motion will be highly rated in Experiment 2, which is an objective evaluation, because it gave a calm impression in general. On the other hand, "Weak Fade," which has a high degree of linkage with the wearer's own motion, is highly rated in Experiment 3 because the correlation between the input of motion and the output of sound is felt more strongly, resulting in higher satisfaction.

# 3 RESULT

## 3.1 Evaluation of Sound Source Attractiveness

In Experiment 1, 30 evaluators listened to 9 sound sources and rated each on a scale of 100 points based on their attractiveness. In this evaluation experiment, the participants are responding based purely on their preference for the sound, without reflecting any consistency

with their behavior. In Experiment 2, 30 evaluators listened to the same 9 sound sources along with visual content and rated each on a 5-point scale based on their attractiveness. In Experiment 3, 30 evaluators performed various movements while listening to the 9 sound sources and rated each on a 5-point scale based on their attractiveness (Figure 8).

Experiment 1		Experimer	Experiment 2		Experiment 3	
Fade Pitch	Mean Score	Fade Pitch	Mean Score	Fade Pitch	Mean Score	
1 st Med High	74.733	1 st Med High	2.967	1 st Medi High	2.633	
2 nd Weak High	72.033	2 nd Weak High	2.767	2 nd Weak High	2.567	
3 rd Weak Med	71.633	3 rd Med Med	2.733	3 rd Weak Med	2.333	
4 th Strong High	70.333	4 th Strong High	2.600	4 th Med Med	2.267	
5 th Strong Med	69.667	5 th Weak Med	2.500	5 th Strong High	2.167	
6 th Med Med	69.533	6 th Strong Med	2.433	6 th Strong Med	2.000	
7 th Strong Low	66.367	7 th Weak Low	2.100	7 th Weak Low	1.667	
8 th Weak Low	64.433	8 th Med Low	1.733	8 th Med Low	1.533	
9 th Med Low	64.267	9 th Strong Low	1.600	9 th Strong Low	1.300	

Figure 8. The Ranking of Attractiveness Evaluation of Audio Sources in Each Experiment

### 3.2 The Influence of "Pitch/Fade Strength" on Each Evaluation Axis:

In Experiment 2, 30 evaluators listened to 9 audio sources accompanied by video and rated them on a five-point scale across five evaluation axes: "attractive", "match", "negative", "positive", and "harmony with the person". Multiple regression analysis was conducted to determine the impact of "pitch" and "fade strength" on each evaluation axis. Pitch was categorized as High (3), Medium (2), and Low (1). Fade strength was categorized as Strong (3), Medium (2), and Weak (1). The significance level was set at 0.05.

-Pitch: Significant correlations were observed across all evaluation axes. A negative correlation was found for the "negative" axis, while positive correlations were seen for the other four axes.

-Fade: Significant correlations were observed across all evaluation axes except for the "negative" axis. Negative correlations were found for the remaining four axes.

In Experiment 3, the same 30 evaluators performed specific movements while listening to the same 9 audio sources and rated them on a five-point scale across five evaluation axes: "attractive," "desire to wear in public," "negative," "positive," and "harmony with the person." Multiple regression analysis was used to determine the impact of "pitch" and "fade strength" on each evaluation axis. The significance level was set at 0.05.

- Pitch: Significant positive correlations were observed for all axes except the "negative" axis.

- Fade: Significant negative correlations were observed for all axes except the "negative" axis.

The coefficients and p-values for each combination of independent and dependent variables are shown in the corresponding tables (Table 1 and Table 2).

	Attractive	Match	Negative	Positive	Harmony
Ditch	coef 0.48	coef 0.54	coef -0.21	coef 0.53	coef 0.37
Pitch	p<0.01	p<0.01	p=0.01	p<0.01	p<0.01
Fada	coef -0.12	coef -0.2	coef -0.09	coef -0.21	coef -0.21
Fade	p=0.07	p=0.001	p=0.24	p=0.002	p=0.01

**Table1.** The significant differences in combinations observed in Experiment 2

	Attractive	Desirability	Negative	Positive	Integration
Ditch	coef0.48	coef 0.38	coef -0.08	coef 0.53	coef 0.39
PILCI	p<0.01	p<0.01	p=0.27	p<0.01	p<0.01
Fado	coef-0.22	coef -0.18	coef 0.01	coef -0.31	coef -0.38
Fade	p=0.004	p=0.01	p=0.88	p<0.01	p<0.01

Table2. The significant differences in combinations observed in Experiment 3

#### 3.3 Effects of the "fade" change at a certain pitch on the evaluation:

Regarding "attractiveness," rankings of audio sources in Experiments 1, 2, and 3 showed a consistent relationship between pitch and ranking, with lower rankings consistently associated with Low Pitched sounds. Multiple regression analysis in Experiment 2 revealed significant correlations between "pitch" and evaluations across all axes. In both Experiment 2 and 3, "pitch" had a stronger impact on evaluations compared to "fade strength." From these results, changes in "pitch" have a relatively strong effect on evaluations in both Experiment 2 and 3. Therefore, to clarify the correlation between "fade strength" and evaluations in each experiment and determine whether there are differences in this correlation between experiments, an analysis of variance was conducted. We set the significance level at 0.05. As a result, no significant differences were observed in the "attractiveness" category for the relationship between fade strength and evaluations across all pitch levels in both Experiments 2 and 3.

Therefore, we conducted analysis of variance to determine whether there were differences in the correlation between fade and evaluations across the other four categories in both experiments. We analyzed if fade influenced evaluations across four categories and three pitch levels. We set the significance level at 0.05. As a result, in Experiment 2, a significant correlation was found between fade variation and evaluations in the "negative" category in the Middle Pitch range. Also, significant differences were observed in the "positive" category at High Pitch. In the "match" category, though slightly above the significance level at P = 0.05 for High Pitch and P = 0.06 for Low Pitch, a significant trend was noted. In the "harmony with the person" category, there was a significant difference in the Low Pitch range, but not in the Middle Pitch range, while for the High Pitch range, it was P = 0.07. The significant differences in the combinations of evaluation categories and pitch ranges in Experiment 2 are shown in Table 3.

In Experiment 3, significant differences were observed in the relationship between fade variation and evaluations across all pitch ranges in the "harmony with the person" category. Furthermore, significant differences were found in the "positive" category in the Middle Pitch range. The significant differences in the combinations of evaluation categories and pitch ranges in Experiment 3 are shown in Table 4.

Table 3. The significant differences in combinations observed in Experiment2

	Attractive	Match	Negative	Positive	Harmony
High Pitch	p=0.28	p=0.05	p=0.24	p=0.02	p=0.07

Med Pitch	p=0.36	p=0.21	p=0.03	p=0.30	p=0.22
Low Pitch	p=0.12	p=0.06	p=0.34	p=0.21	p=0.02

	Attractive	Desirability	Negative	Positive	Harmony
High Pitch	p=0.15	p=0.36	p=0.56	p=0.12	p=0.02
Med Pitch	p=0.38	p=0.45	p=0.10	p=0.01	p=0.04
Low Pitch	p=0.38	p=0.42	p=0.99	p=0.42	p=0.02

Table 4. The significant differences in combinations observed in Experiment 3

Items with no significant differences are shaded in dark gray, and those with a trend toward significance ( $0.05 \le p < 0.1$ ) are shaded in light gray (Table 5).

Table 5. Color coding for significance and trend toward significance

No significant difference
Marginally significant (0.05 $\leq$ p < 0.1)
Statistically significant (p < 0.05)

To visually illustrate how the evaluations vary with different levels of fade strength for those with significant differences, box plots are presented in Figures 9 and 10. As mentioned earlier, significant correlations were found in "negative" category in the Middle Pitch range, "positive" category in the High Pitch



range, and "harmony with the person" category in the Low Pitch range in Experiment 2 (Figure 9). Figure 9. Changes in evaluation relative to fade strength in Experiment 2

In Experiment 3, significant differences were found in the in the "harmony with the person"



category across all pitch ranges, and "positive" category in the Middle Pitch range (Figure 10). Figure 10. Changes in evaluation relative to fade strength in Experiment 3

#### 4 DISCUSSION

The absolute values of the coefficients in the multiple regression analysis consistently show that "pitch" has a stronger influence on the evaluation of sound sources than "fade strength." This is likely because the sound sources are inherently ambiguous in timbre, making variations in fade strength less perceptible compared to changes in octave.

Both Experiment 2 and Experiment 3 showed a positive correlation between pitch and all four positive evaluation items, and a negative correlation with the "negative" item in Experiment 2. This indicates that higher pitch is perceived as more positive and less unpleasant. However, the extent to which pitch can be increased warrants further investigation.

Both experiments also demonstrated a negative correlation between fade strength and the four positive evaluation items, indicating that a weaker fade is preferable.

These findings suggest that the factors influencing evaluations are the same for both observers and wearers. Additionally, the highest rankings in attractiveness were consistently given to the combinations with Medium Fade and High Pitch (C3-G4), indicating that the auditory embellishments are perceived similarly by both observers and wearers, reducing the likelihood of the wearer's preferences being perceived as disruptive.

Comparing the "harmony" items in Experiments 2 and 3 through analysis of variance reveals that Experiment 3 shows more significant differences in "harmony" across a wider range of fade strengths. This suggests that when the sounds are subjectively experienced by the wearer, the fade strength has a greater impact on the sense of harmony. Figure9 and 10 illustrate that weaker fade, or less delay, enhance the sense of harmony. This implies that the actor is more sensitive to discrepancies between motion and sound due to fade, resulting in a lower threshold for perceiving a lack of harmony.

The relationship between the evaluation of movements and sound characteristics was explored through qualitative interviews, which revealed connections between specific actions and sound features. The movements in this study can be categorized into three types: point-like movements such as standing up, squatting, rising, and turning around; state-like movements such as walking; and interpersonal movements such as raising hands and waving hands. In the interviews conducted alongside Experiment 3, participants preferred a calm sound source with a Low Pitch and a Strong Fade for the state movements, and an energetic sound source with a High Pitch and a Weak Fade for the interpersonal movements.

#### 5 CONCLUSION

This study explored the effects of various combinations of pitch and fade strength on the evaluation of sounds. In terms of attractiveness, the combination of "Medium Fade and High Pitch (C3-G4)" consistently ranked first across all experiments, indicating it was the most appealing. Both wearers and observers found this combination favorable, suggesting it is suitable from all perspectives. Furthermore, the absolute values of the coefficients in the

multiple regression analysis revealed that pitch has a stronger impact on the evaluation of sound sources compared to fade strength. Additionally, the influence of fade strength on the sense of "harmony" was found to be greater when the sounds were subjectively experienced by the wearer rather than objectively observed.

Overall, the findings indicate that higher pitch and lower fade strength are generally preferred. This preference was consistent across all experiments, suggesting that auditory embellishments favored by the wearer are unlikely to cause discomfort to those around them.

This study aims to identify the characteristics of sounds that are comfortable for the wearer and do not cause discomfort to those around them when used as wearable auditory decorations.

The results of this study revealed that "high pitch and low fade" are the most preferred types and ranges of sounds. This conclusion will serve as a guideline for creating wearable sounds. Previously, there were no examples of wearable sounds in the context of fashion, and no criteria existed for determining what sounds are appropriate. However, this research and its findings provide a benchmark in this field.

### 6 FUTURE WORK

In the future, we aim to create wearable sounds based on the results of this experiment. Additionally, we plan to conduct further investigations with different settings and conditions. For example, in this experiment, participants took part individually, and the assessment of objective impressions was based on video observation. We intend to explore how the results change when multiple participants wear the sounds simultaneously.

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# STYLE AGENT: SENSITIZING AND EMPOWERING DESIGNER'S CREATIVITY IN CREATING AESTHETIC DESIGNS

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## ABSTRACT

Generative AI applications bring evolutions into design and creative practice by empowering people's creativity with prompt engineering rather than intense ideating and making iteratively. However, recent research shows that creators struggle to describe their concepts with texts in the first place. When some pioneers succeed in doing that, machines often fail to deliver outcomes matching users' visions, probably due to a lack of knowledge of humans' expressive language in the system's training data, such as emotions and abstract feelings. We seized Kansei Engineering as the key enabling methodology to fill the gap and applied it to develop an interactive *Style Agent* system. Six participants were recruited to evaluate our prototype. We found that our *Style Agent* and the underlying CAV machine learning could effectively learn and predict designers' subjective assessments with poster designs used in this research. Meanwhile, *Style Agent* can also assist designers in framing their design visions on intended Kansei and directing their creation with the noticeable design parameters of the inspirational exemplars displayed in the multidimensional design space. In conclusion, our *Style Agent* could provide personalized aesthetic assistance to creators, fostering the creation of designs that embody particular Kansei elements with designers' novel ideas.

*Keywords:* Aesthetics, Multi-Dimensional Space, Visualization, Poster Design, Creativity.

# **1** INTRODUCTION

Al-enabled design applications are becoming popular. The revolution technologies, such as Large-language models and stable diffusion algorithms, demonstrate cognitive capabilities to generate plausible outcomes based on their reasoning thinking. More importantly, the accompanied prompt engineering and interface allow a user to command the system by describing what they want to see without really drawing or making, as they usually do before.

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While new computational applications show the potential to generate astonishing visuals, many artists and designers have struggled to tell the AI and lead the conversations to produce suitable outcomes that match practitioners' visions (Ko et al., 2023).

According to Howard et al. (2008), a typical creative process involves iterative explorations of analyzing the requirements. Practitioners often use doodling and looking up visual references to graduately formulate their concepts and design visions. Without going through this incubating process, it was challenging to articulate what they really wanted to create with textual prompts (Ko et al., 2023). As a result, the prompt interfaces trapped users in a lot of trial-and-error circles. Consequently, it costs enormous energy waste and corresponding carbon emissions (Luccioni et al., 2024), which negatively affect environmental sustainability. To improve human-AI collaborations and reduce wasted time as well as resources, we hypothesized that Kansei Engineering (KE) could fill the gap by using exemplars to sensitize designers' thinking of the expressive qualities and then facilitate users to articulate their design visions that could be interpreted properly by AI systems. This paper presents a Style Agent prototype we developed based on particular types of KE frameworks (López et al., 2021). It includes three primary components (see Figure 1). First, we collected semantic rating data with 156 stimuli and 30 adjective scales from 5 participants. Second, we used the Mood Board Search application (Google Research & Nord Projects, 2022) to analyze the data and pre-train vector models for each adjective scale. At the same time, we used the models to predict the perceptual Kansei of more than one thousand new stimuli. Third, we developed two interactive visualization interfaces to display the exemplars and their corresponding Kansei associations in two and three-dimensional spaces. This multidimensional space aims to sensitize designers' thinking and formulate their design visions in the early design phase. A user can browse the exemplars and see the target audience's possible Kansei perceptions.

We conducted a user study with six designers to individually investigate how well the visual style agent represents the designer's style and how it can support their creation in the design process. After explaining the study and helping them become familiar with the system's interface, we ask him/her to design a poster for an art exhibition in 20 minutes, using Style Agent as the basis for their design ideas. At the end of each task, we collected participant feedback through semi-structured interviews to understand their usage experience and improvement feedback. Based on the results of the qualitative analysis, we found that most of the participants could intuitively use our system to describe the ideas in their minds. Our Style Agent developed in this study can provide good visualization and representation of styles. In addition, it was also found that Style Agent can be used as a source of inspiration and stylization during the concept development phase. One participant said, "I think it helped me more to establish the style quickly in the early stage." The <mark>semantic differential method</mark> used in our system also empowered them to get more suggestions and even to learn from outcomes. Another participant said, "...It's not just the part that I want, but also the opposite part, that is...what kind of situations I want to avoid in my poster, it's also there." We conclude that Style Agent not only meets the basic need for users to identify and communicate their own style but also allows them to have a reference inspiration that can speed up the design process and "try something new."


**Figure 1**. The framework of *Style Agent* consists of three primary components: (A) Developing an interactive machine teaching interface for engaging designers to teach AI systems with design examples. (B) Using machine learning techniques [e.g., Concept Activation Vectors (Kim et al., 2018)] to transform aesthetic algorithms into computational forms. (C) Visualizing the Kansei Design space with examples and vectors (e.g., dynamic) generated from B. Designers can not only use it to identify new opportunities but also manipulate the noticeable design parameters (such as shapes, colors, or materials) to experiment with creative designs for conveying certain Kansei and aesthetics (e.g., expressing energetic and dynamic feelings with balanced quality).

#### 2 BACKGROUND AND RELATED WORKS

In this section, we will briefly review the relevant research and methodologies of common design processes in which designers find and use inspirational materials to help them formulate design concepts for expressing particular emotions or affections to the target audience.

#### 2.1 Inspirations for Designing

Designers frequently rely on visual sources to spark creativity and generate new ideas (Eckert & Stacey, 2000). They seek fresh material and inspiration from various outlets, including magazines, exhibitions, conversations, and online searches (Koch et al., 2020; Lucero, 2012). Many designers value the extensive range of online resources available, with platforms like Behance, Dribbble, and other design websites being key sources of inspiration (Kang et al., 2021).

However, the process often involves using verbal keywords to navigate digital collections (Keller et al., 2006), which can be limiting without contextual understanding. Finding the right image without knowing the context is challenging, not only for the designer's creativity but also for the ability to translate abstract concepts into concrete examples. Browsing digital inspiration platforms for new stimuli before or after identifying relevant keywords can be a solution (Koch, 2020).

#### 2.2 Communication of Abstract Concept

Translating abstract concepts into concrete examples often involves images or image references. The common process includes the following activities (Eckert & Stacey, 2000):

- 1. Communicating new designs through sketches and discussions, making modifications based on inspirational sources.
- 2. Using clusters of images from various categories to demonstrate different styles and design ranges.
- 3. Creating mood boards displaying images that reflect various cultural aspects, colors, and proportions, conveying the overall aesthetic of a category.

Those types of communication, which invoke relevant materials as examples, require the viewer to use their imagination to understand the speaker's position in the "design space" (Shaw, 2012), which increases the possibility of bias in the process of understanding each other's ideas. Interviews with practicing designers have identified five key roles of mood boards in the design process (Lucero, 2009): they help explore the design space and define task boundaries (*Framing*), communicate visions to stakeholders (*Aligning*), examine and integrate contradictory ideas (*Paradoxing*), work between abstract and concrete concepts (*Abstracting*), and set a clear direction for the design (*Directing*).

Our research aims to provide designers with a *style agent* that can help *frame* their abstract visions and *direct* their creation process. To achieve this goal, we think Kansei Engineering is the best methodology for sensitizing designers' imaginations to the particular affections they want their audience to feel. KE's versatile database can also guide designers to experiment with design parameters that are related to the intended expressive feelings.

#### 2.3 Kansei Engineering and Emotional Design

Kansei Engineering (KE) has evolved significantly over the past few decades, establishing itself as a crucial methodology for integrating consumer emotions and perceptions into design. It translates consumer feelings and images into design elements, enhancing product satisfaction and market success (Nagamachi, 1995). The evolution of KE has been marked by the integration of big data, multidisciplinary cooperation, and advanced mathematical algorithms (López et al., 2021). These trends are expected to drive future research and applications of KE, making it more robust and versatile. Furthermore, the concept of Kansei Design has been introduced, expanding the scope of KE to include philosophical and historical perspectives, and promoting its application in various design disciplines (Lévy, 2013).

# 2.4 Artificial Intelligence Empowering Design Process

Artificial intelligence (AI) has the potential to transform the design field by categorizing and processing large amounts of data. This capability can inspire designers by summarizing the work of others in the industry and beyond, aiding in understanding how similar problems have been solved. AI supports the ideation phase by providing numerous design variants for selection (Knearem et al., 2023). While AI accelerates idea generation, it also raises concerns about the automation of aesthetic decisions. Recommendation systems, which align with current trends or specific standards, may reduce aesthetic diversity and lead to standardization (Manovich,

2018). Some worry about a gap between Al-generated outputs and what is aesthetically pleasing to humans.

Designers are increasingly viewing AI as a potential design material (Yang et al., 2020; Yildirim et al., 2022). With the rise of user-friendly text-to-image generation systems like DALL-E and Midjourney, anyone can create a wide range of synthetic digital images at a low cost (Oppenlaender, 2022). These systems have low entry barriers, requiring no training or knowledge of the underlying technology, enabling users to generate high-quality results quickly.

However, ethical issues and the loss of human touch in Al-generated outcomes remain concerns. Many creative professionals find that text prompting can limit creativity due to reliance on textual inputs (Ko et al., 2023). Articulating design intents in the early stages is challenging because design problems are often vague. This study focuses on helping designers articulate their intents and develop design visions using diverse exemplars and representations of the multidimensional design space.

# 3 METHODS

In this section, we outline the overall framework of our system design, describe the user interface for each component, and detail the process of collecting and pretraining exemplars with three design participants. Based on their input, we expanded the exemplars to over 1200 designs and developed a visualization interface to aid the designers' creative process.

### 3.1 The Overview of Style Agent System's Framework

Given the qualitative nature of aesthetics, we employed human-like learning principles (Langley, 2022) to develop the system's scoring functionalities. Initially, we designed an interface to gather users' perceptions of design exemplars using a modular structure based on the type 1 Kansei Engineering system of category classification (López et al., 2021). Specifically, we integrated semantic differential scales in the data-collection interface (see Figure 2). Users view one design exemplar at a time and click on a Likert scale to indicate their perceptions.

After gathering sufficient data, we used Mood Board Search (Google Research & Nord Projects, 2022) to train separate models representing different semantic scales (see Figure 3). This tool employs concept activation vectors (CAVs) to recognize visual concepts. It compares new images by analyzing the angle between the CAV and each image's activations, estimating similarity to a specific concept. The resulting AV score, ranging from -1 to 1, indicates the degree of similarity to the concept.

In the third visualization component, we use CAV scores and principal component analysis (PCA) to calculate multidimensional space and determine the optimal locations of each design stimulus (see Figure 4). This visualization aims to enhance designers' perceptions of alternative aesthetic values, helping them articulate their design intents and visions.

#### 3.2 Component A: Data Collection

To utilize image processing for analyzing visual exemplars and estimating their semantic aesthetic values, we sought high-quality datasets. We selected the <u>typographic poster website</u>, an open platform for graphic designers to share their work, with all files having resolutions higher than 860x1217 pixels. The first author randomly collected over 200 posters of diverse styles, which were then reviewed and reduced to 156 stimuli to avoid redundancy.

To aid designers in articulating their thoughts, we analyzed semantic terms from graphic design (Zhao et al., 2018) and product design research (Chuang et al., 2008; Hsiao & Chen, 2006) to find adjectives describing aesthetic qualities. The semantic differential (SD) method, commonly used in aesthetics and KE research, involves using opposite adjective pairs to guide participants' ratings on a Likert scale. In this study, we selected 30 SD pairs for evaluating visual materials. The composition aligns with the hierarchy of the Kansei evaluation model (Kobayashi et al., 2016). The survey interface contains the poster to be evaluated and the SDs (see Figure 2). To confirm that the semantic data of the posters could be stored completely, the researchers personally tested it to collect 30 sets of SD for 156 posters. We invited another 3 participants who majored in Industrial Design to perform the same collection task, with the aim of using these data as a training set for creating a personal style model for each participant. On average, it took 4.5 hours for a participant to complete all the training tasks.



**Figure 2.** The semantic differential survey was used to collect the data by asking design participants to rate their perceptions of each of the 156 poster examples.

#### 3.3 Component B: Using AI to Analyze the Data and Make Predictions

After collecting data, we processed it to select images for machine learning analysis. The system generated folders for positive and negative correlations for each adjective based on poster scores. Using a 9-point Likert scale, scores of 3 or lower indicated strong impressions of

the left-side adjective, while scores of 6 or higher indicated strong impressions of the right-side adjective.

The Mood Board Search application was used to train models with these stimuli, employing cosine similarity to compare new images to the trained concepts. This algorithm predicted the aesthetic values of an additional 1134 high-quality posters not included in the initial rating tasks. The CAV score, ranging from -1 to 1, indicates the similarity of an image to the trained concept.

However, it is not intuitive to present 1290 posters (156 trained images and 1134 testing ones) in this way because the user needs to keep scrolling up and down to see other images. It is difficult to view and compare the differences between images at the same time, so we only use CAVstudio as a model training tool, not as a data visualization tool.



**Figure 3.** The example of training an ML model in CAVstudio (Google Research & Nord Projects, 2022) to identify images that match the user's concept of 'Avant-garde.'

# 3.4 Component C: Data Visualization

To visualize the semantic adjectives in a multidimensional space, we used PCA to reduce data dimensionality. Each participant's SD sets for all posters were reduced to three groups corresponding to the X, Y, and Z axes, with scores representing their contributions to the coordinates.

We developed two visualization interfaces: a 2D interface showing stimuli of selected semantic scales and a 3D interface (see Figure 4) displaying posters in a canvas that users can rotate. These interfaces help users curate design exemplars and analyze their parameters to inspire new designs that convey specific aesthetic values and qualities. They also provide the function of temporarily saving the clicked posters and presenting them in a clearer way on the right panel so that users can observe their details during the ideation process.





**Figure 4.** In the 2D interface (upper image), a user can select the semantic scales to see associated exemplars belonging to each of the opposite sides. In the 3D interface (bottom one), a user can rotate the space to observe the distributions of designs. They can click the stimuli in both modes to collect inspirational stimuli shown on the right side. This Kansei Design Space can help designers to curate design exemplars and analyze their parameters to inspire them to create new designs that can convey particular Kanseis and aesthetic qualities.

#### 4 SYSTEM EVALUATION AND FINDINGS

We recruited six design students from our faculty through our network. They are all studying in master's programs in industrial design and are between 20 and 25 years old. We assigned them to one of the two groups; each had three participants. The main difference between those two groups is that all participants in the first Group 1 also helped us to pre-train the data described in section 3.3. The experiment procedure and tasks are the same for both groups. The only variant is the data used to visualize the design space. For Group 1, we used individual participants' data to generate their personalized outcomes of the machine-learning models and three-dimensional space. For the second Group 2, we aggregated the raw data from Group 1 and used the same machine learning tool to process it to generate shared models and stimuli coordination. These two groups of participants can help us understand the difference between designing with a self-trained style model and the feasibility of using pre-trained data for aesthetics-related applications.

The experimental process basically consisted of three sessions. Firstly, we explained the purpose of the study to the participants and asked them to present some posters they had designed in the past three months. This conversation aimed to help us understand their design process and the tools they were accustomed to using in designing. Meanwhile, we guide participants in explaining their design practice as a basis for a subsequent comparison. In the second sesnemaking session, we first explained our system to the participants and demonstrated the critical functions of the visualization interface. Then, they were asked to complete a sensemaking task of examining the distributions of stimuli in the three-dimensional space and defining the semantic axes to describe their perceived relationships among those exemplars. To support participants' cognitive thinking, we presented the best matching between each of the 30 SD scales and the three axes based on the results of the principal component analysis. A participant can select the most prominent ones from the list or create new labels to define each axe. Lastly, in the third session, we asked participants to design a poster for an imaginary client using our system as a source of inspiration within 20 minutes. After they completed the poster design, we conducted a semi-structured interview to understand their design process as well as the user experience with our Style Agent system. The total duration of the experiment was approximately 1 hour.

#### 4.1 Preliminary Findings of Qualitative Themes

We used Braun and Clarke's (2006) thematic analysis method to analyze the qualitative responses and interview transcripts and identify themes using both an inductive and deductive approach. As a result, we identified the following five themes, reflecting on the system's influence on their creative processes and design outcomes. To help readers understand a particular participant's feedback from a specific group, in the following report, we used PA-C to represent the three participants of Group 1 and P1-3 for Group 2's participants. For instance, PB belongs to Group 1, and P3 is one of the Group 2.

**1.** Sensemaking and Exploration: Participants, such as P1 and P3, highlighted the value of navigating the 3-dimensional Kansei Design Space to gain inspiration and understand aesthetic

dimensions. They appreciated the ability to view hundreds of poster examples from various perspectives, which facilitated a deeper comprehension of aesthetic categories and trends.

**2. Inspiration and Ideation:** The process of selecting inspirational posters and defining aesthetic keywords was crucial for participants like PA and P2. This step helped them crystallize their design visions and served as a direct influence on their creative outputs.

**3. Design Process and Creativity:** Participants, including PC and P2, expressed that the system significantly impacted their design processes. The availability of examples and keywords on an extended display was instrumental in guiding their design choices and fostering creativity within a structured framework, i.e., framing a design vision of a particular Kansei and playing around with design parameters to create posters that can express the intended feelings.

**4. User Experience and Feedback:** While participants generally found the system innovative and helpful, some participants suggested improvements in usability and navigation. They provided constructive feedback on how to make the system more intuitive and user-friendly. For instance, some people hope to see the keyword search function added because "...the system doesn't allow me to [search] ... if I type in a topic and then go directly to the topic related to it" (PA), they reported that they "want to be able to find what I want faster" (PB).

Overall, our findings indicate that *the Style Agent* system offered a novel approach to poster design, enabling users to explore, inspire, and create within a rich, multidimensional aesthetic and Kansei landscape. While the system was highly regarded for its ability to facilitate a deeper understanding of design elements and their corresponding affections, it shows a great potential to transform the poster design process by leveraging technology to bridge the gap between inspiration and creation. Participants' feedback on its usability highlights the importance of continual refinement to enhance the user experience.

# 5 DISCUSSION

# 5.1 Using CAV and Mood Board Search to Leverage Designers' Subjective Knowledge

Despite the limited number of participants, their experiences and qualitative feedback provide valuable insights for our research on developing tools that support creativity. Concept activation vectors (CAVs) have proven to be effective for analyzing abstract concepts and subjective data (Kim et al., 2018). Our study is pioneering in applying this method to evaluate aesthetic values using semantic ratings from design users. Participants were able to recognize differences and clusters in the stimuli, even without pre-training. This suggests that pre-trained data can provide an initial visualization of the design space. Future systems could include interactive machine-teaching functions, allowing users to personalize models by adjusting stimuli positions or importing new design exemplars with their own ratings.

### 5.2 Sensitizing Designers' Imaginations with Design Space Visualization

One common challenge with text-to-image and large language model applications is the difficulty users face in building an accurate mental model of the system. Often, generated images do not match users' intentions due to the gap between text and visual modalities (Ko et

al., 2023). Our *Style Agent* addresses this by providing a rich array of stimuli in a multi-dimensional space with Kansei axes, allowing users to think and browse using visual language. This approach helps designers systematically consider relevant alternatives and explore new ideas beyond their initial references. It can also mitigate the fixation problem (Dell'Acqua et al., 2023) where AI-generated outcomes lack diversity compared to human-generated designs.

#### 5.3 Design Implications for Creativity-Supportive Tools

Our study focused on exploring and representing roles rather than automatically generating designs [such as (Guo et al., 2021)]. Observing designers during the creation process revealed how they select relevant exemplars, extract features to frame design visions, and realize their concepts through complex cognitive processes. One novel feature of our *Style Agent* system is providing both positive and negative exemplars for specific semantic dimensions, helping users appropriately express their intents and reduce personal biases. Literature suggests that designers tend to stay within their comfort zones. Presenting contradictory exemplars can stimulate reflections and inspire new ways of thinking and designing.

### 6 CONCLUSION

Designers use various methods and tools to gather creative inspiration. Most recent AI design tools often rely on keyword input, which can be challenging when dealing with abstract concepts and expressions of feelings. Consequently, users were frequently stuck with the common trial-and-error approach and the computational systems generated a huge amount of electricity waste and carbon emission. To make it sustainable and improve designers' creative process, we applied Kansei Engineering's methodologies to develop an interactive *Style Agent* system. A user could train their own CAV model with their choices of examples and semantic scales. Then, *Style Agent* can use the model to predict diverse exemplars and visualize them in Kansei design spaces to help designers frame their design visions.

In our study, we evaluated the *Style Agent* system with sensemaking tasks, helping designers become aware of diverse exemplars in a multi-dimensional Kansei space. Participants framed their design visions, selected inspirational examples, and completed a poster design within 30 minutes. Results showed that our *Style Agent* system aids in expressing design visions early in the process. The provided exemplars of both positive and negative meanings helped reduce biases, speed up creation, and improve design outcomes.

# 7 LIMITATIONS

There are three primary limitations in our research. First, our study focused on poster design and we mainly collected examples from a public platform. They all are completed designs, which might limit participants' creativity. Including incomplete samples, such as random examples generated by AI, might enhance diversity and imagination. Second, the poster design task could be more abstract to prevent direct reference to similar posters, allowing more exploration of new concepts. Third, with only six participants, we focused on qualitative interviews for insights into the benefits and limitations of our system. Future studies will include more participants with varied backgrounds to broaden our understanding of supporting designers' creativity.

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# EXPLORING THE CHARM FACTORS OF SMARTWATCH AMONG TAIWANESE CONSUMERS

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# ABSTRACT

Smartwatch have gained increasing attention in the consumer market as smart wearable devices. They offer diverse digital functions and smart applications beyond simply displaying the time, which has piqued the interest of consumers. Market research institutions have reported significant global shipments of smartwatch in recent years, reaching millions of units. However, the adoption of smartwatch among consumers in Taiwan remains relatively low. This study aims to explore the attractiveness factors of smartwatch for Taiwanese consumers. Using the methodology of charm engineering, in-depth interviews were conducted to construct an EGM evaluation structure, followed by a quantitative survey to investigate Taiwanese consumers' preferences for smartwatch and subsequent analysis. The research findings indicate that consumers prioritize the overall appearance and functionality of smartwatch, with a preference for sports-oriented features and distinctive styles. It is recommended to focus on personalization traits in the design of smartwatch in the future.

Keywords: Miryoku Engineering, Wearable Devices, Smartwatch, Quantification theory type I

# **1** INTRODUCTION

# 1.1 Research Background and Motivation

In recent years, smart wearables have emerged in the consumer market, becoming indispensable accessories and tools in people's lives. With continuous technological advancements and the proliferation of smart devices, smartwatches and smart bands are no longer just tools for telling time. They now feature a variety of functions and digital applications, such as health monitoring, smartphone notifications, and activity tracking. According to a report by research institution Counterpoint Research in 2022, global smartwatch shipments in 2021 reached approximately 127.5 million units. The rise of smartwatches (and bands) has garnered widespread attention and interest, and consumers have developed a keen interest in the attractive factors of these emerging products.

Observations have shown that the use of smartwatches and smart bands in Taiwan remains relatively low, with some elderly users receiving them as gifts from younger family members. However, with the rapid development of the smart wearable market, many manufacturers have introduced various designs and styles of smartwatches. This has led to confusion for consumers regarding their needs and purchasing motivations. In this context, it becomes crucial to deeply study the attractive factors of smartwatches.

### 1.2 Research Objectives

This study aims to explore the attractiveness factors of smartwatches (or smart bands) among Taiwanese consumers. Utilizing the Miryoku Engineering approach, this research conducts initial investigations through interviews, questionnaires, and analyses. By understanding these attractiveness factors, the study delves into consumers' preferences and needs regarding smartwatches, providing references for product design and marketing strategies. This, in turn, aids in improving the appearance and user experience of smartwatches, thereby enhancing consumer acceptance and purchase motivation.

# 2 INTRODUCTION

#### 2.1 Smartwatches

Since ancient times, watches have been a long-standing wearable technology. Besides allowing users to quickly check the time, they have also become a popular fashion accessory (Lin, 2023). With the advancement of technology, wearable devices combined with IoT and wireless networks have evolved into smartwatches, which, unlike traditional watches, feature embedded systems and multifunctionality similar to a personal digital assistant (Liu, Chiu, & Chiang, 2016). Smartwatches, integrating IoT technology, can simultaneously connect to smartphones to access online information and enable smart payments. Additionally, with real-time monitoring capabilities, they quickly acquire personal physiological data such as exercise, sleep, and heart rate, benefiting users by allowing them to directly view or track their conditions (Chung, 2021).

According to current academic literature, there is no unified definition for smart wearables specifically concerning smartwatches. Types of smart wearables include watches, bands, bracelets, and wristbands. These devices are worn on the user's wrist, with head-worn wearables also available. However, the market is currently dominated by smartwatches and smart bands (Lin, 2023; Chou, 2022).

### 2.2 Miryoku Engineering

Miryoku Engineering was initiated by Japanese scholar Masato Ujigawa in 1991, bringing together numerous researchers with the primary goal of "creating attractive products and spaces" (Ruan & Lin, 2015). The appeal influences and attracts consumers by adding desirable characteristics such as style, texture, and taste to products, creating unique attractions that draw consumer attention (Lee, 2015). The Miryoku Engineering approach primarily utilizes the "Evaluation Grid Method (EGM)," proposed by scholar Junichiro Sanui. This method involves

in-depth interviews comparing products A and B to understand respondents' cognitive concepts of the products and lists the conditions and classifications accordingly (Wu, 2014).

# **3** RESEARCH METHODOLOGY

The purpose of this study is to investigate the attractiveness factors of smartwatches (bands) among Taiwanese consumers. However, the research does not explore the influence of color attractiveness. Therefore, images of smartwatch and smart band products from the Taiwanese market were collected and converted to grayscale, as shown in Figure 1. The study involved in-depth interviews with eight designers and scholars who have experience wearing smartwatches (bands). Based on the interview results, the EGM (Evaluation Grid Method) was used to understand the respondents' perceptions of smartwatches (bands). These insights were then filtered, organized, and converted into a quantitative questionnaire, which was distributed online to gather data on preferred styles and elements.



Figure 1. Process of Sample Selection for Image Cards

# 3.1 Research Framework and Process

This study is mainly divided into four stages, all aimed at investigating the attractiveness factors of smartwatches (bands). The process and research methods are as follows:

# 3.1.1 Sample Collection

A total of 52 images of current smartwatch (band) products on the market were collected. According to the research limitations, the images were processed by extracting color and removing backgrounds, as well as adjusting the watch faces. Products with overly similar appearances were filtered out, resulting in a final sample of 36 images, as shown in Figure 2.



Figure 2. Filtered Image Card Samples

# 3.1.2 In-depth Interviews

This study conducted in-depth interviews with eight designers and expert scholars who have over one year of experience wearing smartwatches (bands). The interviewees were asked to rank the sample images based on their preferences and provide descriptions. From these interviews, middle-level (original attractiveness evaluations), summit-level (abstract reasons), and bottom-level (specific conditions) descriptions were derived.

# 3.1.3 Evaluation Grid Method (EGM)

Based on the in-depth interviews with the eight respondents, the vocabulary was collected and its frequency accumulated. The summit-level (abstract reasons) were then filtered using the KJ method. Finally, the data was combined and organized into an evaluation grid, as shown in Figure 3.



Figure 3. Evaluation Structure Diagram of Vocabulary After KJ Method Selection

# 3.1.4 Questionnaire Survey and Analysis

Based on the results compiled from the EGM (Evaluation Grid Method) and filtered, the top cumulative summit-level styles were selected as the subjects of the investigation. The three

styles chosen were "Sport Functionality" (53 cumulative instances), "Minimalist Classic" (39 cumulative instances), and "Trendsetter" (53 cumulative instances). However, it was found that "Sport Functionality" and "Minimalist Classic" had a high correlation with middle-level attributes. Therefore, "Sport Functionality" was chosen as the main subject for the investigation, and a quantitative Type I questionnaire was created for further research and analysis.

### 4 RESULTS AND ANALYSIS

This study utilized the Miryoku Engineering experimental survey method, organizing the filtered results into an evaluation grid, and identified the attractiveness factors of the "Sport Functionality" and "Trendsetter" styles. These factors were then converted into a quantifiable analysis using a Likert scale five-point questionnaire. The questionnaire was distributed and completed online, resulting in a total of 70 responses, of which 48 were valid. Reliability analysis was conducted using Cronbach's Alpha coefficient as the standard, with a value of 0.757 indicating the questionnaire's stability and reliability. The results were then statistically analyzed to understand the attractiveness factors of smartwatches for Taiwanese consumers.

#### 4.1 Questionnaire Results and Analysis

The survey results show that there were 20 male respondents (41.7%) and 28 female respondents (58.3%), with slightly more female participants. The age distribution is mostly between 19-26 years old (70.8%), with the majority being 19-22 years old (37.5%), followed by 23-26 years old (33.3%). The education level is primarily university or college (50%), with graduate school or above at 45.8%, and below high school at 4.2%.Regarding the survey on smart wearable users, most respondents have owned at least one device at some point (68.8%), while 18.8% have owned two devices, and 12.5% have owned three or more. The majority of users wear their device daily (52.1%), with 43.8% wearing it occasionally. The main motivations for purchasing and using a smartwatch or smart ring include checking phone notifications or messages, tracking exercise, monitoring health status, and convenient time viewing. Most users received their device as a gift from friends or family (43.8%). The related statistics are shown in Figure 4.



Figure 4. Statistical Chart of Purchase and Usage Motivations for Smartwatches

# 4.2 Quantification Theory Type I Analysis

# 4.2.1 Sport Functionality Style

According to the survey results, the analysis shows that the "sport functionality style" was favored by most respondents, with a mean preference rating of M=3.92 and a standard deviation of Std.=0.77 in the descriptive statistics. From Quantification Type I, it is evident that respondents particularly value the "sport functionality" style's personality traits. They prefer silicone plastic materials with wave-patterned slim bands, accented with some diamond embellishments, as shown in Table 1.

ltem	Category	Category Score	Partial Correlation Coefficient		
Economic Simplicity	Waterproof and Scratch-resista nt	-0.22059	0.486414		
Silicone/F	Plastic Strap	0.44	41773		
Round W	/atch Shape	-0.	4475		
Plair	n Strap	0.02	26391		
Versatile and Compatible	Metal Strap	-0.10977	0.574567		
Leath	er Strap	0.3	94164		
Wove	en Strap	-0.2	27871		
Silicone/I	Plastic Strap	-0.25333			
Thin and Lon	g Watch Shape	-0.4	-0.44557		
Plair	n Strap	0.44	43763		
Wave Pa	ttern Strap	0.5	06846		
Marble P	attern Strap	-0.4	18486		
Thin Strap (	16mm or less)	-0.6	58515		
Functional and Comfortable	Waterproof and Scratch-resista nt	-0.18872	0.513688		
Silicone/I	Plastic Strap	0.1	.0358		
Square W	/atch Shape	-0.02687			
Round W	/atch Shape	-0.3381			
Plair	n Strap	-0.17048			
Wave Pa	ttern Strap	-0.02106			
Hollow-out Strap Design		0.654544			
Thin Strap (	16mm or less)	1.210092			
Personal Style	Metal Strap	-0.06919	0.632447		
Leather Strap -0.18014			L8014		
Wove	en Strap	0.12	0.126749		
Hollow-out	Strap Design	0.36466			

Table 1. Quantification Type I Analysis Table of Style for "sport functionality"

Strap Pendant Design	-1.4653			
Strap with Embedded	0.862014			
Diamonds				
Wave Pattern Strap	-0.17925			
Marble Pattern Strap	-0.24985			
Constant Term 3.916667				
Multiple Correlation Coefficient = 0.73				
Coefficient of Determination (Square of Multiple Correlation				
Coefficient)= 0.54				

# 4.2.2 Trend-setting Style

The "unique and standout style" had a slightly lower preference rating compared to the "sport functionality style" but was still favored by some respondents, with a mean rating of M=3.02 and a standard deviation of Std.=1.17 in the descriptive statistics. From Quantification Type I, it is evident that respondents particularly value the "unique and standout" style's special occasion traits. They prefer wave-patterned bands that are hollowed-out and embellished with diamonds, as shown in Table 2.

Table 2. Quantification Type I Analysis Table of Style for "unique and standout"

ltem	Category	Category Score	Partial Correlation Coefficient		
Special Occasions	Metal Strap	0.268864	0.564182		
Leath	er Strap	-0.	7708		
Hollow-out	: Strap Design	0.94	0.948357		
Strap Pen	dant Design	-0.0	04291		
Strap with Diam	n Embedded Ionds	-0.5	-0.53797		
Marble P	attern Strap	0.84	49649		
Versatile and Compatible	Metal Strap	-0.30305	0.359496		
Leath	er Strap	0.044463			
Wove	en Strap	-0.35258			
Hollow-out	Strap Design	-0.07922			
Strap Pen	dant Design	-0.	-0.0843		
Strap with Embedded Diamonds		-0.0813			
Wave Pa	ttern Strap	0.871206			
Marble P	attern Strap	0.5	70275		
Personal Style	Personal Style	-0.5356	0.521346		
Silicone/I	Plastic Strap	0.10358			
Square W	/atch Shape	-0.02687			
Round Watch Shape		-0.3381			
Plair	n Strap	-0.17048			
Wave Pa	ttern Strap	-0.02106			
Hollow-out	Strap Design	0.654544			
Thin Strap (	16mm or less)	1.210092			

Personal Style	Metal Strap	-0.06919 0.63244				
Leath	er Strap	-0.0077				
Wove	en Strap	-0.28058				
Silicone/I	Plastic Strap	0.230219				
Thin and Lon	g Watch Shape	-0.6	56279			
Plair	n Strap	-0.	0569			
Strap with Embedded Diamonds		0.851456				
Wave Pattern Strap		0.760575				
Marble Pattern Strap		0.233039				
Thick Strap (2	19mm or more)	-1.2054				
Consta	ant Term	3.020833				
Multiple Correlation Coefficient = 0.68						
Coefficient of Determination (Square of Multiple Correlation Coefficient)= 0.47						

# 5 CONCLUSION AND RECOMMENDATIONS

This study utilized the Miryoku Engineering approach, employing in-depth interviews and survey methods, to understand the attractiveness factors and user preferences for smartwatches among Taiwanese consumers. The interviews revealed that most respondents prioritize the overall appearance and functionality of smartwatches (rings), viewing them as trendy accessories and smart lifestyle applications. Features that do not align with these attractiveness attributes are generally not preferred. For instance, woven straps were commonly disliked as they were perceived to be too similar to hairbands. This study focused on two distinct styles with varying levels of perception: "sport functionality" and "unique and standout." It was found that Taiwanese consumers have the highest acceptance and preference for the "sport functionality" style. Through Quantification Type I analysis, the following conclusions were drawn, which can serve as references for future smart wearable product design:

1. Based on the survey results, it was found that most smartwatch (ring) wearers received their devices as gifts. This study suggests that these products have both attractiveness and value, making them suitable for gifting.

2. Consumers value the personalized characteristics of the "sport functionality" style, which reflect their needs for sporty functionality through personalized design. In contrast, the "unique and standout" style is appreciated for its special occasion characteristics, making it more attractive to consumers during special events.

3. In both the "sport functionality" and "unique and standout" styles, the specific condition of "diamond-studded strap design" achieved significant results. This indicates that consumers find diamond-studded strap designs particularly effective in highlighting the personalized attributes of the style.

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# THE EMOTIONAL IMPRESSIONS OF DIGITAL TOOLS ON NOVICE MUSIC COMPOSITION: A COMPARATIVE STUDY EXPLORING USERS' FEELINGS TOWARDS GENERATIVE AI AND ACTIVE LEARNING IN MUSIC ACCESSIBILITY

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# ABSTRACT

This study explores the impact of generative AI music composition tools and active learning methods on individuals with few or no prior experience in music. Using a within-subjects experimental design, 48 participants used both an AI-driven tool (Soundraw) and an active learning platform (Ableton's Learning Music) to compose music. Data were collected through surveys assessing various aspects of the user experience, including engagement, perceived authorship, user satisfaction, educational impact, and emotional connection. The data suggests that both Soundraw and Ableton's Learning Music are effective tools for novice music composition, with participants reporting similar levels of engagement, perceived authorship, user satisfaction, educational impact, and emotional connection for both tools. However, a marginal difference was observed in the area of creative control, with participants feeling that Ableton's Learning Music provided somewhat slightly more creative control than Soundraw.

This marginal difference in creative control may be attributed to the structured, interactive lessons provided by Ableton, which guide users through the basics of music theory and composition, allowing them to apply their learning in a controlled manner. In contrast, Soundraw's parameter-based approach offers high flexibility but may not provide the same level of structured guidance, which could influence users' perceptions of creative control.

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Overall, the findings indicate that both generative AI and active learning tools can enhance the music composition experience for novices, making music creation more accessible and engaging. These insights support the potential for integrating diverse digital tools into music education to cater to different learning styles and preferences.

*Keywords:* music composition, generative AI, active learning method, novice users, user engagement.

# 1. INTRODUCTION

The integration of digital tools in music composition has changed the ways people approach musical creativity, particularly for those without formal music training. These tools offer a range of features that simplify the composition process and make it accessible to a wider audience. Generative AI music composition tools, such as Soundraw (Soundraw, 2024), allow users to create music by selecting various parameters, simplifying the process and enabling users to generate complex musical pieces without deep technical knowledge. Conversely, active learning platforms like Ableton's Learning Music (Ableton, 2024) guide users through interactive lessons on music theory and composition, providing, level by level, a structured learning path that gradually builds their skills.

The integration of digital tools in music education has significantly transformed how novices approach music composition. Two primary approaches—generative AI music composition tools and active learning platforms—have shown particular promise in democratizing access to music creation and enhancing the learning experience for individuals with little to no formal music training. This study examines these tools, focusing on their impact on user engagement, perceived authorship, user satisfaction, educational impact, creative control, and emotional connection.

#### 1.1 Generative AI in music composition

Generative AI tools, such as Soundraw, have been designed to assist users in creating music by leveraging advanced machine learning algorithms. These tools simplify the music composition process by allowing users to select various parameters such as genre, mood, length, tempo, instruments, and intensity. A comprehensive survey (Roberts et al., 2019) reviewed AI music generation tools and models, highlighting the educational potential of such tools in making music creation accessible to a broader audience. Similarly, another study (Zhu et al., 2023) explored deep learning applications in AI music generation, emphasizing their role in education and creative practice. These studies underscore the potential of generative AI to facilitate a more inclusive and engaging music composition experience for novices.

The impact of AI-generated music on mental health and education is another area of interest. A study (Williams et al., 2020) discussed the use of AI for generating functional music to improve mental health, noting that AI-generated music can enhance learning experiences by providing emotionally resonant and personalized content. This aligns with findings from a study (Zhu et al., 2023) which reviewed various AI music generation tools and their applications, suggesting that these tools can effectively support music education by enabling users to explore and create music interactively.



Figure 1. Soundraw's interface.

# 1.2 Active learning in music composition

Active learning in music composition engages students through practical, participatory approaches, promoting creativity and deeper understanding. This method shifts the focus from passive reception to active involvement, using hands-on activities like improvisation, peer collaboration, and digital tools for real-time feedback and refinement. Sabet (2020) found that applications like GarageBand enhance high school students' ability to apply theoretical knowledge creatively. Online platforms such as Moodle and Google Drive support collaborative projects and peer reviews, revealing a boost in engagement and creativity (Ng, Ng, & Chu, 2022).



Figure 2. Ableton's Learning Music's Interface.

Lebler (2007) noted that active learning in music education improves critical thinking and creativity through hands-on activities and peer collaboration. Ng, Ng, and Chu (2022) emphasized the benefits of interactive learning platforms in making theoretical concepts practical. Ableton's Learning Music platform exemplifies these methods by offering an interactive environment for exploring musical fundamentals (Ableton, 2024). Additionally, multimedia platforms and interactive environments improve creative thinking and problem-solving skills by engaging students actively (Bhat, 2023).

#### 1.3 Comparative insights

Comparing generative AI tools and active learning platforms in music composition reveals distinct strengths and weaknesses in terms of user engagement, creative control, and educational impact. Generative AI tools like Soundraw provide high flexibility and creative control, allowing users to select musical parameters and experiment with elements in real-time, thus democratizing music creation for a broader audience (Zhu et al., 2023). These tools are beneficial for those seeking immediate results without needing deep music theory knowledge.

In contrast, active learning platforms such as Ableton's Learning Music offer structured, interactive lessons that guide users through music theory and composition basics, fostering a sense of progression and deeper understanding (Ng, Ng, & Chu, 2022). These platforms are effective in making theoretical concepts practical, enhancing critical thinking and creativity through hands-on activities and peer collaboration (Lebler, 2007; Sabet, 2020). Both approaches cater to different learning styles and preferences, with generative AI tools excelling in creative flexibility and active learning platforms providing comprehensive educational experiences. Users often report strong emotional connections to their music creations with both tools, indicating similar levels of engagement and satisfaction (Bhat, 2023).

#### 1.4 Objective

This study aims to compare these two approaches, focusing on their effects on user engagement, perceived authorship, satisfaction, educational impact, creative control, and emotional connection among individuals with no prior experience in music or technology proficiency. By examining these variables, the research seeks to provide insights into the effectiveness of these tools in enhancing the music composition experience for novices and informing the development of future digital music education tools.

#### 1.5 Research question

How do generative AI music composition tools and digital platforms for active learning traditional music composition influence user engagement, perceived authorship, satisfaction, educational impact, creative control, and emotional connection in music composition for novice users?

#### 2 METHOD

This study employed a within-subjects experimental design, where each participant used both a generative AI music composition tool (Soundraw) and an active learning tool (Ableton's Learning Music). The order of tool usage was counterbalanced: odd-numbered participants used Soundraw first, followed by Ableton's Learning Music, while even-numbered participants started with Ableton's Learning Music and then used Soundraw.

### 2.1 Participants

The study targeted individuals with little to no experience in music composition, aiming for a minimum of 30 participants to ensure sufficient data for statistical analysis. Recruitment was conducted through social media, messaging apps, and in-person invitations, resulting in 48

participants with no prior music experience or significant technology proficiency. Participants ranged in age from 23 to 73, with a mean age of approximately 49. The sample included 23 females, 21 males, and 2 non-binary individuals. Educational backgrounds varied, with 29 holding a bachelor's degree, 11 having a high school diploma, and others having various levels of education. Musical experience was generally low, and technology proficiency ranged from limited to advanced.

### 2.2 Experiment Design

Participants used both Soundraw and Ableton's Learning Music, with the order of usage counterbalanced. This design ensured that any observed differences could be attributed to the tools themselves rather than the order in which they were used.

#### 2.2.1 Choice of Applications

The applications were chosen based on several criteria:

• Free Cost: Both tools needed to have free versions to ensure accessibility for all participants.

• No Download/Installation: Tools should not require downloading, allowing easy access through web browsers.

• Platform Independence: Tools should be usable on any internet-connected device, such as smartphones, tablets, laptops, and desktops.

• Similar Interactions: Both tools should offer similar interaction modes, such as clicking on grid-based cells to alter sounds.

• Focus on Instrumental Sounds: Tools should focus on instrumental sounds to simplify the composition process for participants.

Based on these criteria, Soundraw and Ableton's Learning Music were selected.

### 2.2.2 Procedure

Participants followed a structured procedure via an online survey, which included:

• **Demographic Questions**: Collecting information on age, gender, educational background, musical experience, and technology proficiency.

• Introduction to the Experiment: Providing an overview of the study and instructions on navigating each tool. Participants were given links to Soundraw and Ableton's Learning Music, with separate introductions for each tool.

• Using Soundraw: Participants selected parameters (genre, mood, length, tempo, instruments, intensity), generated music, and recorded their compositions, noting the time spent and song length.

• Using Ableton's Learning Music: Participants completed interactive lessons on beats, notes, scales, chords, basslines, melodies, and song structure. They then used the Playground section to create and export a song, applying the concepts learned in the lessons.

• Opinion-Based Questions: Participants rated aspects such as ease of use, creative control, satisfaction, educational impact, and emotional connection using a 7-point Likert scale.

• **Debrief**: Participants reflected on their experiences and provided qualitative feedback.

This approach allowed for a comprehensive analysis of the tools' effectiveness across various demographic groups, providing insights into how different populations interact with music composition technology. The data suggested that educational background and technology proficiency influenced participants' experiences and the outcomes of their interactions with the tools.

# 2.2.3 Variables

The survey questions were mapped to relevant variables, so when participants responded to a specific question about one of the software in a 7-point Likert scale, they were also rating a certain variable for that software. For example:

• Engagement level: for questions such as "How easy was it to turn your ideas into music using each software?"

• Creative control: for questions such as "How much did each software help you try out different sounds and rhythms?"

• **Perceived authorship:** for questions such as "How satisfied were you with how much control you had over your music using each software?"

• User satisfaction: for questions such as "How simple and easy was each software to use?"

• Educational impact: for questions such as "How well did each software work for someone with no prior music experience?"

• Emotional connection: for questions such as "How much did each software make you feel connected to the music you created?"

# **3 RESULTS**

To understand the impact of using generative AI tools and active learning platforms on novice users, we first examined descriptive statistics for various measures across the two tools, Soundraw and Ableton's Learning Music.

Measure	Soundraw (Mean ± SD)	Ableton's Learning Music (Mean ± SD)		
Engagement Level	4.50 ± 1.34	4.37 ± 1.27		
Creative Control	4.79 ± 1.25	4.53 ± 1.27		

Table 1. Descriptiv	e statistics	for the	observed	parameters.
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Perceived Authorship	4.54 ± 1.47	4.44 ± 1.30
User Satisfaction	4.50 ± 1.39	4.22 ± 1.31
Educational Impact	4.49 ± 1.25	4.23 ± 1.32
Emotional Connection	4.51 ± 1.31	4.30 ± 1.22



**Figure 3.** Strip plot visualization of the differences in how Soundraw (SD) and Ableton's Learning Music (ALM) are perceived regarding each observed variable.

Paired t-tests were conducted to compare the means of various user experience aspects between Soundraw and Ableton's Learning Music. Noteworthy results are discussed below:

М.	t	df	p-value	Cohen's d	Mean Diff.	SE Diff.	Lower	Upper
Eng. Level	1.155	47	0.254	0.167	0.146	0.126	-0.108	0.400
Creat. Control	-1.887	47	0.065	-0.272	-0.292	0.155	-0.603	0.019
Perc. Auth.	-0.980	47	0.332	-0.141	-0.146	0.149	-0.445	0.154
User Satisf.	1.184	47	0.242	0.171	0.167	0.141	-0.116	0.450
Educ. Impact	1.493	47	0.142	0.216	0.208	0.140	-0.072	0.489
Emot. Connect.	1.071	47	0.290	0.171	0.208	0.140	-0.072	0.501

 Table 2. Inferential statistics for the observed parameters.



Figure 4. Before and after plot with box plot visualization of the differences in how Soundraw (SD) and Ableton's Learning Music (ALM) are perceived regarding each observed variable.

The data suggests that Soundraw and Ableton's Learning Music are similarly perceived in terms of all measured parameters, with no significant difference in any of them. Soundraw offers slightly more creative control (p = 0.065), although this difference is not statistically significant. However, the ability to adjust genre, mood, tempo, and instruments in real-time likely contributed to Soundraw's higher creative control ratings, indicating that users may find its parameter-based approach more conducive to experimentation. That said, the unique interfaces and designs of each tool likely contributed to user experiences and should be the focus of future research, rather than attributing differences solely to AI-driven or active learning components.

#### 4 DISCUSSION

Both tools received positive feedback for engaging users without prior music or technology experience. However, the lack of statistically significant differences in user perceptions suggests caution in interpreting the results. Soundraw's Al-driven approach is user-friendly, allowing quick music creation through pre-made loops and patterns, enabling consistent song production in about 30 minutes. However, this reliance on predefined elements can lead to repetitive compositions, limiting creativity. In contrast, Ableton's Learning Music provides a broader range of tools for creating unique compositions from scratch, supporting more complex structures and diverse patterns. It requires more time, typically around three hours, to fully explore its features. While this platform fosters a deeper understanding of music theory and composition, it can be challenging for beginners to create cohesive pieces without significant effort and patience. The time spent on each software influenced the outcomes: users quickly mastered Soundraw but produced repetitive music, while limited time with Ableton's Learning Music led to chaotic compositions due to its higher learning curve. This suggests that user

motivation and willingness to engage deeply are critical for achieving quality results. Soundraw's outputs were consistent but repetitive, making them suitable for simple background music, while Ableton's Learning Music enabled more complex compositions, albeit inconsistently due to varying user skill levels. Differences in user experience likely stem from the unique interfaces and designs of each tool, rather than their underlying AI or active learning methodologies. Soundraw exemplifies high-level abstraction, allowing users to select parameters like mood and genre for quick experimentation, capturing the essence of a song without delving into technical details. Conversely, Ableton focuses on fine-tuning, guiding users through the technical aspects of music theory and composition, enabling detailed control over elements like notes, tempos, and rhythms. This balance between abstraction and fine-tuning highlights the amplitude of music composition, integrating emotional expression with theoretical precision. This study highlights the role of software in shaping creative outputs, aligning with Marshall McLuhan's assertion that "the medium is the message" (McLuhan, 1964). Soundraw's ease of use and pre-made loops result in cohesive yet repetitive tracks, ideal for beginners needing a structured environment. Ableton's Learning Music, with its broader toolset, offers greater creative potential but demands more time and effort, often leading to chaotic compositions from beginners. Software and interfaces are bound to frame the possibilities and limitations of creative work (Manovich, 2001).

# 5 CONCLUSION

Both Soundraw's AI-driven approach and Ableton's structured learning platform received positive feedback, but their distinct interfaces complicate isolating the impact of AI versus active learning. Each tool has unique strengths, highlighting the need for diverse learning resources. Soundraw's abstracted interface allows quick music generation through parameters like mood, genre, and tempo, making it accessible to those seeking quick results. In contrast, Ableton's Learning Music provides interactive lessons in music theory and structure, requiring more effort but supporting a deeper understanding of composition. Soundraw's convenience appeals to users with limited time, while Ableton's comprehensive experience suits those seeking deeper music theory knowledge. The study's methodology has limitations, particularly the lengthy experiment, which may have led participants to rush tasks, affecting data accuracy. Differences in interface design further complicate attributing outcomes solely to AI-driven or active learning components, raising questions about the reliability of the findings. These design differences shape user experiences and make direct comparisons difficult, particularly in isolating AI's effects from active learning. The measured differences in user experience may result from the tools' design as much as from their methodologies. Future research should explore user interactions further, considering long-term learning outcomes and including experienced musicians for broader insights. Despite initial expectations that Ableton's structured lessons would offer more educational value and Soundraw's automation greater convenience, users did not perceive significant differences, underscoring the need for further research. Both tools have the potential to inspire musical practice and offer alternatives to traditional teaching models. Future studies should consider shorter, more engaging experiments to ensure accurate data collection and focus on tools with smaller operational differences to better isolate their impact

on user experience. In conclusion, while this study offers valuable insights, more rigorous research is needed to fully understand the impact and effectiveness of generative AI and active learning tools in music composition. Addressing the study's limitations can lead to more definitive conclusions and enhance the development of digital music education tools.

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# EXPLORING THE CHARM FACTORS OF FILM CAMERAS THROUGH EVALUATION GRID METHOD AND QUANTIFICATION THEORY TYPE I: INNOVATION IN DESIGN AND KANSEI ENGINEERING

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# ABSTRACT

With the advancement of technology, digital cameras have gradually replaced film cameras as the mainstream tool in photography. However, in recent years, the popularity of film cameras has resurged, particularly among younger generations, prompting an exploration of the charm factors that contribute to their appeal. This study aims to explore and quantify the charm factors of film cameras using the Evaluation Grid Method (EGM) and Quantification Theory Type I (QTTI), providing innovative directions for product design. Initially, expert users with extensive experience in film photography were identified through a preliminary questionnaire survey and subjected to in-depth interviews, focusing on the design aspects of film cameras. From these interviews, four core charm factors were identified: nostalgia, uniqueness, high quality, and convenience. Subsequently, QTTI was employed to quantitatively analyze these factors. The results indicated that high quality, nostalgia, and uniqueness are the most valued attraction factors for users. Based on these findings, we conducted innovative product design by integrating the details reflected in these charm factors to enhance the appeal and user experience of film cameras. This study demonstrates the advantages of using Evaluation Grid Method (EGM) in product design by systematically collecting and analyzing users' emotions and needs, converting them into quantifiable evaluation items. These findings enrich Kansei Engineering theory, promote the integration of emotional design with sustainable development,

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and provide valuable insights for future photography product design, while reigniting interest and passion for film photography.

*Keywords:* Film Camera, Charm Factors, Evaluation Grid Method (EGM), Kansei Engineering, Product Innovation

# 1. INTRODUCTION

Since the invention of photography, cameras have profoundly impacted human history, evolving from tools for documentation to mediums for artistic expression (Benjamin, 1972) The transition from early black-and-white film to modern digital technology has deeply impacted lifestyles and cultural memories (Mont, Neuvonen, & Lähteenoja, 2014).

Although digital cameras have become the dominant tool in modern photography due to their convenience and efficiency(Palmer, 2014). film cameras have recently experienced a resurgence, particularly among younger generations. Unlike digital cameras, film cameras require complex operations and delayed image results, which add to their anticipation and appeal. This resurgence of film cameras in the digital age prompts an exploration of the charm factors that attract consumers to these products. To explore these charm factors, this study employs the Evaluation Grid Method (EGM) and Quantification Theory Type I from Miryoku Engineering (Sanui, 1996), a branch of Kansei Engineering that translates personal perceptions into design elements (Nagamachi, 2002), This approach has been applied in various fields, from children's books to car exhibition design (Wei & Ma, 2020) (Kang & Nagasawa, 2023; Lu & Hsiao, 2019), Through expert interviews and surveys, this study identifies and quantifies the core charm factors of film cameras, subsequently using these extracted factors to inform innovative product design aimed at enhancing product appeal.

This study systematically integrates qualitative and quantitative methods, providing valuable insights for film camera enthusiasts and designers. The application of Evaluation Grid Method (EGM) in this context demonstrates its utility in converting qualitative insights into quantifiable design elements, enriching the theory of Kansei Engineering, and promoting the development of sustainable and emotionally resonant product designs.

#### 2. RESEARCH METHODS

The research process of this study is divided into three main phases: Identification of Target Products and Expert Users, employing the Evaluation Grid Method (EGM) including the analysis using Quantification Theory Type I(QTTI), and innovative product design. The Figure 1 illustrates the specific steps of this research process.



Through this three-phase methodological framework, the study aims to systematically identify and quantify the charm factors of film cameras and to base innovative designs on these factors, thereby enhancing the overall appeal and user experience of film cameras.

#### 2.1 Expert User Identification and Selection via Questionnaire Survey

In the initial phase of this study, we conducted a questionnaire survey to identify expert users with extensive experience in film photography. This survey aimed to gain a deeper understanding of user experiences and the charm factors associated with film cameras. The questionnaire covered various aspects, including the duration of film camera usage, preferences for camera types, familiarity with operations, shooting frequency, and overall fondness for film photography. The survey was conducted both online and in physical form, yielding 132 valid responses.

Based on the survey results, we ranked respondents according to the length of time they had been using film cameras, the number of cameras they had used, and their shooting frequency. From this ranking, we selected 9 experts for in-depth interviews. The insights and experiences of these experts provided a valuable foundation for the subsequent research, enabling us to further explore the charm factors of film cameras and analyze their specific manifestations and impacts.

#### 2.2 Conduct Semi-Structured Interviews with Expert Users

In this study, we selected 32 film cameras as representative experimental samples from eight major camera brands currently on the market, with four cameras chosen from each brand. Figure 3 shows a representative sample of this study. The interviewees were asked to select their six favorite cameras from this set and compare them with each other, describing their reasons for selection and their user experiences.



Figure 3. Representative sample of this study

As shown in Figure 4, during the interview process, the study recorded the interviewees' responses verbatim and statistically analyzed the words related to their perceptions mentioned during the interviews, noting the frequency of each word's occurrence. These words will help us analyze and extract the charm factors of film cameras, providing essential support for subsequent research.



Figure 4. The process of interviewing subjects

Through systematic interview design and detailed data collection, this study deeply understands the interviewees' genuine feelings and preferences for film cameras, thereby revealing the unique charm of film cameras.

#### 2.3 Extract initial evaluation criteria through interview

During the interview process, we identified the interviewees' original evaluation items for film cameras by comparing the features of different cameras from the perspectives of "satisfied/dissatisfied" and "most preferred/least preferred." These items represent the interviewees' intuitive perceptions and emotional responses to film cameras, providing a foundation for subsequent charm factor extraction and analysis.

Based on the interview results, we defined several original evaluation items specifically related to the tangible charm of the film camera body. These items include factors such as nostalgia, uniqueness, high quality, control, and preciousness. These elements reflect the main emotions and user experiences related to the physical design and tactile interactions with film cameras.


Figure 5. Original evaluation items at different stages of the product

To further analyze these tangible charm factors, we used the KJ method(Scupin, 1997) to categorize and organize these items, focusing on the physical attributes of the camera body, such as design aesthetics, material quality, and ergonomic features, as shown in Figure 5.

## 3. EVALUATION GRID METHOD (EGM) AND QUANTIFICATION THEORY TYPE I (QTTI) ANALYSIS

#### 3.1 Determine abstract rationales and specific attributes of the evaluation criteria

After identifying the original evaluation items, we further employed supplementary questions to uncover the abstract rationales (upper-level factors) and specific conditions (lower-level factors) associated with each item. Given that film cameras consist of both the camera body and the film, we chose to focus on the emotional responses elicited during the "Initial Contact Stage" with the camera body, as shown in Figure 6.



Figure 6. Factors that Initial Contact Stage

The "Initial Contact Stage" encompasses the user's initial impressions and visual appeal when first interacting with the camera, as well as the process of familiarizing themselves with the camera's design, material quality, and portability. During this stage, we identified the relevant abstract rationales and specific conditions through supplementary questions. For instance, the upper-level factor for the original evaluation item "high quality" could be "material and craftsmanship," with lower-level factors including "metal body" and "fine surface treatment." For "uniqueness," the upper-level factor might be "design aesthetics," with lower-level factors such as "distinctive body shape" and "unique tactile controls."

This detailed classification and analysis allow us to gain deeper insights into the participants' perceptions of the camera body during the initial contact stage, clarifying how these feelings manifest throughout the user experience. These findings will provide more targeted recommendations and innovative ideas for future product design.

#### 3.2 Collecting consumer evaluations through questionnaire

Based on the results of the Evaluation Grid Method (EGM) survey, we designed a questionnaire to quantify the interviewees' evaluations of different charm factors of film cameras. The questionnaire includes Likert scales and multiple-choice questions, targeting a broader range of film camera users to obtain extensive data support.

The main contents of the questionnaire include:

1. Evaluation of Attraction Factors: Respondents were asked to rate the importance of the seven major attraction factors on a scale of 1 to 5. For example, "How important do you think the condition necessary for a film camera with 'nostalgia' is? (1 being the least important and 5 being the most important)."

2、 Evaluation of Specific Lower-Level Factors: Respondents were asked to evaluate the importance of specific lower-level factors. For example, "In a film camera with 'nostalgia,' which feature do you consider the most important in the characteristic 'the camera itself has historical commemorative value'?"

The questionnaire was distributed to film camera users, and we received a total of 58 valid responses. Using Quantification Theory Type I, we analyzed the collected data, which reflected the respondents' evaluations and opinions on different charm factors of film cameras. These data serve as a crucial foundation for subsequent research, helping us to gain deeper insights into the respondents' feelings and needs regarding film cameras, thereby providing valuable references for future product design.

#### 3.3 Perform quantitative analysis using Quantification Theory Type I

In this study, through interviews, it was found that the definition of 'light weight' was not very clear to the users due to the different types of camera frames. Therefore, we conducted an in-depth analysis of the three factors of 'special,' 'high quality,' and 'nostalgia.'

In this study, "special," "high quality," and "nostalgia" emerged as the three most valued attraction factors for film camera users. QTTI Results for Special Senses are shown in Table 1. In the results of Quantification Theory Type I, "special" ranked first with a correlation of 0.569, making it the most significant factor in users' perception of the charm of film cameras. Among the specific lower-level factors, the highest scores were for special edition cameras with unique designs (2.0489), indicating that users highly appreciate the distinctive design of special edition cameras.

Original	Original Sequence Objective and		Specific category	Factor	Correlation
Attractiveness		Concrete		scores	coefficient
		Understanding			
Special	2	Special modeling of the camera	1、Minimalist styling	0.6122	0.4120
			2、Complex Mechanisms	-1.4985	
			3、Craftsmanship meets beauty	0.2226	
			4、Buttons and knobs with	-0.1780	

#### Table 1. QTTI Results for Special Senses

		special details		
		5、Co-branded Styling Negative	2.0489	
		Camera		
1	Record special sights or things	1、Limited number of films	0.4841	0.4205
		2、Recording memories on film	-0.4294	
		3、 Print the date and year of	-1.5270	
		shooting		
3	See the photo	1、Strong granularity	-0.4603	0.1836
	shoot after rinsing			
		2、High contrast	-0.1426	
		3、Film-specific color tones	0.2298	
		4、Focus Failure Blur	-0.0582	
		5、Color difference due to	-0.1521	
		overexposure		

Table 2.	QTTI	<b>Results</b>	for High	quality
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Original Attractiveness	Sequence	Objective and Concrete Understanding	Specific category	Factor scores	Correlation coefficient
High quality	2	Camera has a nice look	1、Leather grain texture on camera	-0.0231	0.1518
			2、Engraving on camera body	0.7534	
			3、Metal material, weighty feeling	0.0042	
			4、Simple styling	-0.1826	
	1	The feedback is very	1、Shutter Release	0.5657	0.4634
		detailed	Button Sound		
			2、Replacement process	-0.7406	
			3、Focusing process	0.1298	
			4、The process of rolling	-0.7419	
			film		

"High quality" had a correlation coefficient of 0.4677, making it another significant attraction factor. QTTI Results for high quality are shown in Table 2. The highest-scoring lower-level factors were the engraved lettering on the camera body (0.7534) and the sound of the shutter button (0.5657), demonstrating the importance of high-quality detail designs (such as engraving and sound) in enhancing user satisfaction.

Table 3. QTTI Results for Nostalgia								
Original	Sequence	Specific category	Factor	Correlation				
Attractiveness		Understanding		scores	coefficient			
Nostalgia	2	Memorable (Historical)	1、limited edition	0.6820	0.2428			
			2、Early Specialized	0.3265				
			Crafts					
			3、Produced for a long	-0.5050				
			time					
			<ol> <li>Styling and</li> </ol>	1.4969	0.1982			
			functionality are limited					
2	1	The feedback is very detailed	1. Adjust the film with the	-0.0035				
			camera's paddle lever.					
			2、Observe the light	-0.1903				
			meter to determine light and darkness					
			3、Receiving the film	-0.1569	0.1018			

3	3 Conventional Shooting Operations	after shooting 1、Strong film saturation	-0.1224
		2、Strong granularity	0.2466
		<ul><li>3、Dark corners are</li><li>obvious</li><li>4、High contrast</li></ul>	0.0800

The "nostalgia" had a correlation coefficient of 0.3814, indicating that the nostalgic traits of film cameras have a strong appeal to users. QTTI Results for Nostalgia are shown in Table 3. Among the lower-level factors, limited edition cameras (0.6860) scored the highest, highlighting the uniqueness and historical sense brought by limited edition products. The fine operational feedback (0.5436) and the noticeable grain (0.2946) further emphasized the nostalgic experience provided by film cameras during use.

Based on these data, we found that "Special", "high quality" and "nostalgia" are the three most valued attraction factors for film camera users, each with high-scoring specific lower-level factors. These results provide essential support for our subsequent design innovations. This study will use these charm factors to guide innovative design, aiming to enhance the appeal of film cameras and meet user needs and expectations.

## 3.4 Design Innovative Products Based on Evaluation Factors

Based on the results of Quantification Theory Type I, we have conducted product design innovations and proposed the OSKAY-Film Photography System, as shown in Figure 7. By retaining the original film photography process and incorporating the specific factors corresponding to the identified attraction factors, we aim to enhance the overall user experience.

This study utilized details such as engraved lettering on the camera body, fine operational feedback, and the sound of the shutter button to enhance the high-quality feel. The engraved lettering and the sound of the shutter button add a sense of quality to the camera, increasing users' pleasure and satisfaction during operation. Additionally, the finely tuned operational feedback enhances the sense of control for users, providing a more precise and professional operation experience.



Figure 7. Innovative design of film camera products

#### 4. CONCLUSION

Since the advent of photography, film cameras have held a unique place in the history of photography, cherished for their aesthetic and nostalgic appeal. This study aims to explore and quantify the charm factors of film cameras using Quantification Theory Type I, providing innovative directions for product design. Initially, we conducted a preliminary survey to identify experts with extensive experience in film photography. Through in-depth interviews and the application of the Evaluation Grid Method (EGM), we performed a laddering analysis to determine the abstract and concrete reasons behind the identified factors.

The results indicated that "special," "high quality," and "nostalgia" are the three most valued factors for film camera users. Based on these findings, we innovatively designed the OSKAY film camera, preserving the traditional film photography process while integrating these charm factors into the design, including high-quality body elements, unique special edition designs, and nostalgic film details.

The contribution of this study lies in revealing the core charm factors of film cameras, providing valuable insights for related product design. While this study primarily focuses on subjective user evaluations, future research could expand the sample size and incorporate market analysis for further validation. Additionally, we deeply analyzed users' core needs and preferences regarding the appearance of film cameras and proposed specific design innovations based on these insights. We hope these innovations will inspire greater interest in film photography and inject new vitality into the film camera market.

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# ASSESSING CHRONIC STRESS USING SELF-SIMILAR FEATURES IN FACIAL THERMAL IMAGES

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## ABSTRACT

In response to growing interest in mental health in Japan, this study examined a new approach to measuring chronic psychological stress using facial thermal images (FTI). Eight participants participated in a 3-month experiment in which FTI was taken daily and a questionnaire regarding psychological stress was administered. The fractal dimension of the FTI, which indicates blood volume variability and vascular structure, was calculated to assess stress levels. The results showed that the higher the chronic stress, the lower the fractal dimension, especially in the cheek area. This suggests that blood flow decreases under high stress and the self-similarity of skin temperature distribution decreases.

Keywords: Facial Thermal Images, Chronic Stress, Fractal Structure

## **1** INTRODUCTION

In recent years, there has been a growing interest in mental health care in Japan, prompting more companies to address employee well-being. Stress, which can be physical or psychological, significantly impacts health when chronic. Daily monitoring and early detection of chronic stress are essential, necessitating practical measurement technologies. This study focuses on psychological stress, referred to as "stress" hereafter.

Traditional methods for measuring chronic stress, such as psychological questionnaires, have advantages like simplicity and low burden (Reigal, 2021). Other methods include measuring cortisol levels in hair and nails, which reflect chronic stress (Izawa 2021; Russell 2012). However, these methods are time-consuming and impractical for daily use.

Facial thermal images (FTI) offer a promising alternative for daily stress measurement. FTI provides instantaneous measurements of skin temperature distribution, which known as relation between autonomic nervous system activity and FTI. Previous studies have demonstrated FTI's effectiveness in indicating acute stress and capturing long-term physiological fluctuations (Ito et al. 2018, Hattori 2023). These characteristics suggest that FTI

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has a lot of information about physiological psychological state. Nevertheless, it is needed to be aware of that FTI is influenced by environmental factors such as temperature and humidity.

We hypothesized that facial skin temperature distribution, influenced by blood volume, exhibits fractal characteristics, which change with stress levels. Specifically, higher blood flow enhances vascular structure visibility in thermal images, increasing fractal dimensions. To test this hypothesis, we conducted a three-month experiment, collecting psychological stress questionnaire data and thermal images. We calculated the fractal dimensions of these images to analyze variations corresponding to different stress states.

## 2 METHODS

In this study, we conducted a three-month experiment to collect daily data on chronic stress. The participants included eight healthy males and females aged 21 to 26. Despite the small sample size of eight participants, this study provides important data. Unlike previous research that measured stress over medium to long-term periods using psychological questionnaires collected at intervals of at least one year, this study conducted frequent experiments twice a week over three months. Additionally, it gathered not only psychological questionnaires but also FTI data. To our knowledge, no other studies have investigated daily physiological and psychological stress information over such a medium-term period. They were fully informed about the study's objectives and procedures. The study was conducted in accordance with the Declaration of Helsinki and approved by the Life Science Committee of Aoyama Gakuin University (approval number: H22-001).

## 2.1 Experimental Protocols and Environment

The experiment took place from May 2023 to July 2023, withheld twice a week. Each experiment followed the protocol shown in Figure 1.

Room Temp Acclimatizatio	erature on Period	FTI Capture Period	Questionnaire Response Period
Responding to the pre-questionnaire	Measuring HRV	Resting with eyes closed	
← → 6 min.		← 1 min.	Until completed
15 min.	$\sim$		l

Figure 1. An Experimental Protocol Overview

Each period consisted of three phases: a room temperature acclimation period (at least 15 minutes), a 1-minute FTI capture period, and a questionnaire response period. During the acclimation period, participants completed a pre-survey and heart rate variability (HRV) measurements. During the FTI capture period, participants were instructed to remain quiet with their eyes closed. The questionnaire phase had no time limit, but participants were asked to respond intuitively.

The experimental setup is illustrated in Figure 2. Participants sat in a chair with a backrest, positioned 1 meter from four cameras: an infrared thermographic camera (A35, FLIR), a Si camera (Genie Nano M1280 NIR, Teledyne DALSA Corp), an InGaAs camera (C14041-10U, Hamamatsu Photonics), and a visible camera (Shenzen Ailipu Technology Co.). The infrared camera had a thermal resolution of 0.05°C, sampling frequency of 1 Hz, and resolution of 256 × 320 pixels, with skin emissivity set to  $\varepsilon = 0.98$ .



Figure 2. Experimental Setup

Two near-infrared light sources were used: a broadband LED (760-1100 nm) and a near-infrared LED (1050-1650 nm). Both were placed 0.8 meters in front of the participant. Various filters and polarizers were used to ensure proper imaging conditions. For all measurements, the temperature of the laboratory was controlled to  $22.85 \pm 0.64^{\circ}C$  and the illuminance to  $47.46 \pm 2.02$  lux. Data on sleep time, body temperature, and last meal time were also collected.

#### 2.2 Psychological Questionnaire

Four psychological questionnaires were used to assess chronic stress: Perceived Stress Scale (PSS) (Lazarus, 1984), Depressive Anxiety Stress Scale (DASS) (Lovibond, 1995), Profile of Mood States (POMS) (McNair, 1971), and State-Trait Anxiety Scale (STAI) (Spielberger, 1983). These questionnaires were used because they have been selected in many studies to measure stress and have been translated into Japanese.

PSS, DASS, POMS, and STAI scores were calculated according to their respective tabulation methods. Scores were standardized with a mean of 0 and variance of 1 for each participant. The questionnaires used in this study were divided by subscale, for a total of 13 questionnaires. This does not allow us to determine the indicators that are important in assessing stress levels. Therefore, principal component analysis (PCA) was applied to the standardized scores. From these results, a single chronic stress index (hereafter referred to as the "chronic stress score") was derived.

## 2.3 Application of Preprocessing to FTI

The thermal images show different facial positions, orientations, and shapes for different participants. A standardized FTI of 255 x 259 pixels was obtained by extracting facial feature points and applying spatial standardization (Nagumo, 2021) to the images. To minimize motion artifacts, the 2 seconds before and after eye closure were excluded, and 56 images were averaged to produce a representative thermal image per experiment.

In addition, FTIs were regionalized by site to allow comparison of fractal dimensions by region. Images showing each region of interest (ROI) are shown in Figure 3.



Figure 3. Each region of interest (ROI)

## 2.4 Self-Similarity of FTI

A "fractal structure" is a complex shape or pattern that is self-similar. Self-similarity is the property of repeating the same shape pattern of the overall shape and the shape of its parts. In nature, it is found in the topography of mountain ranges, the arrangement of trees in forests, the network of rivers, and the structure of blood vessels and lungs, and has a complexity that cannot be expressed by simple geometric shapes. Fractal dimension is a quantitative measure of the complexity of fractal structures. Unlike the usual Euclidean dimension (one-dimensional line, two-dimensional surface, three-dimensional solid), fractal dimension is not an integer, but generally takes non-integer values. This allows for a more accurate characterization of the complexity and self-similarity of fractals. And the method of analyzing these fractal structures and fractal dimensions is fractal analysis. Fractal analysis has been widely used to model complex objects and phenomena found in nature (Burrough, 1998; Li, 2022). It has been applied in a wide variety of fields, including image processing, materials science, and biomedicine. In this study, we apply fractal analysis to FTI. By considering the temperature distribution on the skin surface as a gradient in a two-dimensional plane, the self-similarity (fractal dimension) of the facial skin temperature distribution is obtained.

The method for calculating the fractal dimension in the XY plane is illustrated in Figure 4.



Figure 4. Conceptual diagram of the fractal dimension estimation method

To calculate the fractal dimension of a surface, such as temperature values, we defined unit regions of size  $r \times r$  and calculated the standard deviation ( $\sigma$ ) of the surface elevation within these regions. The number of r-sized tiles, n(r), required to cover the elevation in a unit region can be approximated by:

$$n(r) = \frac{\sigma}{r} \#(1)$$

Here, r represents a comparative height measure. The total number of r-sized tiles, N(r), needed to cover the entire XY plane can be expressed as:

$$N(r) = \frac{XY}{r^2} \times n(r) = \sum_{i=1}^{m} \frac{\sigma_i}{r} \#(2)$$

where m is the number of unit regions dividing the XY plane, and the sum of n(r) over all regions gives the total number of tiles needed to cover the entire surface. If the relationship

 $n(r) \sim h^{-D} #(3)$ 

holds true, the object exhibits fractal characteristics, and the fractal dimension D can be determined from this relationship. Using this method, we calculated the fractal dimensions for all ROIs across all participants and experiments.

#### 2.5 Relationship Between FTI Self-Similarity and Chronic Stress

As a last step, the relationship between fractal dimension and chronic stress score was examined. In order to find the fractal dimension that would correspond to the chronic stress score in this study, ROIs and participants with high correlation coefficients between the fractal dimension and the chronic stress score were selected. Among them, those that were in the top 10% in both of the two indices were considered as high stress state images, and conversely, those in the buy 10% were considered as low stress state images.

## 3 RESULT

## 3.1 Principal Component Analysis for Survey Scores

The eigenvectors for each questionnaire are shown in Figure 5. All indicators except POMS VA and POMS F, representing vitality and friendship, align along the first principal component axis, suggesting it as an indicator of chronic stress. The first principal component accounts for a variance of 0.433, explaining approximately half of the total questionnaire variance. Thus, in the multiple regression analysis, the first principal component's score serves as the dependent variable, termed the ``chronic stress score''.



Figure 5. Plot of eigenvectors and principal component scores for each questionnaire

## 3.2 Fractal Dimension Differences in Stress States by ROI

Figure 6 shows the results of plotting the fractal dimension D on the horizontal axis and the chronic stress score on the vertical axis.



Figure 6. Scatter plot showing the correlation between fractal dimension (D) and stress score.

The correlation coefficient r between these two indices is indicated within the figures. This study focuses on the results for the right cheek region, where the correlation coefficients were generally high. Particularly, Sub. C exhibited a high correlation coefficient. Therefore, attention was given to Sub. C's data, and Figure 7 compares the fractal dimensions under high stress and low stress conditions. Here, "high stress" and "low stress" refer to the top and bottom 10% of both the stress score and fractal dimension, respectively.



Figure 7. Fractal dimension due to high and low stress states

#### 4 DISCUTTION

From these results, it can be said that the fractal dimension is lower in a high-stress state. This suggests a decrease in blood volume in the cheek and a reduction in the self-similarity of the skin temperature distribution under high stress. The cheek region contains buccal fat pads and has a higher heat capacity (Yousuf, 2010). Therefore, under controlled conditions, changes in stress state may result in alterations in the self-similarity of the skin temperature. However,

because the cheek is also more susceptible to external temperature influences, future research should investigate whether significant changes in self-similarity are observed in other facial regions as well. Additionally, this study included only eight participants, indicating a need for a larger sample size in future research.

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# Exploring the Appeal Factors of Dopamine Dressing Short Videos on Douyin through Evaluation Grid Method

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## ABSTRACT

With the rapid development of mobile internet, short video platforms have become increasingly popular worldwide. Douyin, the Chinese version of TikTok, attracts a vast user base through its unique algorithm recommendations and social interaction mechanisms. This study aims to explore the appeal factors of dopamine dressing short videos on Douyin using the Evaluation Grid Method (EGM). By conducting in-depth interviews with users, organizing the data, and constructing evaluation grids, we analyze users' subjective evaluations of these short videos to uncover their intrinsic appeal. The results of this study contribute to understanding the emotional value and visual attraction of short videos, providing new perspectives for future content innovation in short videos.

Keywords: Short video, Dopamine dressing, Charm engineering, Evaluation Grid Method

## **1** INTRODUCTION

## 1.1 Research Background and Problem Statement

In the digital era, short video platforms have become an integral part of daily life. Douyin, an intelligent smartphone short video social application created by ByteDance, primarily operates in mainland China, Hong Kong, and Macau. As one of the most popular short video platforms, Douyin attracts users of all ages with its precise algorithm recommendations and rich social features. Short videos are not just tools for entertainment but also crucial channels for users to express themselves and obtain information.

Dopamine dressing, a fashion trend emphasizing bold colors and designs, was proposed by fashion psychologist Dawnn Karen in 2020. It aims to stimulate happiness through visual stimuli and has become widely popular among young users. Pinterest predicted it to be a future trend

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in 2022, and as of June 5, 2023, topics like #多巴胺女孩穿搭 (dopamine girl dressing) and #多 巴胺穿搭 (dopamine dressing) have amassed 6.62 billion and 1.41 billion views on Douyin, respectively. Despite the popularity of dopamine dressing short videos on Douyin, their appeal factors have not been fully explored academically. This study aims to analyze the sources of appeal in dopamine dressing short videos using the Evaluation Grid Method (EGM), providing new insights into the emotional value of short videos.

## 1.2 Research Objectives and Significance

The main objective of this study is to explore the appeal factors of dopamine dressing short videos on Douyin using the Evaluation Grid Method. Specific objectives include:

1. Identifying the subjective evaluation dimensions of users for dopamine dressing short videos.

2. Analyzing the preferences and motivations of different user groups towards dopamine dressing short videos.

3. Investigating the performance of dopamine dressing short videos in terms of visual attraction and emotional value.

This study not only reveals the sources of appeal in dopamine dressing short videos but also provides practical references for content innovation in short videos, further promoting the sustainable development of short video platforms and enhancing user experience.

## 1.3 Research Methods and Structure

This study employs the Evaluation Grid Method (EGM), collecting and analyzing users' subjective evaluations of dopamine dressing short videos through in-depth interviews, data organization, and the construction of evaluation grids. The research process includes the following steps:

1. Literature Review: Analyze existing research on short video platforms, Douyin's characteristics, and dopamine dressing.

2. Interview Design: Design semi-structured interview questions to collect users' original evaluations, higher-order, and lower-order attributes of dopamine dressing short videos.

3. Data Analysis: Use EGM to construct evaluation grids and identify appeal factors.

The structure of this paper is as follows: The first part is the literature review, introducing relevant theories and research; the second part describes the research methods, detailing the application of the Evaluation Grid Method; the third part presents the research results and discussion, showing the main findings from user evaluations; the final part is the conclusion and future research directions. Through this study, we hope to provide valuable insights for content innovation and user experience enhancement in short video platforms, promoting the sustainable development and emotional value innovation of the short video industry.

#### 2 LITERATURE REVIEW

#### 2.1 Short Video Platforms and User Behavior

The rapid rise of short video platforms has changed media consumption habits. According to Anderson (2020), the immediacy and interactivity of short videos are key factors attracting users. Chen et al. (2021) pointed out that short video platforms enhance user engagement through algorithmic recommendation systems that increase content matching. Xu and Liu (2022) believe Douyin's core technology lies in its powerful recommendation algorithm, which accurately recommends content based on user behavior data. Wu (2021) highlighted the platform's social attributes, where users engage and create through likes, comments, and shares, forming a highly interactive community.

#### 2.2 Dopamine Dressing

Fashion psychologist Dawnn Karen proposed "dopamine dressing" in 2020, suggesting that wearing brightly colored clothing can stimulate the brain to release dopamine, leading to a happy mood (Karen, 2020). According to Smith (2023), dopamine dressing triggers happiness through bright colors and bold designs. In 2022, Pinterest predicted it to be a future trend, and by June 5, 2023, Douyin topics #多巴胺女孩穿搭 (dopamine girl dressing) and #多巴胺穿搭 (dopamine dressing) had 6.62 billion and 1.41 billion views, respectively. Zhang and Li (2022) noted that the success of dopamine dressing short videos on Douyin is mainly due to their visual impact and fashion appeal.

#### 2.3 Application of Evaluation Grid Method in Short Video Research

The Evaluation Grid Method is a qualitative research method and an important tool in charm engineering. Developed by Japanese scholars Junichiro Sanei and Masao Inui (1986) based on clinical psychologist George Kelly's (1955) Repertory Grid Method, EGM captures individual cognitive concepts and organizes them into lists to deeply understand personal psychological cognition of a particular phenomenon. Chen et al. (2020) used EGM to study short video user behavior, exploring users' preferences and motivations through evaluations of different types of short videos.

#### 2.4 Summary

In summary, the rapid development of short video platforms and the success of Douyin provide a rich data background for short video research. As a specific research object, dopamine dressing short videos have appeal factors worth exploring. The Evaluation Grid Method, as an effective research method, can help us better understand users' subjective evaluations of dopamine dressing short videos, revealing their intrinsic appeal. Future research can further combine quantitative analysis to gain more comprehensive insights.

#### **3** RESEARCH METHODS

#### 3.1 Research Design

This study adopts the Evaluation Grid Method (EGM) to explore the appeal factors of dopamine dressing short videos on the Chinese version of Douyin. EGM is a qualitative research

method that reveals respondents' subjective evaluation dimensions through in-depth interviews. The research process includes the following steps:

## 3.2 Literature Review

First, conduct a literature review to analyze existing research on short video platforms, Douyin's characteristics, and dopamine dressing, providing a theoretical foundation for the study. The literature review focuses on understanding the operating mechanisms of short video platforms, the fashion trend of dopamine dressing, and the application of the Evaluation Grid Method in emotional value research.

## 3.3 Interview Design

Before the interview, the interviewee will watch a successful dopamine dressing short video on the Douyin platform before proceeding with the interview. This video has garnered 5.593 million likes, and its creator is one of the influencers who initiated the dopamine dressing trend on Douyin.



Figure 1. The designated short video and the homepage of its creator

Design semi-structured interview questions to collect users' evaluations of dopamine dressing short videos. Interview questions include but are not limited to:

1. Users' specific likes and dislikes about dopamine dressing short videos.

2. Users' perceptions of the most attractive features of dopamine dressing short videos.

3. Users' emotional reactions and visual evaluations of dopamine dressing short videos.

## 3.4 Selection of Interviewees

Select Douyin users from different age groups, genders, and occupational backgrounds to ensure the diversity and representativeness of the sample. Approximately 15 interviews are planned to obtain rich qualitative data.

## 3.5 Data Collection and Analysis

1. Initial Evaluation Collection: During the interviews, ask respondents for their likes or dislikes regarding dopamine dressing short videos.

2. Evaluation Analysis: Guide respondents to clarify their original evaluations, identifying abstract feelings as higher-order attributes and specific factors as lower-order attributes. For example, if a respondent mentions "visual attraction" or similar terms, further explore which aspects (e.g., color matching, clothing design) specifically contribute to this attraction.

3. Construction of Evaluation Grid: Organize all the information obtained from the interviews into lists, arranging higher-order attributes (abstract feelings) and lower-order attributes (specific factors) from left to right, and connect them with lines to construct a hierarchical evaluation grid.

4. Analysis of Appeal Factors: Based on the resulting evaluation grid, further analyze the appeal factors of dopamine dressing short videos and summarize their intrinsic attractions.

## 3.6 Research Ethics

During the research process, adhere strictly to research ethics guidelines to protect the privacy and rights of the interviewees. Before the interviews, explain the purpose and content of the study to the interviewees and obtain their informed consent. All data will be used solely for academic research, and personal information of the interviewees will not be disclosed.

## 4 CONCLUSION

Based on the comprehensive analysis of the interview data, factors mentioned only once were removed. The remaining relevant factors were then connected with straight lines and organized into an evaluation structure diagram to identify the attractiveness factors.



Figure 2. EGM obtained in this study

#### 4.1 Main Findings

Through the analysis of interview responses regarding the appeal of dopamine dressing short videos on Douyin, we identified several key factors that significantly influence viewer attraction and preference:

Vivid Colors: Many respondents mentioned the vivid color combinations in the videos, which provide a strong visual impact. For example, the bright colors not only catch the eye but also enhance the overall visual appeal of the videos.

Strong Cohesiveness: The editing rhythm and overall cohesiveness of the visuals were important factors in viewer evaluations. The videos achieve a complete and coherent viewing experience through tight editing rhythms and harmonious visual designs.

Meticulous Design: The combination of colors, scenes, and backgrounds in the videos is meticulously designed, providing a sense of visual comfort and consistency. For instance, the harmonious matching of colors with scenes makes the visuals appear natural and balanced.

Sense of Everyday Life: Many viewers were impressed by the everyday life atmosphere in the videos. By integrating fashion with daily life scenes, the videos appear grounded and relatable, easily resonating with viewers. For example, the color and scene combinations convey a strong sense of everyday life.

Youthful Vitality: The videos are filled with elements of youthful vitality, such as bright colors and lively plots. These elements make the videos look vibrant.

Sense of Joy: The videos convey a sense of joy and positivity. Many respondents stated that watching these videos made them feel happy. The combination of light-hearted music, brisk editing rhythms, and cheerful visuals creates this joyful atmosphere.

Novelty: The contrast between fashion and scenes and unique elements in the videos bring a sense of novelty, attracting viewer interest. For instance, the unique matching in the scenes forms a stark contrast with everyday life, increasing the video's appeal.

Emotional Appeal: The natural smiles and genuine emotional expressions in the videos have a strong emotional appeal. Viewers are able to resonate with the emotions expressed in the videos, enhancing their connection to the content.

#### 4.2 Discussion

The results of this study indicate that the appeal of dopamine dressing short videos on Douyin stems from their multifaceted design in terms of visual, emotional, and everyday life aspects. The vivid colors and strong cohesiveness of the visuals provide a strong visual impact and a comfortable viewing experience. The integration of everyday life atmosphere and youthful vitality makes the videos relatable and full of energy, attracting young viewers' attention. The creation of a joyful and novel viewing experience makes viewers feel relaxed and happy, while also generating interest in unique elements. Finally, the natural emotional expressions and genuine emotional transmission enhance viewers' emotional resonance, making the videos more impactful.

#### 4.3 Conclusion

This study, through the analysis of user evaluations of dopamine dressing short videos, reveals the key attractiveness factors of these videos. These factors include vivid colors, meticulous design, strong Cohesiveness, sense of daily life, youthful vitality, sense of joy, novelty, and emotional appeal. The successful integration of visual design, emotional expression, and everyday life atmosphere in the videos has gained high levels of viewer appreciation and recognition.

#### 4.4 Future Research Directions

In-depth Study of Specific Design Elements: Future research can further refine the exploration of how specific design elements (e.g., particular colors, scene settings, music choices) affect viewer experience and emotional response.

Long-term Impact Studies: Research can explore the long-term psychological and behavioral impacts of the videos on viewers, such as whether the videos can change viewers' dressing habits or enhance their emotional states.

Integration of Technology and Creativity: Investigate how the use of technological means (e.g., augmented reality, virtual reality) and creative designs can further enhance the attractiveness and user experience of the videos.

By following these future research directions, a more comprehensive understanding of the attractive factors of dopamine dressing short videos can be achieved, providing valuable insights for related video creation and marketing strategies.

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## MIRYOKU TIMBRE: EXPLORING THE APPEAL OF MALE AND FEMALE VOICES THROUGH MIRYOKU ENGINEERING

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## ABSTRACT

With the expansion of the synthetic voice market, a single voice can no longer satisfy users, and voice customization has become a market development trend. Past research has shown that sound is attractive. To further understand sound attractiveness, this study adopts the attractiveness engineering framework to evaluate the attractiveness of the construction method and Kano Model in analyzing sound. The study focused on the timbre attributes of the voice and researched attractiveness engineering. Based on the Evaluation Grid Method results, a Kano questionnaire was created. Based on the results analyzed by the Kano Model, 11 attractive qualities of female timbre were found, namely "comfortable," young," "cute," "happy," "soft," "gentle," "atmosphere," "closeness," " moderate volume," "high and low intonation," "changes high and low pitch in intonation," "intonation has a variety of emotions"; the male voice has four attractive qualities: "atmosphere," "calmness," "low pitch," "moderate speaking speed," and the unidimensional quality is "comfort." According to the results, a research direction is provided for researchers and designers who want to design synthetic sounds in the future.

Keywords: Kano Model, Evaluation Grid Method, Timbre, Miryoku Engineering, Attractive

## **1** INTRODUCTION

According to Global Information's Text-to-Speech market research report, the synthetic speech market will grow from US\$2.95 billion to US\$6.65 billion in the five years after 2024. The vast market has led many technology companies to invest in this field. Microsoft's research team found that consumers like to treat technology as human beings, even if it is a simple technology product with an impersonal design. Voice interaction designers have discovered that a single voice can only please some and cannot satisfy all users (Vlahos, 2019).

Snyder's (2023) study found that voice similarity attraction still exists; the customization of voice personality is essential to strengthen this positive effect. Therefore, customized synthetic

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speech voice has become a research issue for various technology companies (such as Google, Robin Labs, ActiveBuddy, etc.) (Vlahos, 2019). The Association of Japanese Animations conducted a Japanese animation foreign market survey report in 2023, and the report stated that Taiwan has become the overseas market with the most significant number of Japanese animation contracts, with 651 contracts; this shows the development of Japanese animation in Taiwan. There are also many synthetic speeches on the market for software with anime characters' voices as their selling point. Take VoiceVox as an example; it provides many customized character voices for synthetic speeches, providing content creators and game developers with a channel to reduce dubbing costs.

The impression depends not only on visual cues but also on auditory cues; there is an attraction in the sound, and when the observer only hears the target's voice, it will create an impression of the sound's attractiveness to the personality (Zuckerman & Miyake, 1993). This study hopes to understand the appeal of people through Miryoku engineering.

#### 2 LITERATURE REVIEW

#### 2.1 The Attraction of Timbre

The impression depends not only on vision but also on hearing; the sound is attractive, and the listener will have an impression of the attractiveness of the sound on personality just by hearing the sound (Zuckerman & Miyake, 1993). Collins (2000) found that females' judgments of voices depended heavily on men's vocal characteristics. However, there was no relationship between body and vocal characteristics; females could use vocal characteristics to infer physical characteristics. Zuckerman and Miyake (1993) found that attractive voices were perceived as having greater volume; they also found that measures of voice quality accounted for variance in the favorableness of personality impressions. From a perceptual point of view, the sweet vocal style is very distinctive. It has a light timbre and tense vocal resonance (Starr, 2015).

The word "Timbre," also known as "Sound quality," comes from an acoustic concept in Psychoacoustics, which refers to an attribute of hearing that allows the listener to judge two similar but different sounds with the same loudness and pitch (Moore, 2014). The human voice only needs changes in pitch, Timbre, loudness, and time for the listener to perceive that the sound has a specific meaning (Moore, 2014). As an attribute of hearing, Timbre allows listeners to distinguish various sounds and obtain different feelings. Therefore, this study used different timbres as independent variables to explore the charm of male and female timbres. Timbre, a crucial aspect of sound perception, is not solely determined by the frequency spectrum of the sound; temporal fluctuations also play a significant role; while the sound's spectrum is a compilation of various frequency components, the formation of Timbre is not solely reliant on these components; it also evolves, influenced by dynamic characteristics such as the rise and fall, changes, and continuity of sound (Moore, 2014).

Our collaborative study delves into sound attractiveness by analyzing timbre types through the lens of charm engineering. The aim is to gain a deeper understanding of the charm of timbre types and, in doing so, provide valuable insights and directions for researchers and designers, valuing their contributions to the study of sound-related products.

## 2.2 Miryoku Engineering and Evaluation Grid Method, EGM

The Japanese dictionary Kojien points out "Miryoku" as the power that can affect the "heart." In 1991, Japanese scholar Masato Ujigawa and several scholars initiated research on Miryoku Engineering to " create technology and knowledge of attractive products and spaces." In 1998, the Japan Kansei Engineering Society was established, and Miryoku Engineering was officially included as part of Kansei Engineering; its theory has three focuses: basic theory, modeling, and design.

The evaluation grid method is a Miryoku engineering theoretical framework developed by Japanese scholars Sanui Junichiro and Inui Masao after studying and improving the repertory grid method proposed by Kelly (1995). According to the set topics and questions, the participants are guided to compare factors with different degrees of preference to compare the participants' most clear sources of preferences. This method is conducive to profoundly understanding the participants' psychological understanding of a specific topic or knowledge level. The evaluation construction method is divided into three hierarchical structures: upper level - abstract reasons, middle level - original evaluation items, and lower level – specific composition conditions (Sanui, 1996).

#### 2.3 Kano Model

The Kano Model was proposed by Noriaki Kano in 1984. Frederick Herzberg's Motivation Theory influenced Noriaki Kano and his colleagues, and they introduced the attractive quality theory to explain better the role of different quality attributes on customers (Witell et al., 2013). The Kano model is divided into three categories (Must-be quality, One-dimensional quality, and Attractive quality) and two secondary categories (Indifference quality and Reversal quality) (Berger et al., 1993)—figure 1.



**Figure 1.** Kano Model (Source: Matzler et al., 1996)

#### 2.3.1 Must-be quality, M

Must-be quality, a key concept in the Kano model, refers to the quality that customers believe must exist. It's not about producing satisfaction but rather about reducing dissatisfaction. When a required attribute is missing, customers will notice its absence and view it negatively. However, when a required quality is present, customers will not notice it because they believe that attribute must be present. This understanding has significant implications for quality management and customer satisfaction strategies.

#### 2.3.2 One-dimensional quality, O

One-dimensional quality is an attribute that increases customer satisfaction as quality improves. As the attribute gradually meets customer expectations, it changes the customer's perception from dissatisfaction to perfection.

#### 2.3.3 Attractive quality, A

Attractive quality only appears when the product/service has unexpected and customer-satisfying attributes. These attributes can increase satisfaction non-linearly. Even attributes with limited satisfaction will immediately produce satisfaction.

Indifference quality (I) means that no matter whether the quality of this factor is present, it will not make users dissatisfied, so it will not affect customer satisfaction. The product contains attributes that customers want to avoid and cause dissatisfaction; these are called reverse qualities, and the more reverse qualities (R) in a product, the lower the customer's satisfaction (Berger et al., 1993). Matzler et al. (1996) used Kano to survey more than fifteen hundred customers, laying a solid foundation for the attractiveness quality theory. Gitlow (1998) also provides the judgment of quality attribution for the Kano model; he adds A+D+M and I+Q+R and compares the more significant values.

## 3 METHODS

#### 3.1 Research Process

Animation provides a large amount of speech data, data from many different speakers, and data from the same speaker using different styles when portraying different characters; sweet voices are mainly the domain of professional voice actors and rarely provided by general females (Starr, 2015). Therefore, this study used an online survey on the website " $\mathcal{T} = \mathcal{I} ! \mathcal{T} = \mathcal{I} !$ " to randomly select five male and female voice actors from the voice actor rankings voted by more than three thousand netizens and extract the games they have dubbed or animation clips to create sound samples. Each sound sample is about twenty seconds long. After removing the background music, although the length of the samples is the same, the sound's context may differ. When conducting interviews through EGM, the interviewee will first listen to female voice samples, rank the samples in preference, and ask about their original evaluation items, abstract reasons, and specific composition conditions. The male voice sample will be interviewed after interviewing the female voice sample; the same interview steps as when interviewing the female voice were followed. After all interviews, the researchers will sort out the upper level of male and female timbres - abstract reasons, middle level - original evaluation

items, and lower level - specific composition conditions. Based on the interview results, a Kano questionnaire was created for the participants to fill in. Kano analysis was performed on the collected questionnaires to understand the Miryoku of these sounds.

## 3.2 Interview participants

The research interview participants must have more than three years of animation viewing experience or gaming experience and know more than five voice actors in the " $\mathcal{T} = \mathcal{I}$ !  $\mathcal{T} = \mathcal{I}$ ! 2023 rankings". The interviewees will first listen to the voices. Then, the researchers will ask the interviewer why they like the original evaluation items of the timbre and then ask about the specific conditions and abstract reasons for the composition according to the original evaluation items.

## 3.3 Draw an EGM Graph

After interviewing the interviewees, the researchers will integrate the interview results through conceptual commonalities and then integrate the interviewees' evaluation grids to draw two complete EGM graphs: one is the EGM graph for female timbre, one is the EGM graph for male timbre, integrates those the complete original evaluation items, the specific conditions of composition, and abstract reasons.

## 3.4 Create a Kano Questionnaire

The questionnaire is designed to measure qualitative attractiveness factors through quantitative methods and evaluate the attractiveness factors of male and female voices. This study uses the results of EGM interviews and uses factors mentioned more than two times as questionnaire items. The questions are presented in the form of a two-way questionnaire (for example: feeling safe in timbre, not feeling safe in timbre, etc.) and using a Likert five-point scale (like, take it for granted, have no feeling, reluctantly accept, dislike) is used to measure the participants 's feelings.

## 3.5 Kano Analysis

Determine the quality attribution of factors (Attractive, One-dimensional, Must-be, Indifference, Reverse) according to the Kano matrix. At the same time, the "Extent of satisfaction" and "Extent of dissatisfaction" are obtained through the "Customer satisfaction coefficient" (Matzler et al., 1996, pp. 6-18). The CS coefficient shows the degree of impact of product functions on satisfaction, or in the case of "unsatisfied," affects customer satisfaction. In addition, this study also uses Gitlow's (1998) quality attribute judgment formula as a reference for judging overall quality attribution. Comparing the results of kano analysis, CS coefficient, and Gitlow quality attribution. If the quality attribution is tied after encountering the three judgment methods, follow the judgment method proposed by Berger et al. (1993) to classify the product with the most significant impact. (M>O>A>I) for final judgment.

## 4 RESULT

## 4.1 EGM Interview Results

This time, seven participants aged twenty-two to twenty-six, four male and three female, were interviewed. Based on the interview results, we integrated conceptual commonalities. We screened out attractive factors mentioned more than twice to establish the EGM graphs of male and female timbre.

## 4.1.1 The Attractive Factor of Male Timbre

During the interview, the interviewees ranked five male timbre samples. The researchers asked the interviewees about their top two favorite male timbres and also asked them about the attractiveness factor of male timbres (original evaluation items, specific composition conditions, abstract reasons.); all respondents were able to compare and rank timbres. This study collated the attractiveness factors of male voices that respondents preferred. All factors are shown in Figure 2.



(Source: Adapted from this study)

Figure 2 shows the evaluation structure diagram drawn by integrating all attractiveness factors of the male voice. The original evaluation items are "husky," "young and feel like the protagonist," and "steady."

In the original evaluation item of "husky," the abstract reasons for attractiveness are "safety," "languorous," "sonorous," "relaxed," "young age," and "strong emotions," "comfortable" seven items; the specific conditions of composition are "slow speaking speed," "low pitch," "loud volume," "moderate speaking speed," and " changing intonation."

In the original evaluation item of "young and feel like the protagonist," the abstract reasons are "immature" and "youth;" the specific composition conditions are "moderate speaking speed" and " changing intonation," "high pitch, " "high school student status, "and "low volume." Five items.

In the original evaluation item of " steady," the abstract reasons for attractiveness are "lively," " distinct," "atmosphere," "calm," "skilled," "relaxed," and "safety." "Seven items; the specific composition conditions are six items: "moderate speaking speed," "low pitch," "slow speaking speed," "loud volume," "high school student status," and " changing intonation."

## 4.1.2 The Attractive Factor of Female Timbre

During the interview, the interviewees ranked five female timbre samples. The researchers asked the interviewees about their top two favorite female timbres and the attractiveness factors of female timbres. The researchers first asked about access to original evaluation items, specific composition conditions, and abstract reasons; all respondents could compare and rank timbres. This study collated the attractive factors of the female voice that respondents preferred. All factors are shown in Figure 3.



Figure 3. EGM graph of female timbre (Source: Adapted from this study)

Figure 3 shows the drawn by integrating all attractive factors of the female voice. The original evaluation items are "comfortable," "neutral," "young," and "cute."

In the original evaluation item of "comfortable," the abstract reasons for attractiveness are " happy," " soft," "gentle," and "languorous"; the specific composition conditions are "high pitch," "gentle personality," "changes in intonation," "slow speaking speed" and "moderate volume."

Among the "neutral" original evaluation items, the abstract reason is "languorous"; the specific composition conditions are "high pitch," "medium-low pitch," "moderate volume," "fast speech speed," "slow speech speed," and "loud volume."

In the original evaluation item of "young," the abstract reason is "freshness"; the specific composition conditions are "moderate speaking speed," "slurred speech," "little sister's identity," "slow speaking speed," and "high pitch." Five items.

In the original evaluation item of "cute," the top abstract reasons are "young," "vitality," "closeness," "humor," "calm," "atmosphere," "distinct," "freshness," and "happy" nine items; the specific composition conditions are "neutral," "changes in intonation," "medium-high pitch," "little sister's identity," "moderate speaking speed," "loud volume," "fast speech speed" and "high pitch."

## 4.2 Discussion

How to design a timbre and use sound to attract the user's hearing is a science. This study uses charm engineering to sort out the "original evaluation items," "abstract reasons," and "specific conditions of composition" that make timbre attractive to young people. The result is as follows:

1. When participants evaluated the male voice, the original evaluation items were "husky," "young and feel like the protagonist," and "steady." Three items.Numbered item 2.

2. When participants evaluate female timbre, the original evaluation items are "comfortable," "neutral," "young," and "cute." Four items.

3. When participants evaluate male timbre, the abstract reasons are "safety," "languorous," "sonorous," "relaxed," "young," "strong emotion," "comfortable," "immature," "youth," "lively," " distinct," "atmosphere," "calm," and "skilled." fourteen items.

4. When participants evaluate female timbre, the abstract reasons are "happy," "soft," "gentle," "languorous," " freshness," "young," "vitality," "closeness," "humor," "calm," "atmosphere," and " distinct." Twelve items.

5. When participants evaluated male voice, the specific composition conditions were "slow speaking speed," "low pitch," "loud volume," "moderate speaking speed," " changing intonation," "high pitch," and " high school student status," and "low volume." Eight items.

6. When participants evaluated female timbre, the specific composition conditions were "high pitch," "gentle personality," "changing intonation," "slow speaking speed," "moderate volume," "medium-low pitch," "fast speech speed," "loud volume," "moderate speaking speed," "slurred speech," "neutral," "medium-high pitch," "little sister's identity," and "loud volume." fourteen items.

## 4.3 Kano Questionnaire Result

The questionnaires included twenty-six questions in the female timbre questionnaire and twenty-two questions in the male timbre questionnaire. Thirty-seven and forty-seven participants were recruited, respectively, through the online questionnaire. After the filter was not eligible for participants, Thirty-one and Thirty-nine questionnaires were left, respectively. The participants' age distribution was eighteen to twenty-eight years old.

#### 4.3.1 Result of Male Timbre

After screening the twenty questions of the Male Voice Questionnaire, four attractive qualities and one unary quality were sorted out, as shown in Table 2.

ltem	CS	DS	KANO	CS&DS	GITLOW	RESULT
Comfortable	0.42	-0.34	I	0	0	0
Atmosphere	0.55	-0.36	I	А	А	А
Calm	0.64	-0.43	А	А	А	А
Low pitch	0.53	-0.48	А	А	А	А

# **Table 2.** Male timbre kano analysis(Source: Adapted from this study)

Moderate speaking speed	0.43	3 -0.35	Ι	A/O	A/O	0
The four attractive qualities	250	"atmocphor	o " "colm	" and "low	nitch "	and the two

The four attractive qualities are "atmosphere," "calm," and "low pitch," and the two One-dimensional qualities are " comfortable " and "moderate speaking speed."

## 4.3.2 Result of Female Timbre

Only A, O, M, and R are listed for visual observability, and I and O are omitted. After screening twenty-six questions, eleven attractive qualities were sorted out, as shown in Table 2.

Item	CS	DS	KANO	CS&DS	GITLOW	RESULT
Comfortable	0.63	-0.46	А	А	А	А
Young	0.54	-0.48	А	А	А	А
Cute	0.53	-0.50	А	А	А	А
Нарру	0.59	-0.44	А	А	А	А
Soft	0.54	-0.54	А	A/I	А	А
Gentle	0.60	-0.56	А	А	А	А
Atmosphere	0.60	-0.40	I	А	А	А
Closeness	0.60	-0.60	А	A/I	А	А
Moderate volume	0.48	-0.45	I	А	А	А
Changing intonation	0.41	-0.41	I	A/I	А	А
Various emotions	0.51	-0.51	А	A/I	А	А

## Table 2. Female timbre kano analysis

(Source: Adapted from this study)

The eleven attractive qualities are "comfortable," "young," "cute," "happy," "soft," "gentle," " atmosphere," "closeness," and "moderate volume." "Changing intonation," and "Various emotions."

#### 4.4 Discussion

After analysis, it was found that the female voice has eleven attractive qualities, namely "comfortable," "young," "cute," "happy," "soft," "gentle," "atmosphere," "closeness," "moderate volume," "Changing intonation," "Various emotions." The male voice has three attractive qualities: "atmosphere," "calm," and "low pitch," and two One-dimensional qualities: "comfortable" and "moderate speaking speed."

## 5 CONCLUSION

According to the results of the analysis, male and female timbres that the public finds comfortable will increase the attractiveness of the voice. It may be related to the fact that the participants are generally younger; they prefer cute and young timbres. Happy, soft, gentle, closeness, atmosphere, and moderate volume can increase the attractiveness of a female voice; through the research results of Starr (2015), it can be found that these qualities can also be used to create the impression of an older woman. There are changing intonations and various emotions, which can establish a speaking style consistent with the sweet voice being stylistic

(Starr, 2015). Feminine timbres possessing these qualities can all add to the attractiveness of a female voice. The three timbre qualities of male voices, atmosphere, calm, and low pitch, can increase the charm of male voices, which is consistent with the preference for deep voices (Collins, 2000). The two One-dimensional qualities are "comfortable" and moderate volume. That means if a male's voice possesses these two qualities, it can reduce the listener's dissatisfaction with the voice and increase satisfaction. This study only investigated young students who watched animations and their views on the charm of timbre. The study suggests that more participants can be recruited for testing.

These attractive qualities of the male voice may be attributed to pressures from other males and environmental competition, as well as selective pressures resulting from female preferences for deeper voices (Collins, 2000). These factors led participants to favor lower tones. In contrast, the appeal of female voices is quite different, likely due to the influence of traditional culture and the relatively young age of the participants, which contributed to a broader range of attractive qualities in female voices.

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# Exploring the Charm Factors of A-RPGs through Miryoku Engineering

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#### ABSTRACT

This study explores the charm factors of Action Role-Playing Games (A-RPGs) through the application of Miryoku Engineering. In-depth interviews are conducted to identify the charm factors most valued by deeply engaged users of A-RPGs. The Evaluation Grid Method (EGM) and the KANO model are utilized to investigate the essential charm factors necessary for A-RPG design. The findings provide valuable references for future designers, offering insights into the development of captivating and satisfying A-RPG experiences.

Keywords: miryoku engineering, Evaluation Grid Method, A-RPG, KANO model

#### **1** INTRODUCTION

#### 1.1 Background

After popularizing computers, Valve introduced the "Steam" digital game distribution platform in 2003. Following this, action role-playing games (A-RPGs) became playable on television and PCs through the Steam platform. According to Valve, in February 2023, the concurrent user count on the Steam platform surpassed 33 million. From 2014 to 2023, five A-RPGs were awarded Game of the Year at The Game Awards. This study focuses on A-RPGs and aims to explore the charm factors within this genre.

Based on the background of the study, the objectives of the study are threefold:

- Explore the primary charm factors that constitute action role-playing games.
- Explore the charm factors and design elements of action role-playing games.
- Explore the quality attributes of design elements in action role-playing games.

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#### 2 LITERATURE REVIEW

#### 2.1 Steam Platform

In 2003, Valve launched Steam, a digital distribution platform for video games, as a software client providing automatic game updates. By the end of 2005, it expanded to include titles from third-party game publishers, reaching a global audience. Developers could release their games on the Steam platform, offering players the ultimate choice for gaming, discussion, and game creation.

#### 2.2 Action Role-Playing Games (ARPGs)

Action Role-Playing Games (ARPGs), abbreviated as A-RPG, are a genre of electronic games that combine elements of traditional role-playing games (RPGs) with character growth, continuous combat, and adventure, along with elements of action games that feature real-time combat scenes.

#### 2.3 Miryoku Engineering and Evaluation Grid Method

In the Japanese Kogoro Bungaku dictionary, "charm" primarily pertains to the power that can only move the "heart." Charm is a subjective preference by the user, mainly stemming from the self-value judgment system, which originates from the user's sensory reception, psychological decision-making, sociology, and artistic evaluation, among other realms. Masato Ujigawa initiated the study of "Miryoku Engineering" in 1991, bringing together many scholars, aiming to " create techniques and knowledge for producing products and spaces with charm."

When the Japanese Sensory Engineering Society was established in 1998, Miryoku Engineering was incorporated as part of Sensory Engineering. Japanese scholars Junichiro Sanui and Masao Inui referenced the concept of the "Repertory Grid Method (RGM)" proposed by clinical psychologist Kelly in 1955 in "The Psychology of Personal Constructs." They modified it to develop the theoretical framework of Miryoku Engineering. Its theoretical foundation primarily lies in fundamental theory, modeling, and design.

The Evaluation Grid Method (EGM) was modified and enhanced by Sanui Junichiro and Inui Masao in 1986. When comparing evaluation subjects, it employs perspectives of "good or bad" and "likes or dislikes." Then, it incorporates a ladder method based on evaluation items obtained through interviews to organize the mechanisms of the items hierarchically. In-depth interviews are conducted to explore abstract and concrete reasons. EGM is based on cognitive theory and ladder procedures. Thus, interview results can be presented in easily understandable hierarchical network diagrams (Sanui, 1996), as shown in Figure 1.



Figure 1. Visualization of user requirements: Introduction of the Evaluation Grid Method. (Source: (Sanui,1996))

The Evaluation Grid Method is a hierarchical framework consisting of Abstract Reasons (upper level: Abstract Value Judgment), Original Evaluation (middle level: Understanding of Sensations), and Specific Concrete conditions (lower level: Objective Understanding of Specifics), as shown in Figure 2.



Figure1. Ladder construction concept of EGM



#### 2.4 Kano Model

Noriaki Kano and colleagues were influenced by early research on two-dimensional structures and Frederick Herzberg's Motivation-Hygiene Theory when they introduced the concept of attractive quality theory. In 1984, they proposed the Kano model to interpret the different roles that various quality attributes play in consumer satisfaction (Witell et al., 2013). The relationship between satisfaction and dissatisfaction with needs and experiences is not necessarily linear (Kano et al., 1984). According to the attractive quality theory, quality attributes are dynamic and may change over time or due to certain features, potentially turning satisfaction into dissatisfaction (Kano et al., 1984). The theory suggests that factors leading to job satisfaction and dissatisfaction are distinct; when one set of factors increases, the other does not necessarily decrease because they are independent factors (Witell et al., 2013).

Noriaki Kano's framework serves as the basis for developing models related to satisfaction and achievement. The model consists of three main categories: "Must-Be Quality," "One-Dimensional Quality," and "Attractive Quality," along with two minor categories, "Indifferent Quality" and "Reverse Quality," as illustrated in Figure 3.



(Source: (Chen& Chuang,2008))

1. Attractive Quality:

When this quality attribute continues to improve, consumer satisfaction increases significantly. However, even if the quality attribute remains unchanged, it does not cause a decrease in consumer satisfaction.

2. One-Dimensional Quality:

As quality improves, attributes that enhance satisfaction also increase. However, lacking this quality element can lead to consumer dissatisfaction.

3. Must-Be Quality:

Respondents consider this quality attribute to be essential. Lack of this quality element can cause severe consumer dissatisfaction.

4. Indifferent Quality:

Whether this quality attribute is sufficient or insufficient, consumer satisfaction remains unaffected.

5. Reverse Quality:

When this quality attribute continues to improve, satisfaction decreases proportionally. Conversely, when this quality attribute is insufficient, consumer satisfaction increases proportionally.

#### 3 METHOD

#### 3.1 Research Design

This study, which focuses on Action Role-Playing Games (A-RPGs) available on the Steam platform, is structured into two main stages. The first stage involves the selection of four A-RPG

titles based on nominations and winners from The Game Awards between 2014 and 2023. The second stage is the research process, divided into the Evaluation Grid Method and the KANO Two-Dimensional Quality Model.

Participant eligibility criteria required individuals to have at least three months of experience playing A-RPGs on the Steam platform, with at least three hours of gameplay per week.

#### 3.2 PROCEDURES

Explanation of each stage:

#### 1. First Stage: Evaluation Grid Method

This study was conducted in two primary phases. The Evaluation Grid Method (EGM) was employed in the first phase. Seven experienced A-RPG players were selected as research subjects. Participants were asked to choose two games from four sample titles: *The Witcher 3: Wild Hunt, Dark Souls 3, Monster Hunter: World,* and *NieR: Automata.* Each participant spent 30 minutes experiencing their chosen games. Following the gameplay sessions, in-depth interviews were conducted to investigate the reasons for their preferences. Individual evaluation structure diagrams were then created using the Evaluation Grid Method, and these individual diagrams were subsequently integrated into a comprehensive evaluation structure diagram.

2. Second Stage: KANO Two-Dimensional Quality Model

In the second phase, the KANO Two-Dimensional Quality Model was applied. A questionnaire was developed based on the charm factors identified in the first phase. An online KANO two-dimensional quality questionnaire was created using Google Forms, and responses were collected. After excluding invalid submissions, 30 valid questionnaires were retained. The collected data were then analyzed using the KANO model to determine the charm factors of A-RPG games and their influence on player satisfaction.

#### 4 RESULTS

#### 4.1 Exploring Charm Factors of Action Role-Playing Games

In this study, seven A-RPG gaming enthusiasts, all male with an average age of 23-25, were recruited. Following in-depth interviews, individual Evaluation Grid Method diagrams were collected from each participant and meticulously consolidated to create a comprehensive and robust evaluation structure diagram. This diagram illustrates the relationships among charm factors. The primary original evaluation for the A-RPG experience, as identified by participants, includes "game art," "music and sound effects," "game content," "game balance," and "gameplay mechanics."

Moreover, the leading abstract reasons for favoring A-RPGs among participants encompass: "sense of achievement," "detailed and immersive visuals," "sense of coordination," and "immersion." These abstract reasons are essential considerations for A-RPG game designers aiming to enhance the overall gaming experience, satisfaction, and player engagement.



Figure 4. The evaluation structure diagram for action role-playing games.

1. When evaluating action role-playing games, participants primarily cited "game art," "music and sound effects," "game content," "game balance," and "gameplay mechanics" as their primary original evaluation.

2. "Game art" can create abstract reasons such as "detailed and immersive visuals," "immersion," and "satisfying visual experience." In its design, elements such as "realistic 3D effects," "visual effects," "smooth animations," "consistent art style," and "Japanese realistic style" can be targeted.

3. "Music and sound effects" can generate abstract reasons like "sense of coordination" and "immersion." Design elements, including "music coordination with storyline," "integration into gameplay," "diverse event music," and "variety of sound effects," can be emphasized.

4. "Game content" contributes to abstract reasons such as "logic," "high freedom," and "uniqueness." Design elements such as "attack modes," "boss modes," "mission guidance," "customizable characters," and "complete ecosystem" can be incorporated.

5. "Game balance" leads to abstract reasons like "sense of achievement," "challenge," and "pleasure." Design elements including "control difficulty," "tactics and skills," "rebirth mechanism," "proficiency requirements," "difficulty increase with mission advancement," and "fatigue system" can be focused on.

6. "Gameplay mechanics" generate abstract reasons like "smoothness" and "controllability." Design elements such as "impact feedback," "smooth action flow," "multi-perspective," and "semi-automatic attacks" can be emphasized.

#### 4.2 Exploring the Quality Attributes of Charm Factors in Action Role-Playing Games

According to the analysis results shown in Table 1, the classification explanation of quality attributes in action role-playing games is as follows:

#### 1. Attractive Quality (A)

According to the results of the analysis, "diverse event music" and "different attack modes" are classified as attractive. Players feel satisfied when these elements are sufficient, and their absence does not lead to dissatisfaction.

2. One-Dimensional Quality (O)

Based on the analysis results, "visual effects," "smooth animations," "music

coordination with storyline," "integration of music and sound effects into gameplay," "customizable game characters," "rebirth mechanism," "impact feedback," "smooth action flow," "detailed and immersive visuals," "immersion," "sense of coordination," "sense of immersion," "logic," "challenge," "sense of achievement," "pleasure," "controllability," and "smoothness" are classified as one-dimensional quality. Players feel satisfied when these elements are sufficient and of high quality, but their inadequacy leads to dissatisfaction.

3. Indifferent Quality (I)

According to the analysis results, "Japanese realistic style," "realistic 3D models," "consistent art style," "complete ecosystem," "boss modes," "mission guidance," "tactics and skills," "control difficulty," "proficiency requirements," "increased difficulty with mission advancement," "fatigue system," "multi-perspective," and "semi-automatic attacks" are classified as indifferent quality. Whether these elements are present or not does not affect satisfaction levels.

Kano model analysis								
Project	А	0	М	I	R	Category Results	CS	DS
Japanese realistic style	16.67%	23.33%	3.33%	50.00%	3.33%	_	42.86%	-28.57%
Visual effects	26.67%	33.33%	13.33%	13.33%	23.33%	0	62.07%	-48.28%
Realistic 3D models	23.33%	23.33%	0.00%	43.33%	6.67%	_	51.85%	-25.93%
Smooth animations	26.67%	40.00%	10.00%	20.00%	0.00%	0	68.97%	-51.72%
Unified composition elements	13.33%	30.00%	10.00%	40.00%	3.33%	I	46.43%	-42.86%
Music and plot harmonization	13.33%	56.67%	0.00%	26.67%	0.00%	0	72.41%	-58.62%
Musical sound effects are integrated into the game	26.67%	43.33%	0.00%	26.67%	0.00%	0	72.41%	-44.83%
Diversity Event Music	33.33%	30.00%	0.00%	30.00%	3.33%	А	67.86%	-32.14%
Customizable game characters	20.00%	36.67%	0.00%	33.33%	6.67%	0	62.96%	-40.74%
Complete Ecosystem	26.67%	26.67%	3.33%	36.67%	3.33%		57.14%	-32.14%
Attack Mode	36.67%	26.67%	6.67%	26.67%	0.00%	A	65.52%	-34.48%

Table 1. Kano model analysis table

Kano model analysis								
Project	А	0	М	I	R	Category Results	CS	DS
Boss Mode	13.33%	36.67%	3.33%	40.00%	0.00%	I	53.57%	-42.86%
Mission Guidance	10.00%	36.67%	10.00%	40.00%	0.00%		48.28%	-48.28%
Rebirth mechanism	16.67%	40.00%	0.00%	36.67%	3.33%	0	60.71%	-42.86%
Tactics and Skills	26.67%	26.67%	3.33%	40.00%	0.00%		55.17%	-31.03%
Maneuvering Difficulty	16.67%	23.33%	3.33%	50.00%	0.00%		42.86%	-28.57%
Proficiency Requirements	23.33%	13.33%	3.33%	43.33%	13.33%		44.00%	-20.00%
Difficulty increases as the task progresses.	23.33%	26.67%	3.33%	43.33%	0.00%	I	51.72%	-31.03%
Fatigue Value System	6.67%	10.00%	6.67%	60.00%	13.33%	I	20.00%	-20.00%
multi-perspective	16.67%	23.33%	0.00%	46.67%	6.67%	I	46.15%	-26.92%
Semi-Automatic Attack	16.67%	10.00%	0.00%	50.00%	20.00%		34.78%	-13.04%
Impact Feedback	20.00%	43.33%	10.00%	23.33%	0.00%	0	65.52%	-55.17%
Smoothness	23.33%	50.00%	6.67%	16.67%	0.00%	0	75.86%	-58.62%
Detailed and textured images	23.33%	43.33%	3.33%	23.33%	3.33%	0	71.43%	-50.00%
immersion	26.67%	43.33%	6.67%	20.00%	0.00%	0	72.41%	-51.72%
sense of harmony	23.33%	43.33%	3.33%	33.33%	3.33%	0	68.97%	-48.28%
Sense of immersion	13.33%	43.33%	3.33%	26.67%	3.33%	0	60.71%	-50.00%
rationality	13.33%	43.33%	13.33%	26.67%	0.00%	0	58.62%	-58.62%
Challenging	26.67%	36.67%	3.33%	26.67%	3.33%	0	67.86%	-42.86%
Sense of achievement	26.67%	40.00%	6.67%	20.00%	3.33%	0	71.43%	-50.00%
pleasure	26.67%	46.67%	0.00%	20.00%	3.33%	0	78.57%	-50.00%
controllable	30.00%	40.00%	10.00%	16.67%	0.00%	0	72.41%	-51.72%
smooth	10.00%	60.00%	3.33%	23.33%	0.00%	0	72.41%	-65.52%
A: Attractive Quality O: One-Dimensional Quality M: Must-Be Quality								

I: Indifferent Quality R: Reverse Quality

According to the Better-Worse coefficient diagram results (Figure 6), the classification explanation of quality attributes in action role-playing games is as follows:

#### 1. First Quadrant:

Based on the Better-Worse coefficient diagram results, "pleasure," "smooth animation," "music coordination with storyline," "smooth animations," "integration of music and sound effects into gameplay," "challenge," "rebirth mechanism," "visual effects," "sense of immersion," "sense of coordination," "impact feedback," and "smoothness" belong to the first quadrant. These attributes are classified as one-dimensional quality. Players feel satisfied when these elements are sufficient and of high quality, but their inadequacy leads to dissatisfaction.

2. Second Quadrant:

According to the Better-Worse coefficient diagram results, "diverse event music," "attack modes," and "customizable game characters" belong to the second quadrant. These are classified as attractive qualities. Players feel satisfied when these elements are sufficient, but their absence does not lead to dissatisfaction.

3. Third Quadrant:

The attributes "complete ecosystem," "tactics and skills," "increased difficulty with mission advancement," "realistic 3D models," "proficiency requirements," "Japanese realistic style," "semi-automatic shooting," and "fatigue system" belong to the third quadrant. These are classified as indifferent quality.

4. Fourth Quadrant:

Attributes such as "boss mode," "consistent composition elements," "mission guidance," and "logic" belong to the fourth quadrant. These are classified as necessary qualities, which are essential for satisfaction.



Figure 6. Kano model analysis

#### 5 CONCLUSION

#### 5.1 Discussing The Research Findings as Follows

1. Charm Factors of Action Role-Playing Games:

Based on the evaluation grid, the five original evaluations, including "game aesthetics," "music and sound effects," "game content," "game balance," and "gameplay," were mentioned more than twice, indicating their significant importance to players. Players often consider these aspects when seeking out games, which are often showcased in-game trailers. Additionally, concrete conditions such as "realistic 3D models," "visual effects," "coordinated music and narrative," "immersive integration of music," "diverse event music," "variety of sound effects," "control difficulty," "tactics and skills," "sensory feedback in combat," "smooth animation," and "multiple perspectives" are frequently encountered during gameplay. Among these specifics, those mentioned four or more times such as "detailed and immersive visuals," "sense of coordination," "sense of immersion," "sense of immersion," "sense of achievement," "smooth gameplay," and "high level of freedom" are particularly crucial in action role-playing games.

2. Quality Attributes of Charm Factors in Action Role-Playing Games:

According to the analysis, "diverse event music" and "varied attack modes" are charm factors. When these elements are present and of high quality, they contribute to player satisfaction. Conversely, "visual effects," "smooth animations," "coordinated music and narrative," "integrated music and sound effects," "customizable game characters," "rebirth mechanisms," "sensory feedback in combat," "smooth gameplay," "detailed and immersive visuals," "sense of immersion," "sense of pleasure,"

"playable," and "smooth" belong to one-dimensional quality attributes. When present in sufficient quantity and quality, these attributes lead to player satisfaction, particularly when music and content coordination are well executed, contributing to immersion. "Japanese realistic style," "realistic 3D models," "consistent element composition," "complete ecological systems," "boss modes," "mission guidance," "tactics and skills," "control difficulty," "skill level requirements," "difficulty increases with mission advancement," "fatigue value system," "multiple perspectives," and "semi-automatic attacks" belong to indifferent quality attributes. These elements do not significantly affect player satisfaction.

#### 5.2 Findings and Suggestions

The current study has yielded valuable insights into the design and production of Action Role-Playing Games (A-RPGs), highlighting key elements that significantly impact player satisfaction. It has been found that several factors contribute positively or negatively to the overall experience of players. These factors include, but are not limited to, the following: "visual aesthetics," "smooth animation," "coordinated music and narrative," "integration of music and sound effects," "customizable game characters," "respawn mechanics," "sensory feedback during combat," "smooth gameplay," "detailed and immersive visuals," "immersion," "sense of accomplishment," "pleasure," "playability," and "game smoothness."

This future direction will be instrumental in helping designers optimize the appeal and playability of both 2D and 3D A-RPGs, ultimately contributing to the advancement of the genre.

#### **6 LITERATURE REVIEW**

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## DISCUSSING THE CHARM FACTORS OF ABSTRACT DYNAMIC GRAPHICS FROM THE PERSPECTIVE OF KANSEI ENGINEERING

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#### ABSTRACT

This study aims to explore the psychological impact of abstract dynamic graphics using Kansei Engineering. As the usage rate of media networks increases, people's aesthetic appreciation for visual graphics has also been gradually rising. Identifying the specific dynamic compositions that stand out is a core issue among the various dynamic visuals, often leading to difficulties for creators in making decisions. Therefore, the researchers used the Evaluation Grid Method (EGM) to interview participants. To ensure the accuracy of the interview data, participants were required to have basic color cognition and be graduates with a master's degree in design. After extracting the "original elements" of graphic compositions that the participants considered necessary, the researchers further categorized these elements into "abstract" and "concrete" attractive factors. By understanding the design composition and emotional elements that make abstract dynamic graphics appealing to viewers, approximately 33 participants' preferences and satisfaction were collected through a forward and reverse questionnaire. The results were analyzed using the KANO quality model to extract the precise quality attributes (attractive quality, one-dimensional quality, indifferent quality, and reverse quality). The practical implications of these findings for the creation and research of related visual graphics are significant. They provide a clear roadmap for designers and researchers, enhancing the quality and appeal of their work.

Keywords: VJ, Evaluation Grid Method (EGM), KANO Quality Model

#### 1 Background and Motivation

In an era where the media industry is nearing maturity, the impact of abstract dynamic visual graphics on media has become increasingly profound. These graphics are widely used in popular short videos, exhibitions, and projection stages, with some designs leaving a particularly lasting impression. It is a trend for abstract visual types to become diverse. Although there are existing design principles for abstract dynamic graphics, there is a

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pressing need for a more detailed understanding of the conditions for attractive factors in research. In terms of production, if the necessary factors or one-dimensional quality requirements can be provided, it would not only speed up the production process but also enhance the final completeness of the product.

### **1.1** Research Scope And Limitations

1. Research Sample Limitation: This study focuses on young and middle-aged adults who are accustomed to electronic devices and familiar with color changes. Therefore, the research group is set to be between 18 and 35 years old. People over 35 years old are not included in the scope of this study.

2. Research Scope Limitation: No audio information is involved during the testing phase of this study to avoid the influence of music on the testers' perception when added to dynamic graphics and to ensure the accuracy of experimental data.

3. Research Application Scope: Abstract dynamic graphics have many applications. This study focuses on exploring the factors of attractiveness. The data can be used for the initial design of dynamic images and subsequent design adjustments.

### 2 Literature Review

### 2.1 Definition of Abstract Dynamic Graphics

Abstract dynamic graphic art, emerging in the 19th century, initially faced public misunderstanding. Betancourt's research identifies visibility music by pioneers like Ruttmann, Richter, Eggeling, and Fischinger as prototypes of dynamic images. Integrating these graphics into interfaces enhances visual experiences (Betancourt, 2013).

Hong Lei (2022) defines abstract dynamic graphics as time-changing images presenting new information. They are characterized by (1) existing as dynamic videos, (2) lacking specific information or designated items, and (3) primarily used in exhibitions, film/television, or instruction.

Figure 1. TAS - Bloom (2017) (Source: https://www.tasvisuals.com/)
Figure 2. 4K ABSTRACT VJ MOTION BACKGROUND    NEON LIGHT TUNNEL FREE VJ LOOPS    4K VJ LOOPS 2020(2020) (Source: https://www.youtube.com/watch?v=4yrpJn0kNNM)

#### Table 1. Examples of Abstract Dynamic Graphics

#### 2.2 Kansei Engineering

Attraction comes from the self-image within, where one's self-perception determines the strength and depth of attraction. However, "attraction" is a vague concept, often considered a general term for something captivating. It is holistic, with social functional influences, rather than the result of a singular function in a specific area.

"Kansei Engineering" was initiated in 1991 by Masato Ujigawa and several scholars, aiming to explore the techniques and disciplines involved in creating fascinating products and spaces. By 1998, with the establishment of the Japan Kansei Engineering Society, Kansei Engineering became a part of the field of Sensory Engineering. Japanese scholars Junichiro Sanui and Masao Inui, after studying the concept of the "Repertory Grid Method" from the book "The Psychology of Personal Constructs" published by clinical psychologist Kelly in 1955, further developed and refined it, eventually establishing the theoretical framework and model design methodology of Kansei Engineering.

#### 2.3 Evaluation Grid Method

The Evaluation Grid Method (EGM) was developed by Japanese scholars Sanui Junichiro and Inui Masao. They refined it based on their study of Kelly's Individual Construct Method (RGM, Repertory Grid Method) I 1995. The method guides respondents to compare different factors based on their preference levels, established themes, and questions. EGM allows for identifying the respondents' most distinct sources of preference, facilitating a deeper understanding of their psychological cognition regarding a particular theme or object.

During interviews, respondents are asked to compare objects A and B and are asked about their similarities and differences. Through this process, researchers can further grasp the preferences and perspectives of the respondents regarding the theme (objects A and B), ultimately allowing for the deduction of different characteristics of the target object (Kelly, 1995). This method was initially designed for clinical purposes and can thus elicit participants' construction systems with minimal assumptions (Sanui, 1996). Sansui Junichiro and Inui Masao (1986) refined the method by introducing two procedures. Firstly, when comparing evaluation objects, they approached from the perspective of "superiority" or "inferiority" and "liking" or "disliking." For example, Tzu-Wei Tsai (2023) utilized the Evaluation Grid Method to explore the original factors, abstract items, and specific elements of augmented immersive media, thereby contrasting the respondents' preferences and quality attributes. Secondly, they incorporated the ladder technique (Laddering) into the evaluation process, which hierarchicalizes the evaluation mechanism and elicits abstract and concrete reasons behind the evaluations. As EGM is based on cognitive theory and ladder procedures, the interview results can be presented as a hierarchical network diagram that is easy for designers to understand (Sanui, 1996).

The Evaluation Grid Method could be used to delve the interview result into three hierarchical levels: abstract reasons (upper level: abstract value judgments), original evaluation items (intermediate level: sensory understanding), and specific conditions of composition (lower level: objective, specific understanding).



Figure 3. Three-tier Structure of the Evaluation Grid Method

#### 2.4 Kano Model

The Kano model was introduced by Noriaki Kano in 1984. Influenced by earlier research on two-dimensional structures, particularly Frederick Herzberg's Motivation Theory, Kano expanded upon this theory by introducing the concept of "attractive quality." Through this model, Kano explained how to distinguish between "sufficient" and "excellent" levels when considering customer satisfaction (Kano et al., 1984). The theory of attractive quality suggests that factors leading to job satisfaction differ from those leading to job dissatisfaction, and subjective aesthetic quality is a crucial determinant of customer satisfaction (Chen et al.; M. C., 2008). The model indicates that satisfaction and dissatisfaction are separate concepts in the consumer's mind and should be considered separately (Kano et al., 1984). The framework proposed by Kano serves as the foundation for models related to the development and achievement of satisfaction and fulfillment.



The Kano model includes features such as "Must-Be Quality," "One-Dimensional Quality," "Attractive Quality," "Indifferent Quality," and "Reverse Quality," as described below. Please note that categories are represented by streamlines on the two-dimensional graph, demonstrating how objective and subjective perspectives are interconnected. Different patterns are associated with each category, depending on how the two dimensions interact at different performance levels.

1. Must-be quality refers to the attributes that customers consider essential. If a product or service lacks these essential qualities in some respects, customers will immediately notice. It is worth noting that when these essential functions are included in the design, customers will be delighted. However, if these attributes are present, customers often pay little attention, and customer satisfaction stays the same beyond the neutral level (Berger et al., D., 1993).

2. One-dimensional quality: One-dimensional quality is the attribute that increases customer satisfaction as quality improves. Traditional quality concepts sometimes assume customer satisfaction is directly proportional to the product's functionality (Berger et al., D., 1993). The concept is represented by a 45-degree line in Figure 4, which starts from the dissatisfied quadrant (third quadrant) and linearly moves upward to the satisfied quadrant (second quadrant).

3. Attractive quality: Attractive quality appears only when a product/service has unexpected and satisfying attributes. In other words, customer satisfaction exhibits super-linear growth as the attribute performance improves (Chen et al.; M. C., 2008).

4. Indifferent quality: Testers generally remain neutral or may have no requirements for quality elements (Berger et al., D., 1993), and customer satisfaction is not affected by product performance.

5. Reverse quality: Reverse quality refers to attributes that customers do not want and cause dissatisfaction. Customers become more dissatisfied as standard performance improves (Chen et al.; M. C., 2008). The pattern of this dimension starts from the satisfied/dissatisfied quadrant (first quadrant) and linearly moves downward to the satisfied/dissatisfied quadrant (fourth quadrant), as shown in Figure 4.

Berger et al. (1993) summarized the analysis approach of the Kano model, using Better and worse coefficients to calculate the impact of quality on customer satisfaction.

#### 3 Research Methodology

#### **Evaluation Grid Method execution process**

Purpose: Firstly, interviews will be conducted using the evaluation construction method to extract the most representative results of attractive factors.

Method: Familiarizing the interviewees with the content before the interview begins, this study will arrange selected dynamic image types related to abstract image terms, picture cards, and various types of abstract dynamic videos on the desktop as templates. At the beginning of the interview, the recording button is pressed to play the introduction videos featuring abstract compositions sequentially. The question-and-answer session began after the interviewees watched them and ranked them according to their preferences. Their abstract, original, and specific reasons are extracted based on the interviewees' responses. Finally, the compiled transcripts are drawn into charts, and after integrating all interviewees' responses, the evaluation construction diagram summary is completed.



Figure 5. Interview Process Diagram

Recruit six interviewees. To enhance the accuracy of data collection, the interviewees must have a basic understanding of color perception and hold a master's degree in a design-related field. In addition to basic color discrimination abilities, they have been regularly exposed to films, videos, and other color-related works for approximately two years. Various introductory videos and cards were prepared for comparison and memory recall to understand the interviewees' preferences for different dynamic images and factors related to their psychological perceptions.

#### KANO model Execution process

Objective: To extract evident characteristics of "must-be quality," "one-dimensional quality," "attractive quality," "indifferent quality," and "reverse quality" from abstract dynamic images.

Approach: A questionnaire outline was prepared based on the factors from the previous Evaluation Grid Method. The questionnaire was distributed and consolidated using Google Forms. A total of thirty-three respondents completed the questionnaire. After collecting the responses, the data was analyzed using the KANO quality model, and the results were presented in graphical form.



Figure 6. Research Process Diagram

#### 4 Results

According to the interview results collected using the Evaluation Grid Method, as shown in Figure 7:



Figure 7. Integration of the Evaluation Grid Graph

Based on the results obtained from the Evaluation Grid Method, the integration reveals the following details:

1. A beloved abstract dynamic graphic composition consists primarily of ten abstract elements: "fantastic," "orderly," "dynamic," "simple and concise," "sense of space," "richness," "neat," "diverse," "immersive," and "comfortable." Designers aiming to enhance the visual experience of dynamic graphics must effectively address these sensory imageries.

2. Key evaluation aspects identified by participants during the experience of abstract dynamic graphics include "screen colors," "graphic presentation methods," "sensory and atmosphere," "distinctive features of graphics," and "preference factors."

3. Screen colors create "fantastic" sensory imagery. Design considerations for composition may include elements such as "monotonously simple," "rich color usage," and "organized color tones."

4. "Graphic presentation methods" contribute to the perception of "orderliness" and "dynamic feeling." Design considerations may involve aspects like "clean line presentations," "thematic purposes," "layered lines," "diverse screen changes," "obvious dynamic jumps," and "focused elements."

5. "Sensory and atmosphere" contribute to the perception of "orderliness" and "dynamic feeling." Design considerations may include elements such as "rich color usage," "clean line presentations," "immersive integration," "thematic purposes," and "focused elements."

6. "Distinctive features of graphics" contribute to the perception of "orderliness," "dynamic feeling," "simplicity," and "sense of space." Design considerations may include elements such as "rich color usage," "diverse screen changes," "thematic and purposeful compositions," and "endless extension of composed lines."

7. "Preference factors" contribute to the perception of "richness/neatness/diversity," "immersion," "simplicity," "comfort," "fantasy," and "sense of space." Design considerations may involve elements like "layered line compositions," "simple/sorted color tones," "obvious and stable dynamic rhythm," "thematic purposes," and "endless extension of composed lines."

The quality classification results of the KANO model two-way questionnaire are presented in

ticle	A	0	м	т	R	Q	CS (A+D)/ (A+O+M+I)	DS (A +M) /(C+A+M+I)×(-1)	ΚΑΝΟ	CS/DS	Gitlow (Quality antibute indoment)	Attribute Results
Rich colors on the screen	8	2	3	16	0	2	0.3448	-0.3793	I	I	Ī	Т
Monotone colors on the dynamic	4	0	2	20	5	0	0.1538	-0.2308	I	I	T	T
Regular colors on the screen of a	5	3	4	16	2	1	0.2857	-0.3214	I	Т	Т	Т
Dynamic graphics have a whimsica color style on the	5	2	2	22	0	0	0.2258	-0.2258	I	I/A	T	Ţ
Screat The sense of movement in the dynamic graphic recressentation is	8	1	4	17	1	0	0.3000	-0.4000	I	1	1	1
Dynamic graphics have a clean line performance	10	1	4	16	0	0	0.3548	-0.4516	1	1	1	1
there is a dear the me or purpose in the dynamic graphic graphic	7	2	4	18	0	0	0.2903	-0.3548	Ţ	I	I	I
Layers of lines in a dynamic graphic representation.	8	4	4	14	0	1	0.4000	-0.4000	T	ΑЛ	Λ	Α
Dynamic shapes c/thiodyleus lumes in motion.	8	3	3	17	0	0	0.3548	-0.3548	T	АЛ	Т	T
There is a sense of immersion in the visual atmosphere of the dynamic	12	5	I	13	0	0	0.5484	-0.4194	I	Α	Λ	Α
Dynamic graphics have a visual focus	6	3	4	17	1	0	0.3000	-0.3333	Ι	1	1	1
Dynamic graphics are simple and dry	6	1	1	23	0	0	0.2258	-0.2258	1	A/I	1	1
Dynamic graphics have a sense of Nonce	7	3	4	17	0	0	0.3226	-0.3548	1	1	ſ	1
Dynamic graphics have colorful and rish betures.	5	4	3	18	1	0	0.3000	-0.2667	1	А	1	1
Dynamic shapes have a varied image.	7	8	Ű	16	Ü	0	0.4839	-0.2258	1	0	1	1
Dynamic graphics pre thythmic	- 9	6	1	15	- 0	0	0.4839	-0.3226	1	А	А	А
are characterized by imes that extend indefinitely	3	4	3	21	0	0	0.2258	-0.1935	I	0	Т	I
Dynamic shapes are confortable to look at.	6	9	4	12	0	0	0.4839	-0.3226	I	0	0	0
The color oslette of the animated graph colors mole.	3	1	1	26	0	0	0.1290	-0.1290	T	A/I	Т	T
The dynamic ordering of a dynamic graph is neatly practiced.	4	2	5	19	1	0	0.2000	-0.3000	1	1	1	1
Dynamic shapes have a stable sense of mation.	4	1	6	20	0	0	0.1613	-0.3226	1	1	1	1

Table 3:

#### Table 2. Quality Classification of Two-way Questionnaire

The results of the KANO model show the proportions of the six attributes, as well as the better (equal to CS) and worse (equal to DS) values compared to the classification results. The analysis principles are as follows:

1. The classification results refer to the attribute with the highest proportion among the six.

2. Better and worse (satisfaction impact/dissatisfaction impact) are used to determine the sensitivity of users to changes in the level of functionality/service.

3. Better (increase in satisfaction index) = (A+O) / (A+O+M+I); this index ranges between 0 and 1, with higher values indicating higher sensitivity and priority.

4. Worse (decrease in dissatisfaction index) = -1 * (O+M)/(A+O+M+I); this index ranges between -1 and 0, with higher values indicating higher sensitivity and priority.

From the analysis results of the KANO quality model, the following conclusions can be drawn after integrating the main attractive qualities:

1. Attractive Quality A: There are a total of three items, including "Lines in dynamic graphics with a sense of hierarchy," "Immersive integration feeling in the visual atmosphere," and "Dynamic sensation."

2. One-dimensional Quality O: One item includes the visual perception of "looking comfortable and soothing."

3. Indifferent Quality I: There are a total of seventeen items, including "Rich colors in the picture," "Monotonous colors in the picture," "Regular and orderly color tones in the picture," and "Fantasy color style in the picture."



The KANO Quality Model Analysis Quadrant Results are shown in Figure 8:

Figure 8. Better & Worse Coefficient Chart

According to the statistical results, the analysis of the abstract dynamic graphics quadrant is as follows:

1. In the first quadrant, the one-dimensional quality O includes: "the screen has diverse changes," "the lines exhibit layered characteristics," "the graphics feature spatial elements," "the dynamic graphics appear comfortable and soothing," and "the dynamics exhibit rhythmic movement."

2. In the second quadrant, the attractive quality A includes: "immersion in the visual atmosphere," "rich colors on the screen," "noticeable fluctuations in dynamics," and "clean line presentation in graphics."

3. In the third quadrant, the indifferent quality I includes: "orderliness in dynamic performance," "clear themes or purposes in graphics," "regularity in lines," "fantasy color styles on the screen," "monotone coloring in the screen," and "simplicity in dynamic graphics."

4. In the fourth quadrant, the must-be quality M includes: "regular and orderly color tones in dynamic graphics," "visual focal points in dynamic graphics," "extending and indefinite lines in dynamic graphics," "neat arrangement of dynamic sequences," and "stability in dynamic graphics."

#### 5 Conclusion

Specific abstract dynamic graphic charm factors were explored using the Evaluation Grid Method and the KANO Quality Model. Quantitative questionnaires were created based on the qualitative interview results to understand the most concrete sensory factors evaluated by the participants. Consequently, the main components of charm were identified. Thus, the study draws the following conclusions:

Attractive qualities in abstract dynamic graphics include "Layered presentation of dynamic graphic lines," "Immersive feeling in the visual atmosphere," and "Dynamic rhythm." While providing these quality attributes will enhance user satisfaction, more quality is needed to lead to user satisfaction.

One-dimensional quality includes visually "Comfortable and soothing" sensations. Providing such quality attributes in abstract dynamic graphics will enhance consumer satisfaction, yet insufficient quality does not lead to consumer dissatisfaction.

From these conclusions, it is evident that people are most sensitive to elements categorized within those above one-dimensional and charming qualities. The contents of indifferent quality can be compared, and ineffective elements can be excluded in advance. In future productions based on the integrated results of these charm factors, the improved dynamic graphics will better meet customer quality requirements. Ultimately, the research findings are intended to provide references for researchers and practitioners in visual media production and study.

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## INTERACTIVE LEARNING SYSTEM FOR SELF-DIRECTED LEARNING OF INTERDISCIPLINARY TEAM DESIGNERS

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#### ABSTRACT

This study found that the communication difficulties between designers and engineers in interdisciplinary teams mainly stem from a lack of understanding of each other's basic knowledge. Therefore, we attempted to use interactive design on mobile devices to enable designers to engage in self-directed learning of basic engineering knowledge during fragmented time to solve the knowledge learning needs of designers and engineers during discussions. To reduce learning costs, we adopted a common summary method used by designers for the learning design. Each day, designers go through the four processes of retrieval, decision-making, operation, and results to gradually understand engineering knowledge, thereby reducing communication difficulties with engineers in the team.

*Keywords:* interdisciplinary teams, interactive design, fragmented time, basic engineering knowledge, self-directed learning

#### **1** INTRODUCTION

#### 1.1 Research Background

Designer often face challenges in interdisciplinary courses, particularly during the ideation and implementation stages. These challenges include insufficient programming skills for building models and difficulties in communicating with team engineers. The degree to which designers in a cross-disciplinary team understand engineering knowledge will affect the solutions that engineers can envision during team collaboration during the conception phase, as well as help engineers with production assistance during implementation, which may affect the progress of the project. This includes the fact that when designers conceive and implement products with engineers in the team, the conceptual plan is limited or the implementation process is delayed due to the designer's insufficient understanding of engineering knowledge. Therefore, designers will find that insufficient understanding of basic engineering knowledge

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affects product production during collaboration in cross-disciplinary teams, and then they will have the idea of spending time learning engineering knowledge.

However, most of these designers are college students. due to the busy schedules of university students (fragmented time) and the high cost of interdisciplinary learning, many ultimately abandon opportunities for project enhancement. This study focuses on university students enrolled in interdisciplinary courses. These students typically face the dual demands of completing project work and meeting credit requirements, making time management more difficult compared to other periods in their academic careers. Consequently, they struggle with coursework and have limited time for additional learning.

By interviewing these students, we identified the challenges they face with programming and time management. Based on these findings, we designed an appropriate learning plan and interface to help address these issues.

#### 1.2 Research Problem

Our research has found that in cross-disciplinary course collaboration, designers are easily limited by insufficient engineering knowledge during the conception and collaboration stages of product collaboration (shown in Figure 1). At this time, designers should learn quickly according to time requirements. Obtain the knowledge required for the current conceptual stage. Interdisciplinary course project usually marks the end of the conceptualization phase and the beginning of the implementation phase at mid-semester. Prior to the conceptualization stage, courses typically involve empathy games aimed at design ideation, allowing design and engineering team members to brainstorm together (Shih et al., 2023). This study takes digital media designers in a cross-disciplinary course team as a case study. Through interviews, we found that the problems faced by digital media designers in learning engineering knowledge include:

1. Insufficient independent learning planning ability for cross-field course knowledge.

2. The course progress cannot fully learn the knowledge required for cross-field courses.

3. There is a lack of systematic organization of knowledge progress during class.

4. Insufficient learning time management ability.

To help the digital media designers in the team effectively learn basic engineering knowledge, we aim to design a learning tool based on time management assistance processes. This tool will quantify the necessary knowledge for interdisciplinary courses, allowing design students to use their fragmented time outside of coursework to learn engineering programming knowledge via their mobile phones. This approach will help reduce communication difficulties between design students and engineering students in interdisciplinary teams, enhancing creative ideation and team collaboration.

The learning process design incorporates design summary methods, and we will test it based on cues that trigger intrinsic motivation in participants. This will help confirm the effectiveness of the design process in keeping interdisciplinary team design students engaged during the learning period.



Figure 1. empathy games stage(Shih et al., 2023)

#### 2 LITERATURE REVIEW

#### 2.1 Interdisciplinary Learning

Interdisciplinary courses typically integrate students from at least two different academic disciplines to collaborate on projects. Common combinations include senior students (usually in their third year) from programming and design-related departments. While these students are often proficient in their respective fields, studies have found that design students tend to lack familiarity with engineering knowledge, particularly programming. This gap can hinder effective idea exchange with engineering experts (Chou et al., 2013). Therefore, it is inferred that designers should possess basic programming skills to facilitate communication in interdisciplinary collaborations.

Designers often summarize their design process through case retrieval, decision-making, operation, and results, and transition through cognition, imitation, experience, and variation(Liao & Chang, 2014). By integrating basic programming knowledge into this design logic, we can reduce learning costs and enhance communication between design and engineering students.

#### 2.2 Self-directed Learning

(Freeman et al., 2014) found that students engaged in active learning perform better in science, engineering, and mathematics compared to those in traditional educational settings, with lower failure rates. Self-directed learning requires triggering intrinsic motivation, which is believed to yield better results than extrinsic motivation as it inherently fulfills learning satisfaction without external rewards. Self-Determination Theory (SDT) identifies three needs: autonomy, competence, and relatedness (Ryan & Deci, 2000). (Yotsuya et al., 2020) discovered that motivational phrases boosting competence can enhance intrinsic motivation, though they must be tailored to individual differences.

For instance, (Hoffmann & Matysiak, 2022) study on individuals under 39 learning financial literacy revealed three groups:(1.) low current need for financial knowledge,(2.) desire to enjoy

the present;(3.) plans but no time for learning. The third group mirrors the challenge faced by interdisciplinary design students in learning engineering knowledge. While non-traditional learning methods (ex: gamification) can be effective for interdisciplinary knowledge acquisition, they still need to address the issue of limited time.

#### 2.3 Time Management

In addition to enhancing intrinsic motivation, the choice of educational medium significantly impacts the user experience for learners. Busy university students often use online learning methods to communicate with instructors through Learning Management Systems (LMS), allowing cross-regional learning without the constraints of time and place (Hamidi et al., 2020). Although this type of online learning effectively enhances learning experiences and teacher-student communication, the quality of online learning while doing, (2.) interactive experiences, and (3.) feedback (visual and auditory) (Lee et al., 2018). Despite emphasizing teacher-student interaction, the effectiveness of online learning in managing self-directed learning can be questionable. Additionally, considering the busy nature of modern society, learners often need to break down learning tasks. (Kaufman, 2014) proposed a method in "How to Learn Anything in 20 Hours," which breaks down the learning process into four parts: (1) Decompose the skill into smaller tasks. (2) Gather the necessary tools for learning. (3) Eliminate distractions. (4) Practice for at least 20 hours (frequent short sessions).

This approach highlights that effectively learning a skill involves breaking it down into manageable parts, determining the efficiency and depth of learning based on the degree of task decomposition. Combining this with (Liao & Chang, 2014) four design summary methods for learning engineering knowledge and aligning it with the learner's available time can potentially yield better learning outcomes.

#### 2.4 Summary of Literature Review

In summary, we have identified that communication difficulties in interdisciplinary student teams comprising design and engineering students stem from a lack of mutual understanding of each other's knowledge. To address this, we aim to integrate designers' design methods with the learning of programming knowledge in the engineering field. Designers' design thinking primarily involves four processes: retrieval, decision-making, operation, and results, supplemented by four transitions: cognition, imitation, experience, and change. Using this framework, we seek to incorporate engineering knowledge to facilitate self-directed digital programming learning for designers in interdisciplinary teams, with a focus on effective communication.

While self-directed learning is more attractive compared to traditional learning methods, we found that one of its main challenges is time management. Therefore, by adopting the "20 hours to learn anything" approach, which emphasizes short, frequent learning sessions, we attempt to address the issue of learning during fragmented time.

#### **3 RESEARCH METHODOLOGY**

#### 3.1 Experimental Plan

This study focuses on the 2023 interdisciplinary course themed "Smart Campus" under the project "Maker: Machine as an Inspiration." The subject of the project is the "Arduino Ultrasonic Module Robot Road Detector" (as shown in Figure. 2), with a research group comprising seven members. The evaluation targets Arduino-related technologies as the primary programming knowledge. Initially, in-depth interviews were conducted one-on-one basis with non-engineering students in the course group (4 males and 3 females). The interviews questions were mainly semi-structured interviews and allowed the interviewees to conduct open-ended questions and answers, and these questions and answers were integrated through situational research, aimed to identify communication challenges encountered during the team's conceptualization process from the course commencement to the end of the term. Through the interviews, we found that the main pain points of the interviewees during the course learning process include:

1. Insufficient planning for collecting necessary programming knowledge and learning methods for the final project proposal.

2. Excessive class time dedicated to imparting non-essential knowledge, resulting in limited time for programming study.

3. Lack of structured knowledge learning arrangement after the course ends.

4. Inability to effectively manage the completion deadline for the final product due to busy academic schedules, leading to increased pressure regarding the course.



Figure 2. Interdisciplinary Curriculum Team Concept Briefing

Based on these pain points and the reviews on online learning, we found that online learning can potentially solve the issues of acquiring knowledge and managing study time during the course. However, it lacks effective strategies for self-directed learning and time management after the course ends. Utilizing the collected student information and integrating methods from the literature to enhance designers' learning in engineering fields and time management, we have established the following requirements for the interactive design in this study: (1) Core Learning System: Use the four processes of retrieval, decision-making, operation, and results to reduce students' learning costs. (2) Fragmented Time Utilization: Segment the learning topics and prepare the necessary knowledge so that each self-study session is limited to 10 minutes. This approach maximizes the use of students' fragmented time, such as breaks and commuting

periods. (3) Time and Problem-Solving Records: Record the time spent on problem-solving and the topics covered to help learners discuss and summarize engineering programming knowledge effectively.

#### 3.2 Interactive Design System

Based on the above requirements, we first attempt to draft a flowchart, targeting mobile devices (for learning during fragmented time) and combining the necessary materials for interdisciplinary learning to create the system. This system aims to enhance the engineering knowledge required for design students in interdisciplinary courses.

Players will first input the subject they need to learn (such as engineering programming) and the expected completion date for their goal through the project interface. The system will then generate a serious game related to the learning goal. Users need to overcome challenges related to the selected field to progress within the system. These challenges may involve traditional question answering, practical simulations, or other forms of tasks. Through the prompts in the system interface allow users to know their current learning progress and knowledge acquisition status (as shown in Figure 3).



Figure 3. self-directed learning interactive system flow chart

The system is divided into four main interfaces: the project interface, the main interface, the challenge interface, and the project creation interface. The project interface is used to create current learning goals (as shown in Figure 4(a)), the main interface serves to view the current learning progress and access the challenge interface through buttons. Through the character status bar, users can see the number of questions answered in the current learning course and the current number of learning days (as shown in Figure 4(b),item 1), managing the learning content in a quantified manner.



Figure 4. (a) project creation interface; (b) main interface & challenge interface

The engineering knowledge requirements in the database should be designed to facilitate communication between designers and engineers in interdisciplinary courses. This will be accomplished by consulting with engineering personnel involved in interdisciplinary courses. Using the "Maker: Machine as an Inspiration" course as a template, the Arduino functionalities will be the basis for the conceptual phase of the course design (understanding Arduino applications for ideation). The subsequent implementation phase will focus on basic Arduino assembly knowledge.

The knowledge segmentation levels are designed to enable designers to initially conceptualize the potential outcomes of their final product during the ideation phase using functional applications. The grading of knowledge is determined based on the priority and complexity of the engineering knowledge required in the course after discussions with cross-disciplinary course staff. During the implementation phase, the focus shifts to providing the assembly knowledge necessary for the engineering team to complete the final product. The levels are divided as follows (as shown in Table 1): (1.) Beginner: Basic Arduino functionality,(2.)Intermediate: Advanced Arduino features and sensor implementation, (3.) Advanced: Arduino input principles and display usage. The learning content is categorized according to difficulty levels, and users are required to understand:(1.) Basic applications of Arduino, (2.) Correct assembly techniques.

	Arduino function application	Arduino assembly knowledge
Beginner	Microcomputer basic architecture and applications	Basic components (LED)
Intermediate	Bluetooth module and WIFI module application	Sensors (sensors, motors)
Advanced	Input principles and basic experiments	Display (LCD)

 Table 1. Arduino knowledge learning allocation

This study's design sets the target days at a maximum of 10, 20, or 30 days, with 1 to 3 tasks per stage to ensure that the proficiency in each type of knowledge increases according to the time spent.

Users are reminded daily to enter the challenge interface from the main interface and can click on the provided questions for that day (as shown in Figure 4(b), item 2). During problem-solving, the system uses a timer to time each challenge question (as shown in Figure 4(b), item 3). After completing the day's challenges, the system records errors and questions that took more than 2 minutes to solve, allowing students to review and reflect later. Engineering personnel in interdisciplinary courses collaborated to predefine the database used as the engineering knowledge base. We collaborated with the engineering staff of the interdisciplinary course in advance to discuss the learning content and expected outcomes of the course syllabus, and defined in advance the technical requirements for the database to be used as the engineering knowledge base (including Arduino assembly and functional applications).

The learning points of engineering knowledge were integrated into the commonly used "Electronics Toolkit" for non-professional Arduino users. The "Electronics Toolkit" allows learners to experiment with Arduino components in a virtual environment. First, learners understand Arduino functions through the course presentation of "Maker: Machine as an Inspiration" (as shown in Figure 5, item 1). Then, the system guides them to use the "Electronics Toolkit" to operate the function (as shown in Figure 5, item 2).



Figure 5. Engineering knowledge base guidance (taking Arduino as an example)

The questions are evenly divided according to the number of days set by the user, with reminders scheduled based on the user's time. Thus, the daily learning process is (1) retrieval: Review the relevant engineering knowledge points for the day (5 min). (2) decision-making: Use the diagram provided to generate creative ideas (2 min). (3) operation: Solve the provided challenge questions (2 min). (4) results: Record the results of the challenge questions and review later (1 min).

#### 4 RESULTS AND DISCUSSION

The experiment test was constrained by the interdisciplinary courses participated in by the interview subjects, with two third-grade students participating in the "Arduino Ultrasonic Module Robot Road Detector" as the subjects. Their usage time was recorded throughout the process. the test results were primarily judged based on the time spend whether the groups they participated in effectively achieved the course objectives. During the project creation stage, we required the subjects to choose Arduino programming as their subject and select a 30-day duration, setting the project name using a nickname to generate the game. The subjects spent approximately 20 seconds on setup. Next, the users switched to the main interface using the UI at the top and then proceeded to enter the day's challenge by clicking the clearly marked blue selectable challenge. They spent about 1 minute transitioning to the challenge interface and viewing the results. Each day, about 9 minutes were spent watching course presentations and using the "Electronics Toolkit." Thus, in the simulation test, each challenge took approximately 10 minutes, meeting the system design requirements for utilizing fragmented time.

Subsequent tracking of the team working on the "Arduino Ultrasonic Template Robot Road Detector" project (as shown in Figure 6) revealed that during the ideation stage, the system

helped designers solve issues with using Lego materials by switching to using Arduino smart cars for road detector mobility. This expanded the designers' range of ideas in the engineering field. In the implementation stage, the "Electronics Toolkit" assisted designers with Arduino connection methods and sensor assembly, providing methods for distance detection and pre-testing. This helped designers understand and troubleshoot data during implementation. Therefore, it can be inferred that the system design in this study effectively aids designers in interdisciplinary courses with ideation and implementation using Arduino.



Figure 6. Result of Arduino Ultrasonic Template Robot Road Detector

After completing the process, the subjects provided feedback. They suggested that the setup should have more precise learning objectives (e.g., goal-oriented product completion) to better determine the user's learning purpose. Additionally, they felt that the challenge operation process should be based on the mobile user's experience, with the design of subsequent challenges aiming to keep the duration within 4 minutes. This result confirms that the cross-regional learning model proposed by (Hamidi et al., 2020) combined with the learning methods proposed by (Kaufman, 2014) can effectively enhance designers' understanding of engineering fundamentals in interdisciplinary courses. Based on these results, future research should include increasing the number of subjects from interdisciplinary courses to improve the feasibility of the hypothesis and attempting to design systems for teaching courses in different fields to gain more comprehensive user feedback.

#### 5 CONCLUSION

This study attempts to drive self-directed learning among design students in interdisciplinary courses to acquire basic engineering knowledge, thereby facilitating communication with team engineers. Initially, we reviewed literature and interviewed students in interdisciplinary courses that primarily use Arduino as a manufacturing technology. We identified the learning difficulties and time management issues faced by design students, including insufficient resource collection and learning methods for engineering knowledge, and inadequate time for in-course and post-course learning. Although online learning methods can address cross-temporal teaching issues between teachers and students, they do not solve the challenges of self-directed learning.

To address this problem, we defined the learning of Arduino-related knowledge as a challenge faced by designers in interdisciplinary teams. Combining the commonly used summary methods of designers, we designed an interactive system based on (Kaufman, 2014) learning model. The system targets mobile devices, allowing users to select engineering subjects and expected learning durations through the project interface. The learning database integrates corresponding Arduino course presentations and uses the "Electronics Toolkit" for virtual scenarios. By limiting the daily challenge response time, the system encourages gradual knowledge acquisition through small, prolonged practice sessions. The daily learning process is designed following (Liao & Chang, 2014) retrieval, decision-making, operation, and results model to enhance the intrinsic motivation of students in interdisciplinary courses.

The experiment, tested with two students from the "Arduino Ultrasonic Template Robot Road Detector" team, showed that the daily operation time aligns with the defined fragmented time for students. The ideation and implementation challenges faced by the team could be addressed by the interactive design of this study, thus validating the experiment's effectiveness. This study uses the combination of Kansei Engineering and interactive design to study the emotional needs of cross-disciplinary team designers in learning engineering knowledge. For example, through interviews, we compiled designers' feelings when learning engineering knowledge as the basis for tool design. Through this method, we learned the role of the sentiment analysis method of Kansei Engineering in the design of learning tools.

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## SOCIAL EMOTION ITS INCREASING IMPORTANCE

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#### ABSTRACT

Until now, emotion has been discussed mainly in terms of the individual, and in a passive way. However, with the rapid changes in society and the expansion of our living space, it has become important to consider emotion from a broader perspective, from the individual to society. Although our perspective has broadened, our way of thinking remains as passive as ever. However, the original Latin word for emotion means to take action, and such active discussions have hardly taken place. Therefore, in this lecture, I will discuss how we can utilize emotion to create the next generation of society.

Keywords: Emotion, Active, Creative, Next Society...

#### 1 INTRODUCTION

"Social Emotion" is getting wide attention these days. Indeed, although "Emotion" has been discussed many times, most of them discuss personal emotion. "Social Emotion" points out that emotion should also be considered and discussed in much wider framework of society. I totally agree with this opinion. But the current discussion of "Social Emotion" is only paying attention to emotion in the current framework of society.

This paper proposes that we should further consider developing a new society by making the most of emotion. As the Industrial Society is getting close to its end and now we need to design and develop the next society. The Industrial Society was brought forth by the INdustrial Revolution, which is product-centric. So their productivy and performance were important. And as they are tangible, we could count them. We could apply quantitative and objective evaluation.

But the Industrial Society brought forth many issues, too. One of the important problems is excessive consumption of energy. We are running out of energy. We cannot sustain the society.

in the present framework of the Industrial Society. Today, such tools as ChatGPT, generative AI are expected to be solutions for these problems. But they use a lot of energy, too. Thus, unless we design and develop a completely different society, we cannot survive anymore.

Fig. 1 shows the change of soociety with time. The world 1.0 is the current Industrial Society and the world 2.0 is the next society. The world before the Industrial Society is world o,o.



Figure 1. Society change with time

What comes up as a promising solution is that we, humans, can think about the future. We can live for tomorrow. In fact, in the old days, we challenged to make our dreams come true. And "Emotion" played an important role for motivaing us to this challenge. We, humand, are different from person to person. Thus their ways of feeling are very much diverse.

This paper points out that the current Industrial Society is coming to its end. So, we must start to design and develop the next society. The Industrial Society has created many problems, such as decreasing labor force, excessive consumption of energy.

Although population is increasing in the developing countries, it is quickly decreasing due to decreasing childbirth in the developed countries. Therefore, the developed countries cannot sustain industry due to the lack of labor force. In the developing countries, there are enough number of labor force, these people lack literacy, so they cannot run the system.

More important issue is excessive consumption of energy. We are running out of energy source.

Therefore, we need to desgin and develop a next world in a completely different framework. This paper discusses how we can design and develop such a new society for the next generation and proposes an approach to achieve this goal.

#### 2 WHAT CHARACTERIZES HUMANS

we can think about the future. Animals live for now. They do their best to adapt to the current environment and situation. So, when they change, many animal species die out. But we look for emotional satisfaction, so we grow emotionally. Thus many human species survive. In short, we keep on with evolution.

We, humans, live for tomorrow. As Abraham Maslow pointed out (Maslow, 1943) we humans, try to satisfy our material needs, such as food and housing, for today just as animals do, but with time, we come to pursue mental satisfaction. i.e., emotion and finally we make our maximum efforts to satisfy our emotions. And we are different from person to person. Our body builds and the way of feeling vary individually. Yes. That is "Selfactuatization ". We would like to establish the world of "Self" (Fig. 2). Interestingly enough, the title of his paper in whiche he proposed this idea is "A Theory of Human Motivation". It truly indicates how emotion and motivation are closely related.



Figure 2. Maslow's human needs

As we pay our efforts to establish the world of "Self", the human species increase diversity. Therefore, even the outside world changes, and many animal species die out, many human species survive.

About 40 years later after Maslow, Edward Deci and Richard Ryan proposed "Self Determination Theory" (Deci and Ryan, 1985), in which they clarified that we get the maximum happiness and the feeling of achievement, when we do the job internally motivated and self-determined, and no external award can provide this level of happiness and the feeling of achievement.

Thus, the current Industrial Society certainly satisfies our material needs, but if cannot satisfy our metal needs. We are not emotionally happy in the current Indusctrial Society.

Deci and Ryan clarified another important point. Self-Determination is deeply associated with "Growth".

This brings us to realize that Maslow's human needs meant that humans would not be able to adapt to changes in the outside world if they continue to respond like animals. Thus, this leads us from satisfacion of material needs to spiritual growth

This brings us to realize that Maslow's human needs meant that humans would not be able to adapt to changes in the outside world if they continue to respond like animals. Thus, this leads us from satisfacion of material needs to spiritual growth.

#### 3 PERCEPTION-MOTIVATION-DECISION MAKING-ACTION-EMOTION (PMDAE) CYCLE

Fig. 3 shows how we pursue emotional satisfaction.



Figure 3. Perception-Motivation=Decision Making-Action-Emotion (PMDAE) Cycle
# 4 EMOTION AND MOTIVATION

We should remember that "Emotion" and "Motivation" come from the same Latin "Movere". And emotion means "e=ex+motion". Thus, emoton literally means to "move out". In short, it means that we go out into the outside world to establish our own world.

Up to now, we have been considering emotion on a personal basis. The emergence of "Social Emotion" changed the scene. But still wesee emotion as an outcome. However, if we consider its Latin origin, we realize that emotion motivates us to take action.

So what tools do we have? We are currently in an age of rapid changes and it is impossible to predict what will happen next. Until now, changes were smooth, so we could differentiate them and predict the future. However, now changes are so sharp that we cannot predict anymore.

So what do we do? Babies teach us. Babies learn to crawl, walk, and even speak without being taught by anyone. Babies are making the most of their innate talents. That's right. They are making the most of their instincts and becoming independent. Jean piage clarified thies process (Piaget).

# 5 EMOTION AND DECISION MAKING

Thus, emotion is deeply associated with decision making. When we think of decision making, we often think of knowledge. In fact, the term "intelligent person" is used to mean someone who has the ability to make good decision and intelligence is associated with the amount of knowledge. However, knowledge is a structure of each individual's own experiences and varies greatly from person to person.

In times of great change, what is important is not knowledge but wisdom. Wisdom is how the body responds when it comes into direct contact with the outside world

Fig. 4 compares humans and octopuses. Humans rely on knowldge. Knowledge is processed by brain. So, human intelligence is brain intelligence.

Octopuses, on the other hand, have large heads. But their brains are small and their capabilties are those of dogs. But octopuses directly interact with the outside world with their bodies, making the most of their eight arms. Thus, they are known as expert of escape. They can even escape from the screwed container. What we need now is wisdom. In short, it is body intelligence.



# **Evolution Tree**

Figure 4. Human and octopus

# **6 EMOTION AND SOCIETY**

Until now, we have perceived emotion passively. However, if we consider its Latin origin, it is easy to see that emotion means to move out, and rather it encourages positive decision-making as described above. Thus, "Emotion" started to be regarded in the broader perspective, i.e., "Society".

Up until now, computer processing has only paid attention to solving problems, i.e., how to solve them. However, for example, in business, the top priority is the strategy, that is, what to do. The goal, or its purpose, is important.

"Social Emotion" is rapidly gaining attention due to the recognition that it is important to consider emotion from a societal perspective in light of the drastic change in society and the rapid expansion of our living space.

The word "Society" also cmes from the Latin which means "comrade, friend ". In other words, it means to make friends. So, we have to consider how we can design and develop a society which increases friend-making opportunities.

When we hear the word "Society", the words " Culture" and "Civilization" come up. Interestingly enough, wherever we look at in the world, the seeds of a new culture are born in the first 20 years of each century, and then, they develop by about the middle of that century. Then they go on to create a civilization that will shape the culture of the next century.

Therefore, now is the time to create a new society, i.e., we should create a new "Culture" which will be changed to "Civlization" in the 22nd century.

"Emotion" plays a key role in driving such changes.

# 7 WHAT BABIES TEACH US

Then, how can we create such a new world of emotion? The world is changing rapidly. Tomorrow is becoming more and more unpredictable. But babies survive and grow in such environment and situation. The environments and situations vary from baby to baby. But they directly interact with their outside worlds and learn to crawl, walk and speak !

Jean Piaget (Piaget) made it clear that we learn how to cope with our outside world when we are babies. What they have nothing other than their "Instnct". They have an inborn capability, i.e., "Instinct" to grow in the unexperienced world. But they apply "Instinct" by trial and error. If we can develop an instinct support tool. We can develop "Social Emotion" in more effective way.

## 8 MAHALANOBIS DISTANCE-PATTERN(MDP) apptosch to support instinct

MDP is developed. To undertand it easily, let us take swimming as an example (Fig. 5).





Figure 5. MDP approach

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Mahalanobis Distance was developed to remove outliers in design of experiement [4], but if note that it is ordinal scale, we can prioritize our decisions. In the widely and rapidly changing world, we need to prioritize our strategy.

In swimming, water changes continuously. So, we cannot apply mathematical approaches. This is the same situation as in the outside world now. But if we put wearable sensors on the swimmer, we can produce such a table in Fig.5. Each row corresponds to each muscle at its location. And if calculate MD between time T1 and T2, we can obtain distance and divided this distance by this time span, we can get speed. And acceleration is obtained by dividing it again by this time span. Thus, this table shows the total movement of the swimmer's muscle. If MD is decreasing, it means that that muscle is moving in the desired way. If increasing, then we need to change its way of movement. Thus, we can improve our movement.

Pattern in this MDP approach is related to Fourier Transform (FT). When we observe in time spce, we cannot identify its characteristics. But if we shift to frequency domain. we can identify its characteristics. In fact, we succeeded in detecting emotion from face by introducing cartoom face model [5]. Even from a static cartoon image, we can identify the emotion of a character in a cartoon. Thus, by introducing FT, we can identify the characteristics of the movement in swimming. Thus, we can self-learn how to swim.

This approach is, therefore, applicable to a wide areas. Not only sports, but business, etc.

In fact, medical diagnosis is carrierd out based on flows. Blood flow, heart beat, etc. It may be described that we are making decision based on body emotion.

## 9 SUMMARY

Let me summrize by quoting Mark Twain:

20 years from now you will be more disappointed by the things you didn't do than by ones you did do. So throw off the bowlines. Sail away from the safe harbor. Catch the trade winds in your sails. Explore. Dream. Discover.

- MARK TWAIN

Let us explore, Dream and Discover the new world of "Social Emotion"

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# EXPLORING THE RELATIONSHIP BETWEEN GAZE PATTERNS AND IMAGE PREFERENCE USING EYE-TRACKING TECHNOLOGY

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# ABSTRACT

The idea of using physiological measurements for Kansei Engineering is attractive as it offers a non-subjective way to capture the perceptions of users, in contrast with the more common self-reporting tools. Eye-tracking technology has been used to assess the visual interest of a product, and sometimes this visual interest has been correlated with preference. In the present study twenty participants viewed pairs of images, and their gaze patterns were recorded using eye-tracking. Results showed that while initial gazes were mostly neutral, the last gaze often corresponded to the preferred image, but not always. Furthermore, it was not proved that the more an image is looked at, the more preferred it is. These findings suggest that while eye-tracking provides valuable insights, it may not fully replace self-reported methods for assessing product preference.

Keywords: Kansei Engineering, Eye-tracking, image preference, visual interest

# 1 INTRODUCTION. ROLE OF PHYSIOLOGICAL MEASUREMENTS IN KANSEI ENGINEERING

Kansei Engineering aims to quantify and understand user emotions conveyed by products. The most common way to achieve this is using questionnaires with Likert or semantic differential scales, where users self-report what they feel. Another alternative – but not so common – for self-reporting the users' perceptions is rating products with images instead of words (such as in the tool PrEmo¹).

Self-reporting the kansei has the huge advantage of being easy to do, and many studies have proved its value and utility. However, a difficulty that usually arises with measuring perceptions based on questionnaires is the fact that participants in the study necessarily "rationalize" their responses. It is obvious that we are not accessing the most primary, non-rational reactions, when we ask people to read and write.

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An alternative that appears as very attractive to overcome this difficulty is capturing some physiological response of the users when faced with a stimulus. The physiological response is something that the user cannot consciously control – or at least is much more difficult –, so apparently gives a more direct access to the primary reaction. There are several physiological measurements that can be used: electrodermal activity, EDA (captures if the person is sweeting), electromyography, EMG (captures muscle contraction), electroencephalogram, EEG (measures brain activity), eye-tracking (captures where and how long a person is looking) or facial expression recognition (able to extract key facial landmarks and assign emotions to them).

One of the problems of using physiological responses to capture emotions conveyed by products is that it requires more resources than simply using a questionnaire. Not only the measuring devices are expensive, but also the preparation and data processing can be time consuming. Another problem is that these devices tend to be invasive, and the uncomfortability of the participant in the study can affect the responses. However, there has been a revolution during the last years in terms of feasibility of capturing physiological responses. Many devices are no longer that expensive or intrusive. For instance, there are instruments for measuring EDA that send data to a mobile phone by Bluetooth that cost now a fraction of what the mobile phone costs. Eye-tracking and facial expression recognition work also very well with a simple webcam and appropriate software. This approachability in physiological measurement technology can explain, in part, the incredible increase in research using these methods in the last years².

So, the current accessibility of many physiological responses makes using them for emotion measurement very viable. But this does not solve one big problem that these kinds of measurements have: the difficulty of interpretation. If users give a high rating on the kansei word modern for a certain product, the interpretation is straightforward: that product is perceived as modern. If users sweat a little when faced with that same product, what is the meaning of that?

We will focus our study on eye-tracking technology. Eye-tracking technology has been widely used in various domains to gain insights into how individuals process visual information, with foundational studies² and more recent methodological overviews³. In general, it seems reasonable to consider that the more time a person looks at a particular area in an image, the more visual interest it generates. Sometimes, this first statement is taken a step further, assuming that visual interest is highly correlated with preference⁴: if a person looks at a product very long, this means that person likes the product. To what extent this is true? And if it is (more or less) true, is it true for everyone, or just for some people?

## 2 EXPERIMENTAL SETUP TO ANSWER SOME SIMPLE QUESTIONS

This study presents a modest research challenge: analyzing how people look at two images in the first seconds of being presented with, and trying to discover if people look more at images that they like the most.

## 2.1 What we want to discover

As stated before, the assumption that the more time a person looks at a particular area in an image, the more visual interest it generates, seems very reasonable. For this reason, many eye-tracking studies use fixation duration (the amount of time the eye remains on a specific point) as an indicator of interest.

The statement assumed by some studies that the more cumulative fixation time an image receives, the more preferred, is more debatable. If preference for a product correlates well with the amount of time a person looks at it, we could use this information coming from eye-tracking technology to discover preference only using a physiological, not subjective, measurement. We could then remove the need to use self-reporting questionnaires for assessing preference (the typical questionnaires where people have to rate an image in a Likert scale, from 1 to 7 or from 0 to 10, for instance).

Therefore, the primary research question we are interested in is the following: is there any relationship between gaze patterns and image preference? In particular, the main question is unfolded in these three specific questions, that will be answered using the collected data:

- Do people look at the picture they like the most first?
- Do people look longer at the picture they like the most?
- Is the last picture people look at the most preferred one?

# 2.2 Experimental setup

The idea behind the experiment is simple. We show two images, side by side, one on the left and the other on the right. The pairs of images have some relation; either the composition or the silhouette is similar, or the elements shown are comparable (animals, buildings, cities, ...). We have checked that saturation, brightness and contrast of both images are similar. Figure 1 shows one of these pairs of images. We call each one of the pairs of images a slide.

We use 8 slides in total. In each slide, there is a blank area between both images. This blank area in the middle is necessary because eye-tracking systems with a webcam have a precision error of around 15%: the empty space in the middle guarantees that the person is really looking at the image on the left or on the right.

The 8 slides are shown to 20 different participants (13 women, 7 men; ages between 19 and 35). Each participant is placed in front of a computer with a webcam. The webcam is used to register the eyes gaze, using the online platform realeye.io.



Figure 1. One of the slides shown in the experiment

# 2.3 Data collection process

Before the data collection starts, a calibration process is followed. For the calibration process, the user has to place the mouse and the eyes' gaze on a red dot on a gray background. The red dot changes its position several times. This is enough for the eye-tracking system to work correctly.

The data collection has two parts:

1. The visualization of the 8 slides, where the eye-tracking system is used. Each slide is displayed during 3 seconds. After the 3 seconds, a grey screen is shown during 5 seconds to rest the eye and prepare the participant for the next slide. The 8 slides are presented in random order for each one of the participants.

2. A questionnaire where the user is presented, again, with each one of the 8 slides. For each one of the slides, the user has to choose (with the mouse) which image is the preferred one. The 8 slides are, again, presented in random order.

Once the participant has received all the necessary explanations, the data collection process takes about 10 minutes. We can assume that there is no fatigue effect thanks to this short data collection period.

# 2.4 Collected data characteristics and preparation for analysis

The eye-tracking system collects data quite often (more or less every 30-70 ms), but not at regular intervals. For instance, the first half second of measurements for participant 1 when faced with the first slide were taken at 38 ms, 70 ms, 103 ms, 132 ms, 165 ms, 200 ms, 238 ms, 267 ms, 301 ms, 336 ms, 366 ms, 399 ms, 437 ms, 467 ms and 499 ms. In order to have the same number of observations for each participant, and to be able to compare their behavior, we have converted the time to regular intervals of 50 ms, doing a linear interpolation of the response. Therefore, we have 60 observations for each participant and slide. The response is a percentage, going from 0% (when the person looks at the pixel located in the most left position of the screen) and 100% (when the person looks at the pixel located in the most right position

of the screen). Only the horizontal position (left or right) of sight is recorded, not the vertical position (top or bottom). Table 1 shows the first observations for the first 6 participants, as an example.

t	P1	P2	P3	P4	P5	P6
50	54,8	62,7	77,4	67,6	49,8	60,4
100	58,7	51,8	82,0	62,4	47,0	59,9
150	60,3	44,2	76,8	28,9	47,5	57,2
200	54,9	50,5	59,3	64,3	45,2	47,2
250	56,5	41,0	65,7	58,7	46,0	48,6
300	52,7	46,4	63,9	64,1	48,6	53,9
350	57,1	35,3	66,5	48,2	38,1	47,1
400	49,8	29,0	67,6	54,6	20,9	35,6
450	52,2	40,0	52,0	58,0	22,2	30,8
500	57,0	39,3	50,4	47,3	21,5	38,4

**Table 1.** Table of data obtained from the eye-tracking experiment with x-position in percentageformat and interpolating the values to obtain 60 samples for all participants

When looking at each participant and slide, we get graphs such as those shown in Figures 2 and 3 (left). The horizontal axis has time (from 0 ms to 3000 ms), and the vertical axis has the location of the sight (from 0%, left, to 100% right). The graphs on the right of Figures 2 and 3 are heatmaps of the gaze.



Figure 2. Gaze pattern (left) and heatmap of gaze (right) for one slide and participant

Figure 2 shows a pattern of sight where the participant first looked at the center of the screen, later briefly looked at the image on the left (the image that he dislikes the most), and finally kept his sight on the image on the right (the image that he prefers).

Figure 3, on the contrary, shows a very different sight pattern. The participant basically alternates between the two images, staying about 0,3 or 0,4 seconds in each image.

There is a lot of variability in the gaze patterns among participants and slides, and making groups and characterizing them is an unattainable task. However, the most general pattern is looking alternatively at the image on the left and on the right, in a faster or slower manner.



Figure 3. Gaze pattern (left) and heatmap of gaze (right) for one slide and participant

# **3** ANALYSIS AND CONCLUSIONS

In this section, we will try to answer the three questions that we posed in Section 2.1. We will use both the data from the eye-tracking system and the questionnaire on image preferences to answer them.

### 3.1 Do people look at the picture they like the most first?

For answering this question, we take the position of the first gaze for each participant and slide, and draw the dotplot that we can see in Figure 4. Almost all first gazes (72%) go to the central part of the screen, meaning that the participant does not look at neither the image on the left nor the image on the right. This is quite understandable: when faced with a new slide, the person starts at a neutral central point, and later moves the sight to one image or the other. Even when the first gaze is on the image on the left or the right, it is close to the center (we do not have first gazes under 20% – far left – or over 80% - far right).



Figure 4. Position of the first gaze for each participant and slide

#### 3.2 Do people look longer at the picture they like the most?

This is one of the main research questions we want to answer: can we state that the more an image is prefered the more time the person looks at it? For each participant and slide, we accumulate the time the participant is looking at the most prefered image, and the time the

participant is looking at the least prefered image (remember we have 20 participants, and each participant is exposed to 8 slides). We do not take into account the time the participant is looking at the central part of the screen (neither image on the left nor image on the right).

Table 1 shows, for each participant (row) and each slide (column) which image (either A, left, or B, right) was the most looked and the most prefered. When the most looked image is also the most prefered, the background is green, when it is not, it is red.

	ľ	1	Ľ	2	l	3	ŀ	4	ļ	5	l	6	ľ	7	l	8
	most	prefe-														
	looked	rence														
P1	В	В	Α	Α	В	В	Α	Α	В	Α	Α	Α	Α	Α	Α	Α
P2	В	В	Α	Α	В	В	Α	В	В	Α	В	В	Α	Α	Α	Α
P3	В	В	В	А	В	А	Α	Α	В	А	Α	А	В	А	Α	Α
P4	В	В	В	А	В	В	В	В	В	А	В	В	В	В	В	Α
P5	Α	В	В	Α	Α	В	Α	Α	Α	Α	Α	Α	В	В	Α	В
P6	Α	В	В	Α	Α	В	Α	В	В	Α	В	Α	Α	Α	В	Α
P7	Α	В	Α	Α	Α	В	Α	В	Α	Α	Α	Α	В	Α	Α	Α
<b>P8</b>	Α	В	В	А	В	В	В	В	В	А	Α	Α	В	В	В	Α
P9	В	В	Α	Α	В	В	В	В	В	Α	В	А	Α	В	Α	Α
P10	В	В	В	А	В	В	В	Α	В	В	В	Α	Α	В	В	Α
P11	Α	В	Α	Α	А	В	Α	В	Α	Α	Α	Α	Α	Α	В	В
P12	Α	В	Α	Α	В	В	В	Α	Α	Α	Α	Α	Α	Α	Α	В
P13	Α	В	Α	Α	В	В	Α	Α	Α	Α	Α	Α	В	Α	Α	Α
P14	В	В	В	А	В	В	Α	Α	В	В	В	В	Α	А	В	Α
P15	Α	Α	Α	Α	В	В	В	В	Α	Α	В	Α	Α	Α	В	Α
P16	В	В	В	Α	Α	В	Α	В	Α	Α	В	В	Α	Α	Α	Α
P17	Α	В	В	Α	В	В	В	В	В	В	Α	В	Α	Α	Α	А
P18	В	В	Α	Α	В	В	Α	Α	В	Α	Α	Α	Α	Α	В	Α
P19	В	В	Α	А	В	В	В	В	Α	А	В	В	Α	Α	Α	А
P20	А	В	А	А	В	В	В	В	Α	А	Α	А	Α	В	В	В

 Table 1. Summary of the most looked at and the most preferred images for each participant

Table 2 shows the percentage of times the most looked image is also the most preferred one. Although the figures are above 50% for all slides, the 95% confidence intervals for the proportion (shown in the last column) almost always include 50%. Therefore, we cannot state that the most preferred image is also the most looked.

Slide	most looked = most preferred				
1	55%	[32% – 77%]			
2	55%	[32% – 77%]			
3	70%	[46% – 88%]			
4	65%	[41% – 85%]			
5	60%	[36% – 81%]			
6	75%	[51% – 91%]			
7	72%	[46% – 88%]			
8	53%	[27% – 73%]			

**Table 2.** Proportion of times a participant looks more the most preferred image (the interval in<br/>brackets is a 95% confidence interval)

## 3.3 Is the last picture people look at the most preferred one?

For answering this question, we do exactly the same as for the first question, but taking the data of the last gaze (Figure 5). In the first gaze, 72% were looking at the center. The situation is now very different with the last gaze: only 11% of participants are looking at the center, the majority of participants (89%) are looking at one of the two images.



Figure 5. Position of the first gaze for each participant and slide

Table 3 shows the percentage of times the most preferred image is the one looked at in the last gaze.

Slide	Number of times	Proportion
Most preferred	80	50,0 %
Least preferred	60	38,8 %
Center (no image)	18	11,2 %

Table 1. Proportion of times each image is looked at

A formal hypothesis test to compare the proportion between most preferred and least preferred images gives a p-value of 0,042 (computed with Minitab statistical software), meaning that we can state, with the usual significance level of 5%, that there are significant differences between these two proportions.

Therefore, it is more common that the last image a person looks at is the one he or she prefers.

# **4** SOME FINAL THOUGHTS

The gaze pattern of participants, captured using eye-tracking technology, is very different depending on the participant and the images shown. However, we discovered, based on data collected with our experiment, the following:

• The first gaze is usually to a neutral area. We cannot state that the more an image is liked, the more it is looked at (although the pattern seems to go in this direction).

• Most times, the last image the participant looks at is the preferred image. But we cannot use this statement to infer that the last image looked at is always the most preferred image, as 39% of the time the opposite happens.

More studies could be done to delve deeper into the relationship between gaze patterns and preferences. One limitation of our study was that each slide was only shown during 3 seconds. Perhaps this amount of time is too low: the experiment could be repeated with longer time expositions.

In any case, the results from our experiment show that more time looking at an image does not imply preference.

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# TACIT KNOWLEDGE AND CREATIVE ELEMENTS IN DISPLAY DESIGN

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# ABSTRACT

This study aims to explore the relationship between tacit knowledge and creative elements in product display design. Product display is a core component of commercial design, carrying significant sales strategies and trend information. In common sales spaces, product displays often use various forms and atmospheres to attract consumers, influencing their purchasing motivations and affective imagery. However, some professional knowledge in this field remains tacit, primarily residing in the minds of experienced designers and practitioners. Decoding this tacit knowledge related to product displays would greatly benefit relevant design personnel and the educational field.

This study attempts to analyze experts' key perspectives on the generation of creativity in product display design. Semi-structured interviews were conducted with industry and academic design experts, and cases related to product displays were collected by experts as the basis for extracting key elements of product display design. Additionally, grounded theory was employed for coding, and MAXQDA 2022 was used to visualize the coding results, providing a more direct understanding of the relationship between experts' tacit knowledge and creative elements.

The research results show that experts from different backgrounds have varying views on the key elements in product display design that evoke consumer affective responses. The overlapping concepts clarified the creative elements generally focused on by the experts. Overall, the study results indicate that brand image, visual effects, atmosphere creation, and display design play significant roles in enhancing consumers' emotional responses. Specifically, elements such as sustainability, layered presentation, material application, contextual style, and orderly display frequently appeared in the experts' descriptions, indicating their importance in practical design processes. These findings provide a theoretical foundation and practical guidance for the evaluation and application of product display design, helping designers better understand and apply tacit knowledge to create more innovative display solutions.

Keywords: tacit knowledge, creative elements, product display design, kansei image

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#### 1. INTRODUCTION

#### 1.1 Research Background

The relationship between tacit knowledge and creative elements has become a research focus. Tacit knowledge, accumulated by designers through experience and intuition, is difficult to express explicitly but is crucial for creative design. Nonaka and Takeuchi (1995) proposed the Knowledge Creation Theory, stating that tacit knowledge can be transformed into explicit knowledge through interaction and practice, a process called externalization. During the creative design process, designers can convert tacit knowledge into specific design solutions through interaction and sharing with team members, thereby enhancing the innovation and effectiveness of the design.

In product display design, designers interact with other designers, clients, and audiences to gather feedback and inspiration. These experiences promote the flow and accumulation of tacit knowledge, transforming it into design experience, improving design efficiency and innovation. This study focuses on the experiences of industry designers and academic design teachers in evaluating creativity in product displays, aiming to identify the key creative factors in product display design that attract more consumer attention and explore the Kansei factors influencing consumer perception. Sanders and Stappers (2018) emphasized that the flow and sharing of tacit knowledge during the co-creation design process are of great significance for innovation. Patitad, Suto, and Yokoi (2014) proposed modeling tacit knowledge using Bayesian networks by analyzing expert-designed webpages to extract tacit knowledge and apply it to design support systems, helping to improve novice designers' abilities.

This study uses expert interviews as the main investigation method, with image cases collected by experts according to the research-set tasks. Research by Lee, Harada, & Stappers (2002) showed that designers could more effectively convey feelings and concepts, stimulate inspiration, and meet client needs when using image collages. Additionally, Sakay Rodriguez, Masuko, & Yamanaka (2021) emphasized that the characteristics of images play a crucial role in eliciting different levels of impressions from viewers, highlighting the importance of visual tools in the design process. Brown (2009) further emphasized that visual tools in design thinking can promote creativity and organizational innovation. Understanding and utilizing appropriate visual media can inspire more creativity and analyze the context of design during the design conception phase.

Therefore, in this study, during expert interviews, image cases collected by experts were used as media to stimulate inspiration. By extracting the implicit knowledge constructs from expert experiences, the study aims to identify elements that enhance the creativity and practicality of display design.

# 1.2 Research Problems

This study aims to explore the characteristics and key elements of highly creative product display designs. By analyzing verbal data obtained from expert interviews, this research seeks to identify which elements in display design can evoke Kansei responses from consumers, as well

as to understand how design experts evaluate these creative elements. The core questions of this study include:

• How do design experts evaluate the creative elements in display design?

• Which elements in product display design can evoke Kansei responses from consumers?

# 2. METHOD

# 2.1 Expert Interviews

This study used expert interviews to investigate tacit knowledge and creative elements in product display design. The interviews focused on "Elements and Applications of High Creativity in Product Display Design," with experts collecting 10-15 image cases related to the theme, including past projects or brainstorming aids. To ensure independent opinions, six product display design experts were individually interviewed. After experts described each design case, researchers guided the conversation to obtain deeper insights.

Interview durations were adjusted based on the number of images collected and the depth of descriptions. With the experts' consent, interviews were recorded and transcribed for subsequent analysis and coding. The experts, including three industry designers and three academic design teachers, all have extensive practical and instructional experience in product display design. Expert background information is presented in Table 1.

Expert	Gender	Position & Experience (Years)	Specialty Areas	Cases
DE-01	Male	Senior Visual Designer for 10 years	Brand Consulting, Brand Design, Visual Display Design	13
DE-02	Female	Secretary-General of the Design Development Association for 8 years	Visual Display Design, Exhibition Event Planning	13
DE-03	Male	Senior Visual Designer for 11 years	Visual Display Design, Exhibition Planning	10
TE-01	Male	Assistant Professor, Visual Communication Design Department for 18 years	Visual Display Design, Creative Design, Brand Design	15
TE-02	Female	Associate Professor, Visual Communication Design Department for 19 years	Brand Design, Corporate Identity System, Packaging Design	13
TE-03	Male	Assistant Professor, Fashion Design Department for 16 years	Product Design, Fashion Design, Thematic Exhibition	14

# Table 1. Expert Background Information

# 2.2 Coding of Expert Verbal Data

This study employs the coding method of grounded theory to analyze the verbatim transcripts of expert interviews, following the coding paradigm of Strauss and Corbin (1990).

Firstly, open coding is conducted to extract key creative elements and tacit knowledge from the experts' descriptions. Next, axial coding is used to classify and organize these key concepts, aiming to analyze the internal relationships and structures within the interview data from the six experts. Finally, selective coding is employed to construct a theoretical model of tacit knowledge and creative elements in product display design.

During the coding process, MAXQDA Analytics Pro is used to ensure the accuracy and consistency of the coding results. The final coding results are utilized to analyze the experts' judgments and explanations of product display design. This approach not only allows for an understanding of the insights of the six experts but also facilitates a comparison of the perspectives of industry and academic experts, identifying their intersections and differences. Based on these findings, the study provides reference suggestions for design practice and educational content.

## 3. RESULT

#### 3.1 Expert Analysis

## 3.1.1 Analysis of Creative Elements by Design Experts

When analyzing the creative elements in product display design as perceived by industry experts, several prominent features and key elements were identified, as shown in Figure 1. The study found a high level of consistency in the experts' emphasis on material application, situational style, and associative qualities.

The frequent mention of material application (36 times) indicates its effectiveness in creating diverse display atmospheres and enhancing consumers' Kansei responses. Furthermore, situational style (32 times) and associative qualities (26 times) are considered crucial for sparking creativity and strengthening the connection between the display and consumers. These findings are closely related to the practical demands and experiences of industry experts, focusing primarily on how material selection and situational design can evoke emotional resonance in consumers.

#### 3.1.2 Analysis of Creative Elements by Teaching Experts

In the analysis of creative elements by teaching experts, Figure 2 reveals a greater focus on functional emphasis (19 times), color application (18 times), and resonance (13 times). Teaching experts frequently discussed functional emphasis, often mentioning its importance in educational applications and guidance for students. As such, they regard the functional aspects as playing a critical role in display design, effectively conveying product information and enhancing the practicality and functionality of the display.

Moreover, color application and resonance are also highlighted as key elements that enhance attractiveness and emotional connection. These findings reflect the priorities of teaching experts in theoretical research and educational practice, especially how visual techniques, such as the combination of color and functional design, can improve display effectiveness. Teaching experts tend to emphasize the rational and practical aspects of display design, which are



common topics in both education and design practice research.

Figure 1. Analysis of Creative Elements by Design Experts



Figure 2. Analysis of Creative Elements by Teaching Experts

# 3.1.3 Intersection of Creative Elements Between Designers and Design Experts

Through the separate analyses of industry and teaching experts, Figure 3 elucidates the perspectives of both groups on creative elements, highlighting their similarities and differences. The intersection of opinions on creative elements between designers and design experts can be observed in Figure 3, which shows significant overlaps in material application (51 times), situational style (45 times), and functional emphasis (37 times). This indicates the universal importance of these elements in display design.

However, teaching experts show a higher focus on resonance and color application compared

to industry experts, who place greater emphasis on situational style and associative qualities. This divergence underscores the different priorities between the two groups, with teaching experts leaning towards theoretical and educational aspects, while industry experts prioritize practical and experiential components.



Figure 3. Intersection of Creative Elements Between Designers and Design Experts

These intersections and differences in design concepts reflect the varying priorities of industry and teaching experts in practical applications and theoretical research. Industry experts tend to emphasize concrete applications in practical operations, while teaching experts focus more on theoretical exploration and functional presentation. The analysis of these experts' tacit knowledge provides valuable insights for the practice and education of future product display design.

## 3.2 Kansei Reactions in Product Display Design

#### 3.2.1 Trends in the Distribution of Key Factors in Product Display Design

To understand the experts' opinions on the key factors in product display design, as shown in Figure 1, this study uses a coded list structure to present the importance and relative significance trends of each creative element as emphasized by the experts. Each element is explained individually to elucidate the reasons behind its significance.



Figure 4. Expert Code Distribution of Key Factors in Product Display Design

#### Brand Image

The integration of nature and sustainability (such as natural elements and eco-friendly design) is highlighted as key components, reflecting a shift in design trends towards environmental awareness and sustainability issues influencing design practices. Market positioning and image shaping illustrate the core strategic aspects of display design, emphasizing the close relationship between product display, brand image, and consumer perception.

#### Kansei Response

Kansei response describes the overall emotional and cognitive reactions of consumers to product display design, distinguishing between sensory and rational reactions. Consumer experiences are a combination of both. For instance, sensory reactions are elicited by visual and atmospheric elements of the display (such as colors, textures, and lighting), evoking feelings of comfort, excitement, or curiosity, directly affecting the emotional connection between the consumer and the product. Rational reactions involve the cognitive processing of information conveyed through the display design, emphasizing product functionality, practicality, and brand value, thereby aiding consumers in making more informed purchasing decisions.

## Visual Effects

Color usage, minimalist aesthetics, focal points, and transparency are considered crucial factors for enhancing visual appeal and focusing consumer attention. These elements are essential in creating a visually stimulating environment that can strengthen the consumer's impression.

#### Atmosphere Creation

The application of materials, sensory aids, and environmental styles not only shapes an immersive atmosphere but also enhances the overall shopping experience. A well-crafted consumer atmosphere is vital in creating a comfortable and inviting environment, significantly

enhancing the affective aspect of the consumer experience.

# Display Design

Orderly presentation, interactive methods, element application, and visual creativity are core to effective product display design. These components encompass the functionality, arrangement, and visual aesthetics of the display. The distribution of expert codes highlights the multifaceted nature of product display design, indicating that balancing visual appeal, functionality, and consumer attributes is essential for achieving optimal display effectiveness.

# 3.2.2 Comparative Overview of Expert Verbal Coding

The verbal coding descriptions from experts, after analysis, reveal the distribution trends of key elements. Visual representation allows for a clear comparison of the perspectives of experts within the same group and across different groups. In Table 2, the trends in opinions on key display elements are illustrated for brand image (yellow), Kansei response (purple), visual effects (green), atmosphere creation (red), and display design (blue).





#### 4. DISCUSSION

#### 4.1 Application and Impact of Creative Elements in Product Display Design

Our in-depth analysis of creative elements in product display design reveals that these elements enhance product visual appeal and strengthen consumer emotional resonance, aligning with Nonaka and Takeuchi's (1995) Knowledge Creation Theory. Both industry and academic experts emphasize material application, situational style, and color usage as crucial elements.

Industry experts focus on practical applications, such as material selection and environment creation, to attract consumer attention and improve display effectiveness. Academic experts highlight the functionality and theoretical aspects, particularly in color application and display functionality, believing these elements effectively convey product information and enhance the shopping experience. These findings support Sanders and Stappers' (2018) argument on the flow of tacit knowledge in co-creation design.

The results suggest that the effective application of creative elements can enhance the innovativeness and practicality of display design, fostering superior design solutions in practical projects. Designers should comprehensively consider and flexibly apply these creative elements to achieve optimal results.

#### 4.2 Relationship Between Expert Evaluations and Consumer Kansei Responses

This study also reveals the relationship between design experts' evaluations of creative elements and consumers' Kansei responses. Industry and academic experts reached a consensus on several key factors, particularly in material application and situational style, which are considered the main drivers of consumers' Kansei responses.

Industry experts point out that the choice and use of materials can significantly impact the effectiveness of displays and directly influence consumers' emotional responses. They emphasize that through innovative material applications, designers can create visually impactful and emotionally resonant display designs. For instance, DE-01 expert mentioned in the [Highlight Characteristics] case, "*Nowadays, people really like to create a significant contrast between product materials and display materials*," and in the [Energy] case, "*The sense of energy is gathering, so I think the overall atmosphere, I feel it is created by the use of materials and colors, resulting in a sense of energy.*" Similarly, DE-02 expert discussed material application in the [Wabi-sabi Style] case, "*I think it is mainly because the wall surface is very plain, and the wood is not complete; it is a bit imperfect, but together, it looks good, with a sense of Zen and beauty.*" DE-03 expert also highlighted the use of tactile materials in exhibitions in the [Memory of Touch] case, "*More and more exhibitions allow you to touch the products, to feel what they want to present. I think adding touch enhances memory.*"

Academic experts emphasize that functional design and color application are important factors in eliciting consumers' Kansei responses. They believe that through appropriate color coordination and functional design, the overall quality of display design can be improved, enhancing the consumer shopping experience. For example, TE-01 expert mentioned in the

[Nature] case, "*He doesn't add many colors. Even if there are colors, they are like light pastel paintings, or what we call ink wash paintings made with a brush.*" TE-02 expert explained the concept of color matching in packaging design in the [Pure and Focused] case, "*I think, when some people use colors or adjust Kansei responses, they must measure the concept of contrast. So, to create focus, like the white color just now gives an overall impression.*" TE-03 expert mentioned the atmosphere of the display space for 3C products in the [Clean, Tidy, Clear, and Transparent] case, "*Our visual style is always as plain as possible, focusing on functional display.*"

Overall, the evaluations of creative elements by design experts provide valuable insights that help designers better understand and apply these elements in practice, enhancing the effectiveness of product display design and consumers' Kansei responses. Future research and practice should continue to explore the application of these creative elements in different contexts and further validate their impact on consumer behavior.

## 5. CONCLUSION

The research results indicate that creative elements play a crucial role in product display design. The evaluations of these elements by industry and academic experts provide valuable insights that help designers better understand and apply these elements to enhance the effectiveness of product display design and consumers' Kansei responses. Future research and practical work should continue to explore the application of these creative elements in different contexts and further validate their impact on consumers. Overall, this study not only deepens our understanding of creative elements in product display design but also provides practical guidelines for designers, ensuring that they can create innovative and attractive display designs, thereby enhancing brand image and consumer experience.

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# A STUDY ON REPRODUCING AND CREATING EMOTIONAL EXPRESSIONS IN ART USING GENERATIVE ARTIFICIAL INTELLIGENCE

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## ABSTRACT

This study explores how Generative Artificial Intelligence (Generative AI) technology can be used to assist traditional artists in recreating and creating emotional expressions from their artistic process. The research involved three traditional artists (oil painting, ink painting, and fashion design sketch) participating in experiments through interviews, Generative AI dynamic image generation, independent artist creation, and quantitative evaluation. Results show that Generative AI-generated dynamic images significantly improved in emotional intensity, visual appeal, and innovativeness, especially in ink painting and hand-drawn works. Artists generally demonstrated high acceptance of Generative AI tools, believing that dynamic images could more completely express creative emotions. The study also found that Generative AI technology has advantages in presenting natural dynamics and material textures. This research opens up new possibilities for integrating traditional art with digital technology, while providing valuable insights into the future application of Generative AI in artistic creation.

*Keywords:* Generative AI, Emotional Expression, Traditional Art, Dynamic Imagery, Artistic Innovation

# **1** INTRODUCTION

Traditional artists (such as oil painters, water-color painters) typically experience rich emotions during the creative process and express these emotions in static artworks. With the rapid development of generative artificial intelligence (Generative AI) technology, artists face new opportunities to transform the emotions from their creative process into dynamic expressions. This paper aims to explore how to use Generative AI to help traditional artists recreate and create the emotions in their creative process, achieving the integration of traditional art and digital technology.

The emotional experience in the artistic creation process has always been a focus of researchers. Botella et al. (2013) delved into artists' creative processes, revealing the central position of emotions in artistic creation. Gabler (2023) pointed out that artists can express emotions through self-reflection, choosing appropriate media, and color psychology techniques. Reyner (2023) emphasized the role of color layering, edge processing, and detail reduction in

enhancing emotional expression in paintings. Furthermore, Silvia's (2005) study deeply explored audiences' emotional responses to art, providing important insights into understanding how art evokes emotions.

Research by Psychology Today further confirmed that colors are more effective than lines in conveying emotions, and audiences can intuitively understand the emotional content in abstract art. Famous paintings like Picasso's "The Weeping Woman" demonstrate how to express profound emotions through artwork.

In addition to emotional expression in static paintings, time and dynamic elements also play important roles in emotional expression. Animation technology can introduce time elements into artistic creation, making emotional expression richer and more three-dimensional. Jansen & Canter's (2020) research explored the use of time elements in visual art, providing empirical support for dynamic representation enhancing emotional expression. Factors such as environmental design, light and shadow processing, rhythm, and music in animation can significantly enhance the expressive effect of emotions. For example, using color, light and shadow, and speed in animation can create stronger emotional responses (Buchanan, 2023; Chen & Ibrahim, 2023).

Generally, digital technology is often considered unable to effectively express emotions. However, Paul's (2015) work "Digital Art" comprehensively introduced how digital technology changes the way art is created and appreciated, providing a new perspective for emotional expression in digital art. Through artists' creative presentation methods, these technologies can recreate the emotional or mood expression of original paintings. Elgammal et al.'s (2017) research explored how to use Generative Adversarial Networks (GANs) to create art, demonstrating the enormous potential of AI in artistic creation. Lee et al. (2023) further pointed out that AI-generated artworks can evoke viewers' emotional responses and provide new creative inspiration for artists. This human-machine collaboration model opens up new possibilities for artistic creation, embodying the deep integration of technology and humanities. However, the acceptance and evaluation of AI-generated art remain issues worth discussing. Hong & Curran's (2019) research explored people's attitudes towards AI-generated art, providing important references for understanding the social acceptance of AI art. Pelowski et al.'s (2016) latest psychological model of how audiences experience and respond to art also provides a theoretical framework for analyzing audience reactions to AI-generated art.

Affective Computing is a field that studies how computational systems can understand and express human emotions. Picard (1997) proposed in "Affective Computing" that affective computing can enhance the naturalness and effectiveness of human-computer interaction and be applied in multiple fields (such as education, healthcare, entertainment). This concept laid the theoretical foundation for AI's emotional expression in artistic creation.

# 2 RESEARCH PROBLEM AND OBJECTIVE

With the rapid development of Generative Artificial Intelligence (Generative AI) technology, traditional artists are facing new opportunities to transform the rich emotions from their

creative process into dynamic expressions. This study aims to explore how Generative AI technology can assist traditional artists in recreating and creating emotional expressions from their artistic process, as well as the impact of this new technology on art creation and appreciation. By combining traditional art and digital technology, we hope to open up new dimensions of artistic expression while evaluating the application prospects of Generative AI in artistic creation.

Research Problems:

1. How can Generative AI technology be utilized to assist traditional artists in recreating and creating emotional expressions from their artistic creative process?

2. What are the differences in emotional expression between Generative AI-generated dynamic images and original static works?

3. What is the level of acceptance among traditional artists for using Generative AI tools in their creative process?

 How does the application effect of Generative AI technology differ across various art forms (such as oil painting, ink painting, and fashion design sketches)?
 Research Objectives:

1. Explore the potential of Generative AI technology in recreating and enhancing emotional expression in artworks.

2. Evaluate the performance of Generative AI-generated dynamic images in terms of emotional intensity, visual appeal, innovativeness, and overall effect.

3. Analyze the characteristics and differences in applying Generative AI technology to different art forms (oil painting, ink painting, fashion design sketches).

4. Investigate the feasibility and future development directions of integrating traditional art with digital technology.

5. Assess the acceptance and responses of artists and audiences towards Generative AI-generated works.

6. Provide empirical evidence and recommendations for the application of Generative AI technology in artistic creation.

# **3** RESEARCH METHODS

This study employs a mixed-method approach, combining qualitative interviews and quantitative assessments. Three artists (an oil painter, an ink painter, and a fashion design sketch artist) were selected based on their expertise and willingness to apply AI in their creative process. This selection reflects the challenge of finding artists open to AI integration, potentially biasing the sample but allowing for an in-depth exploration of AI's impact across different art forms

This study adopted an experimental method, inviting three traditional artists (an oil painter, an ink painter, and a fashion design sketch artist) to participate in the test. The specific steps are as follows:

•Initial Interview: Interview the three artists to explore their emotional experiences and emotional expressions during the creative process. Interview questions include but are not limited to their emotional changes during the creative process, the techniques and media used, and their initial views on Generative AI.

•Generative AI Dynamic Image Generation: Use natural language to describe the artists' emotions during creation, and generate corresponding dynamic images through Generative AI tools. The description content needs to be detailed, including the intensity, duration, and specific manifestations of emotions.

•Artist Independent Creation: Teach artists to use Generative AI tools, allowing them to generate dynamic images reflecting their creative emotions independently. During this process, artists need to record their user experiences and difficulties encountered for subsequent analysis.

•Second Interview: Interview the artists again to understand their views and experiences on recreating creative emotions through Generative AI. The interview content includes their satisfaction with Generative AI-generated works, differences from original works, and outlook for future applications.

•Quantitative Evaluation: Design a rating scale and invite 20 participants (including 3 original authors) to rate the original static works and Generative AI-generated dynamic images. Rating dimensions include emotional intensity, visual appeal, innovativeness, and overall effect, with a rating range of 1-10 points.

### 4 RESEARCH ANALYSIS

This study uses a self-designed Likert scale for evaluation, ranging from 1 to 10 points. The scale design is based on key dimensions of art evaluation from existing literature and has been adjusted through pre-testing. The evaluation dimensions include emotional intensity, visual appeal, innovativeness, and overall effect

This study collected evaluations from 20 participants (including 3 original authors) on three types of artworks (oil painting - Wind Lion God, ink painting - landscape, hand-drawn - fashion) in their static original and Generative AI-generated dynamic versions (Figure 1) through questionnaires. The evaluation dimensions include emotional intensity, visual appeal, innovativeness, and overall effect.



Figure 1. Three types of artworks (left-original; right-Generative AI-generated)

## 4.1 Questionnaires Analysis

This study compared the ratings of static originals and dynamic versions generated by generative AI for three different art forms (oil painting, ink painting, and fashion design sketches). The rating dimensions include emotional intensity, visual appeal, innovativeness, and overall effect, using a 1-10 point Likert scale. The following will present the rating results for each art form and provide a brief analysis.

## 4.1.1 Descriptive Statistics for Each Work

Tables 1-3 present the rating statistics for each artwork type. Across all three forms, the dynamic AI-generated versions generally received higher ratings than their static counterparts, with the most significant improvements observed in innovativeness and visual appeal.

a) Wind Lion God (Oil Painting):

Dimension	Mean (Static)	Mean (Dynamic)	Std Dev (Static)	Std Dev (Dynamic)
<b>Emotional Intensity</b>	6.90	7.30	1.71	1.78
Visual Appeal	7.35	7.65	1.93	1.84
Innovation	5.45	6.95	1.88	1.99
Overall Effect	6.95	7.55	1.70	1.70

**Table 1.** Rating Statistics for Wind Lion God (Oil Painting) in Static and Dynamic Versions

## b) Landscape (Ink painting):

Table 2. Rating Statistics for	Landscape (Ink Painting)	in Static and Dynamic Versions
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Dimension	Mean (Static)	Mean (Dynamic)	Std Dev (Static)	Std Dev (Dynamic)
Emotional Intensity	5.25	6.45	1.89	1.73
Visual Appeal	5.35	6.85	1.76	1.76
Innovation	4.65	6.55	1.87	1.79
Overall Effect	5.50	6.85	1.61	1.66

#### c) Clothing (Fashion Sketch):

Table 3. Rating Statistics for Clothing (Fashion Sketch) in Static and Dynamic Versions

Dimension	Mean (Static)	Mean (Dynamic)	Std Dev (Static)	Std Dev (Dynamic)
<b>Emotional Intensity</b>	4.80	5.85	1.77	1.90
Visual Appeal	4.65	5.95	1.81	2.04
Innovation	4.45	6.05	1.79	2.14

<b>Overall Effect</b>	4.90	6.10	1.71	1.94
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The rating results for these three art forms provide us with a rich data foundation, enabling us to conduct an in-depth analysis of the effects and potential of generative AI technology in different artistic fields. The following sections will provide a more detailed statistical analysis and discussion of these data.

## 4.1.2 Paired Sample T-Test Results

	Oil Painting	Ink Painting	Sketch
Emotional Intensity	t = -1.477	t = -3.559	t = -3.559
Emotional Intensity	p = 0.156	p = 0.002**	p = 0.002**
Viewal Anneal	t = -1.455	t = -4.583	t = -4.359
visual Appeal	p = 0.162	p < 0.001***	p < 0.001***
Innovation	t = -4.583	t = -5.745	t = -4.796
innovation	p < 0.001***	p < 0.001***	p < 0.001***
Overall Effect	t = -2.667	t = -4.359	t = -4.123
	p = 0.015*	p < 0.001***	p = 0.001**

Table 4. Paired Sample T-	Test Results for Static ar	nd Dynamic Versions of	Various Artworks
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#### *Note:* * *p* < 0.05, ** *p* < 0.01, *** *p* < 0.001

#### 4.1.3 Significant Improvement in Innovativeness

All works showed significant improvement in innovativeness, especially landscape (t = -5.745, p < 0.001) and clothing (t = -4.796, p < 0.001) works. This indicates that Generative AI technology has outstanding advantages in injecting new forms of expression into traditional artworks.

## 4.1.4 Improvement in Visual Appeal and Overall Effect

Landscape and clothing works showed very significant improvements in visual appeal and overall effect (p < 0.001). The Wind Lion God work also showed significant improvement in overall effect (p < 0.05). This indicates that the dynamic version generated by Generative AI successfully enhanced the visual impact of the works and improved the overall artistic experience for the audience. Generative AI technology has a noticeable effect on enhancing visual appeal, especially in light and shadow processing and animation speed. This result is consistent with Jansen & Canter's (2020) research, confirming the importance of time elements in visual art.

4.1.5 Changes in Emotional Intensity

Landscape (t = -3.559, p = 0.002) and clothing (t = -3.559, p = 0.002) works showed significant improvement in emotional intensity, while the improvement in the Wind Lion God work (oil painting) did not reach statistical significance (t = -1.477, p = 0.156). This result reflects the complexity of emotional conveyance and may be related to the characteristics of different art forms. The significant improvement in emotional intensity for ink painting and hand-drawn works might be due to the inherent differences in dynamic representation of these art forms. The softness and fluidity of

ink paintings and the expressive nature of hand-drawn sketches can be better expressed through animation techniques, while the heaviness and texture of oil paintings are more challenging to recreate dynamically.

Table 5. Comparison of Ratings Between Original Authors and Viewers				
Artwork Type	Versi on	Original Author Rating	Viewer Average Rating	Differe nce
Oil Painting (Wind Lion)	Static	6.00	6.94	-0.94
	Dyna mic	5.00	7.47	-2.47
Ink Painting (Landscape)	Static	9.00	4.95	+4.05
	Dyna mic	9.00	6.21	+2.79
Fashion Sketch (Clothing)	Static	8.00	4.53	+3.47
	Dyna mic	7.00	5.74	+1.26

4.1.6 Differences in Evaluation Between Original Authors and Viewers

These differences reflect the different understandings and experiences of creators and audiences towards artworks. Especially in Ink painting and hand-drawn works, the original authors' ratings were significantly higher than viewers', which may be related to the gap between creative intent and actual perceived effect.

Analysis results show that Generative AI-generated dynamic images have significant improvements in emotional intensity, visual appeal, and innovativeness. These results demonstrate the potential of Generative AI technology in artistic emotional expression.

**Changes in Emotional Intensity**: Ink painting and hand-drawn works showed significant improvement in emotional intensity, while the improvement in oil paintings did not reach significance. This may be due to the inherent differences in dynamic representation of these art forms. The softness and fluidity of Ink painting paintings can be better expressed through animation techniques, while the heaviness of oil paintings is more difficult to recreate dynamically.

**Improvement in Visual Appeal and Overall Effect**: Generative AI technology has a noticeable effect on enhancing visual appeal, especially in light and shadow processing and animation speed. This result is consistent with Jansen & Canter's (2020) research, confirming the importance of time elements in visual art.

**Significant Improvement in Innovativeness**: All works showed significant improvement in innovativeness, especially landscape and clothing works. This indicates that Generative AI technology has outstanding advantages in injecting new forms of expression into traditional artworks.

## 4.2 Interview Results and Thematic Analysis

Interviews with the three artists revealed valuable insights into their experiences with Generative AI tools. Through thematic analysis, we identified the following main themes:

- The impact of AI technology on the artistic creation process
- The advantages of dynamic images in emotional expression
- Artists' acceptance and adaptability to AI tools
- Differences in the application of AI technology across different art forms

These themes reflect that artists' overall attitude towards AI technology is positive, but there are also some concerns and challenges. Below are the key findings from each artist:

Oil Painter: When using Generative AI technology, she not only hoped to recreate the emotions at the time but also to create new emotions. She expressed emotions closer to what she wanted to express in her mind through dynamic images and believed that this method provided more creative possibilities.

Ink painting Painter: He stated that Generative AI technology compensated for the lack of emotional expression in the creative process. For Ink painting landscape paintings, many artistic conceptions cannot be fully expressed in static paintings, but through dynamic images, the entire painting became more vivid, and the dynamic display on the timeline made the painting more lively and emotionally deep.

Fashion Design Sketch Artist: She believed that using Generative AI could fully express the soft texture of fabrics, and dynamic display could better show the wrinkles and lightness of fabrics. The dynamic fashion show display could express the confidence and posture of female models walking, making the emotional expression of fashion design sketches richer and more complete

The analysis of these interviews showed that artists generally expressed interest in Generative AI tools, believing they could assist in better expressing emotions and creating new possibilities in their respective art forms."

## 4.3 Analysis

Artists' Acceptance of Generative Al Tools: Through interviews and observations, we understood the artists' acceptance and adaptation to using Generative Al tools. Artists generally expressed interest in these tools, believing they could assist them in better expressing emotions.

**Emotional Recreation Effect:** By comparing artists' original static works with Generative AI-generated dynamic images, we evaluated the effect of emotional recreation. Results showed that dynamic images could more completely express the artists' creative emotions.

**Feasibility of Integrating Traditional and Digital**: We explored the potential application of Generative AI technology in traditional art creation and analyzed its impact on traditional artists

and future development directions. Artists believed that digital technology could enrich their creative means and bring new ways of expression to traditional art.

This study found that traditional artists generally had a high acceptance of Generative AI tools and believed that dynamic images could more completely express their creative emotions. The experiences of interviewed artists showed that Generative AI technology could not only recreate emotions at the time of creation but also create new emotional expressions in dynamic images. This indicates that in the digital age, the integration of traditional art and digital technology has broad prospects, and Generative AI can bring new ways of expression and creative inspiration to artistic creation

## 5 RESEARCH FINDINGS AND FUTURE RESEARCH

## 5.1 Advantages of Generative AI in Paintings

•Dynamic presentation of nature has great advantages in emotional expression: For example, wind moving objects, moving clouds and mist, flowing water, waterfalls, snowfall, sunlight, dynamic shadows, fluttering leaves, flowers and hair, fish swimming in water, water splashes, etc.

•Expressing materials or textures: For example, soft fabrics fluttering in the wind, reflective water surfaces, wrinkles, shiny and refractive metals, transparent and reflective glass, flowing hair, etc.

## 5.2 Research Limitations

•Small sample size: This study only included three artists, which may not fully represent the overall attitude of the artistic community.

•Limited art forms: The research only covered oil painting, ink painting, and fashion design sketches, and did not include other art forms.

• Unknown long-term impact: This study only focused on short-term effects and was unable to assess the long-term impact of AI technology on artistic creation.

#### 5.3 Future research can further explore the following directions

•Improvement of Generative AI Technology: Based on artists' feedback, improve the user interface and functions of Generative AI tools to better support the artistic creation process.

•Diversified Art Forms: Expand the research scope to explore the application of Generative AI technology in other art forms, such as sculpture and music, to further verify its potential in emotional expression.

•Long-term Impact Study: Explore the long-term impact of using Generative AI tools on artistic creation, including changes in artists' creative styles and changes in audience acceptance of dynamic images. •Interdisciplinary Research: Combine psychology, computer science, and art research to deeply explore the application and impact of Generative AI technology in different interdisciplinary fields.

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# PUBLIC EMOTIONS AND VISUAL PERCEPTION OF BUILDINGS IN THE CITY

A CASE STUDY OF PUBLIC BUILDINGS IN TAIWAN

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# Abstract

The use of architectural appearance imagery in cities has become a popular method for understanding people's emotional responses and perceptions of public spaces. It is important to understand the impact of visual elements in urban architecture on stress to develop accurate and practical plans and strategies for healthy and sustainable living environments. This study investigates the architectural features of public building facades and proposes measures to reduce audience stress. A total of 30 Taiwanese-style public buildings were selected for investigation. To explore the relationship between public buildings and stress relief, semi-structured interviews were conducted with 100 participants after presenting the 30 building shapes. The study assesses the stress-relieving effects of various building facade image features using the semantic differential method (SD method) and the 7-point image scale. The results indicate that using complex shapes on the exteriors of public buildings may pique public interest, but it does not alleviate stress. Instead, it increases visual pressure on the city. The exterior of the building features numerous symmetrical shapes, or changes in shape that account for less than 30% of the building's overall appearance. This design element can help to alleviate public pressure. These findings offer valuable insights for the planning and development of sustainable and psychologically supportive urban environments.

*Keywords:* Public Emotion, Visual Perception, Sustainable city, Visual Pressure, Architectural Shape

# **1** INTRODUCTION

City planners and society increasingly recognize the importance of the ecosystem in sustainable urban development. Spaces require services related to the ecosystem for recreation,

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aesthetics, and spiritual experiences [1]. Therefore, it is essential to evaluate the aesthetic elements that impact the delivery of cultural ecosystem services in architecture. These factors are distinct from others as they demand on-site experience and directly affect human well-being [2].

Stress Reduction Theory (SRT) is a theory of environmental psychology to explain the relationship between environmental exposure and mental stress [3]. High-density cities have become dominant in urban habitats worldwide due to rapid urbanization over the past decade. Research suggests that high-density urban landscapes are more oppressive than low- or medium-density urban landscapes [4]. In this study, we examined the public buildings in Taiwan focusing on stress relief and perceived safety. Office workers from high-stress groups were interviewed after work to find answers to the following questions.

- What public building features do citizens like? Is this preference consistent across different visitor needs (e.g., overall preference, stress relief, and perceived safety)?
- Are diverse materials and building envelopes important factors influencing user preferences? Does their importance vary based on different needs, such as stress relief and perceived safety?

Different preferences are expected for public buildings related to different needs. Thus, we hypothesized that a variety of materials and building facades are important influencing factors depending on citizen needs.

## 2 QUALITY OF LIFE AND CITY SUSTAINABILITY

#### 2.1 Correlation Between High-density cities and Mental Stres

In urban development, quality of life is defined in three dimensions. The first dimension relates to personal aspects, such as overall happiness and satisfaction with the city. Therefore, individuals hope to fulfill their physiological needs such as drinking, eating, and sleeping, as well as obtain necessities such as housing and adequate income. Therefore, we examined the collective dimension of an individual's social and economic position in the community [6]. This dimension refers to a sense of belonging to society which is positive or negative related to an individual's social circumstances [7]. Additionally, the material dimension is defined as goods and services in sufficient quality and quantity [8]. Access to goods and services of sufficient quality and quantity needs, including transportation, health, education, leisure, and culture [9]. This discussion will cover the city's offerings.

Ulrich et al. [10] proposed SRT and argued that natural environments reduce mental stress while artificial environments induce it. Although this theory has been referred to by researchers, its application was controversial in artificial environments with most focusing on natural environments or materials. The theory suggests that urban density is positively correlated with mental stress. In urban areas, individuals are frequently exposed to buildings which substantially impacts their mental well-being.

Architecture is crucial in populated cities and contributes to depression [11]. Although many studies have examined the effect of natural elements in cities on citizen stress, none have yet

explored the potential correlation between artificial elements in cities and mental stress. According to Asgarzadeh et al. [12,13], individuals have essentially a form of negative psychological stress. Crowded environments can weaken people's self-control, leading to mental stress [14,15].

### 2.2 QUALITY OF LIFE AND ARCHITECTURAL DEVELOPMENT

The definition of quality of life in an urban environment varies depending on the country, region, and the physical and social circumstances of an individual [3]. Although such statements often refer to residents' satisfaction with their city, the assessment methods can vary. Researchers use qualitative methods and scales to measure personal perceptions and satisfaction. Quantitative methods are also used with indicators such as wealth, affordability, health, quality, and safety of access to services. Urban quality of life indices derived from these methods differ according to measures of an individual's ability to survive and thrive as a result of the economic, social, and urban solutions provided by the city [3]. The quality of life is greatly influenced by the quality of the city. Therefore, it is important to ensure that cities are well-organized and designed to promote the well-being of citizens. Cluttered cities can exacerbate psychological stress among residents.

At the socioeconomic level, studies attribute the quality of life in urban environments to the provision of an economic, social, and urban framework that is conducive to human activities. Tan et al. [16] have suggested that the quality of urban life improves with changes in social development, which increases opportunities for high-paying jobs or changes and enables individuals to afford or pursue better housing and other facilities, thereby improving their quality of life [17]. Interest in post-work quality of life is growing. Thus, after-work classes and yoga practices for relaxation are increasing. Additionally, cultural, spiritual, and community attachment are important in determining the quality of urban life. Local traditions and architecture enhance the vitality of urban life and increase personal satisfaction [3]. Simultaneously, a strong sense of community attachment enhances social cohesion and resilience to maintain urban sustainability and quality of life [3]. This, in turn, affects the competition and comparison of urban architectural appearance. Ultimately, a livable city depends not only on economic factors but also on the mental well-being of its residents, better access to various social services such as hospitals and doctors, and a generally well-educated population [3]. Therefore, under such circumstances, the improvement of the urban environment becomes even more important.

#### 2.3 Visual Complexity of Buildings

What is the meaning of the term 'message'? Messages can have different meanings depending on the context [18]. In the case of buildings in the city, changes in appearance convey the design concept. In neuroscience, the term is often used to refer to stimulus encoding, decision-making, and memory storage. In an urban context, what citizens see can be interpreted as a form of messaging, such as the appearance of buildings and crowded streets. This can lead to psychological stress for individuals.



Figure 1. Kaohsiung Music Center

The brain receives messages from multiple sensory channels to process. The key challenge is to capture people's attention with only relevant information. Objectivity must be maintained, and subjective judgment must be excluded. However, it is worth noting that information that does not meet this standard is behaviorally relevant. This highlights the complexities and pressures that communicating large or complex messages can have on public reception.

The term 'visual complexity' in architecture refers to the level of detail or intricacy that influences people's perception [20]. This means that excessive details enhance visual complexity but they also overwhelm the viewer with too much information. Berlyne [21,22] has suggested that a high degree of visual complexity holds people's attention for longer periods. However, it is crucial to balance visual complexity and the amount of information presented. Therefore, it is essential to present information clearly and concisely, avoiding sprawling descriptions and complex terminology. Nasar [23] defined visual complexity as 'diversity' and evaluated the visual quality of residential scenes through surveys based on objective assessment. It is important to use precise terminology when discussing visual complexity and avoid decorative language. In other words, the more complex the appearance of a building, the longer citizens pay attention to it, and the greater the psychological pressure to be caused. This is because the brain requires more time to process complex information.

## 3 METHODOLOGY

#### 3.1 Survey Method

Various studies confirmed that exposure to a natural urban environment led to positive changes in mood and stress reduction as well as a lower heart rate compared to the built environment. Thus, it is needed to make the building relieve the pressure on the citizens. Due to the purpose of the present research and the basis of existing theory, we adopted experimental methods to investigate the stress-relieving building facade.

In past research, we used experimental methods to obtain the subject's views on the decompression structure to obtain the participants' feelings. Therefore, in this study, we used the same research method to examine the impact of the quantity of building materials on high-stress people. For each of the 70 participants, we analyzed their perceptions of stress relief and pressure and investigated how each perception was related to previous and subsequent

thoughts and external stimuli. The decompression index of 30 buildings was evaluated through the Decompression Building Scale.

## 3.2 Participants

To examine the influence of building exterior materials on individuals experiencing high levels of stress, we analyzed the impact of building materials on psychological stress. We recruited 100 Taiwanese office workers, aged 35 on average, with at least 5 years of work experience (Table 1). Semi-structured interviews were conducted individually in the same room. During the interviews, each participant was shown ten architectural images aimed at relieving stress and was interviewed for forty minutes. The selected sample buildings were shown, and participants chose buildings they had seen in person, online, or in their daily lives. These public buildings are located in Taiwan, a culture familiar to the participants.

Pro	ject	Number of times	%	Project		Number of times	%
Contra	Male	43	43		20 or below	3	3
Gender	Female	57	57	1	21-30	37	37
	Govern-				31-40	43	43
	ment Offi- cal	27	27	Age	41-50	11	11
	Adminis- trative	26	26		51 or above	6	6
	Project as- sistant	16	16		Junior High School or below	4	4
Profession	Business	4	4	High- est Ed- uca- tion Level	General and vo- cational high school	17	17
	Self-em- ployment	4	4		Post-secondary school	10	10
	Seward- ship	2	2		University/Col- lege	56	56
	others	21	21	1	Master or above	13	13

Table 1. Participants in This Study

We asked 10 experts (Table 2) in architectural design to select representative and relatively stress-relieving buildings from these two types of buildings. We used a stress index scale (Health Promotion Agency, Taiwan Ministry of Health and Welfare) to select 10 office workers who showed a stressful lifestyle from the previous 100 participants (Table 3). These 10 participants selected a total of 523 stress relief-related adjectives during a KJ method screening process.

Table 2. List of Experts				
code	Personal Profile	code	Personal Profile	
A1	Mr. Du Age: 55-60 Occupation: Distinguished Professor	A6	Mr. Ho Age: 60-65 Occupation: Emeritus Professor	
A2	Miss Yang Age: 50-55 Occupation: Associate Professor	A7	Mr. Liu Age: 40-45 Occupation: Executive Officerr	
A3	Mr. Zhang Age: 40-45 Occupation: Associate researcher	A8	Mr. Pan Age: 40-45 Occupation: Assistant professor	
A4	Miss Lin Age: 40-45 Occupation: Architect	A9	Miss Kong Age: 45-50 Occupation: Environmental designer	
A5	Miss Chen Age: 45-50 Occupation: Director of Design Company	A10	Miss Zhang Age: 35-40 Occupation: Executive Officer	

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Table 3. High-stress Tster

code	Basic information	code	Basic information
	Miss Shen (Tainan)		Mr. Lee (Fengshan)
B1	Age: 30-35	B6	Age: 40-45
	Occupation: Project Assistant		Occupation: government administrator
	Mr. Xiao (Kaohsiung)		Miss Zheng (Yunlin)
B2	Age: 35-40	B7	Age: 35-40
	Occupation: professional soldier		Occupation: administrative Specialist
	Miss Chiang (Pingtung)		Miss Young (Hsinchu)
B3	Age: 45-50	B8	Age: 45-50
	Occupation: public servant		Occupation: scholar
	Miss Chen (Taipei)		Mr. Shen (Pinatuna)
^{B4} Oc	Age: 35-40	BQ	Age: 45-50
	Occupation: government agency	00	Occupation: firefighter
	personnel		occupation. menginer
	Mr. Zhong (Keelung)		Miss Wang (Taichung)
B5	Age: 40-45	B10	Age: 45-50
	Occupation: Education staff		Occupation: Company senior personnel

#### 3.3 Procedure

We used experimental methods to obtain the subject's views and feelings on the decompression structure. We collected buildings with Taiwanese cultural characteristics for investigation. Each subject was assigned to observe two types of buildings (buildings with more than three materials and less than three materials.). Participants chose one of three constructive conditions including (1) no stimuli available (after observing, participants were given only a brief overview of the building's design, eg location, building name, designer's name), (2) restricted access to stimuli (participants have access to the stimulus search tool, but only once per session, i.e. using web pages to retrieve material), and (3) unlimited access to stimuli (we used the search tool multiple times within the access time limit.). Thus, we studied the stress-relieving architectural choices for the participants. We required the judgment of the participants in a short period, which was closer to the true feelings of the participants themselves.





#### 3.4 Data Analysis

If individuals are exposed to a high-stress environment, either in their personal or professional lives, they may experience cognitive overload and fatigue due to the abundance of visual information. This information can become overwhelming, particularly during the initial stages of reception. Similarly, excessive information, such as overly complex building designs, can cause stress for residents, especially when these elements interact. Simpler buildings are easier to handle and provide a stress-relief effect for residents. In this study, the stress of 70 participants was assessed by using the Stress Index Scale provided by the Department of Health Promotion, Ministry of Health and Welfare, Taiwan. Ten participants showed high stress scores

in the Jiro Kawakita (KJ) method. The top five words expressed by the participants were 'comfortable,' 'kind,' 'friendly,' 'simple,' and 'fun.'

Adjective	Votes	Related
Comfortable	101	satisfied, easy, cozy, cheerful, quiet
Kindly	80	safety, peaceful, amiable, gentle, benevolent, beneficent
Friendly	73	nice, kind, heavenly, Steady
Simple	68	bright, plain, still, pure
Fun	39	happy, colorful

Table 4. Top 5 Attractive Feelings

These two types of buildings have a massive number of exterior materials. After discussions with experts, it was found that the more types of different materials, the more likely it is for viewers to feel stressed.



Figure 3. 30 test buildings.

In testing, we first selected people who visited test sites (Fig. 3). 100 participants (43 women) were office workers. We briefed the evaluation process and asked the participants to choose an adjective or preference to express their feelings about the images to reduce the chances for them to assess the scale of the buildings. After the participants saw the slides for 60 s, they rated the degree of stress reduction. The test results showed that most participants believed

that the fewer materials used in the building's exterior, the more stable and relaxing they felt. The more natural the material was, the more comfortable they felt, too.



Figure 4. Measurement results of two types of buildings.

## 4 DISCUSSIONS

The buildings in cities are shaped by perception-based characteristics such as material, color, shape, form, light, and size [24]. Materials show details [24,25], encapsulating contours and compositions [24,26,27]. Colors reflect the structure of different tones in the scene [24,28]. Material, shape, and color- are considered to be the most basic visual elements that represent the built environment [28]. According to Lynch [29], the shape, color, and arrangement of urban environments contribute to the formation of clear and useful mental images, including details such as materials and shapes.

During the COVID-19 pandemic, architectural types were associated with stress relief, especially. People's emotions are affected by what they see. Excessive material on the exterior of buildings increases the amount of information which affects the emotional response of the people. During the COVID-19, people were not forced to move around the city. If they saw buildings with many materials from the windows, it affected emotions and reactions. When they walk around, they are more affected. Therefore, people consider the current development and urban form for the judgment standard that is affected by the spiritual interests of citizens. Architecture relieves stress and improves mental health if it is designed with consideration for the spatial environment [30]. It is required for buildings to create a positive atmosphere especially for patients as visual surroundings can significantly impact their moodd.

#### 5 CONCLUSIONS

Currently, over 50% of the world's population resides in urban areas, and the number will increase to 70% by 2050. Despite the increase in urban building and population density, living in cities is linked to higher risks of mental health issues compared to rural areas. For instance, individuals living in cities have an almost 40% higher risk of depression, which is double that of schizophrenia. Anxiety, stress, and isolation are more often observed. [31] This indicates that cities need to exert the most significant psychological pressure on individuals from a social, cultural, or economic perspective. The most immediate form of pressure is visual. Therefore, when creating environments, designers must consider design elements that reduce the impact of external factors on the reception of information.

The findings in this study suggested that buildings with excessive decoration and detail are fascinating but cause stress. Too many decorations on buildings overwhelm people with excessive information. Thus, multi-feature visual complexity is required for urban renewal. For instance, when renewing historical streetscapes, the principle of preserving urban memory is required. Instead of reproducing each element in an imitative manner, a multi-feature visual complexity is used for buildings, facilities, or furniture to maintain a similar level of complexity by using surface materials with similar textural complexity. It is important to consider the residents' well-being. In the past, urban architecture was often developed solely according to the designer's aesthetics but emphasis is put on functionality and livability recently.

This study was conducted based on the experience of the participants and their perceptions of building materials. It is necessary to include more designs and materials. The building must be isolated from its environment to conduct more organized experiments. We used software to remove things other than buildings in images. Participants were influenced by environmental impressions when judging materials were changed. Therefore, they often had different opinions based on their imaginations. However, it was still possible to examine the stress-relieving building's materials. That is, individuals' judgments of material changes depended in part on their mood. There are various emotions involved in these judgments being affected by changes in the environment.

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# FEATURE EXTRACTION BASED ON BLOOD PRESSURE FLUCTUATION MECHANISM IN VISIBLE AND NEAR-INFRARED FACIAL IMAGES USING SPARSE CODING

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## ABSTRACT

In the field of Kansei evaluation, blood pressure has been used for autonomic-based evaluation. In addition, hypertension is one of the most common causes of cardiac and cerebrovascular diseases. Early detection and prevention of hypertension requires routine blood pressure monitoring to detect hypertensive states. Remote blood pressure monitoring using facial images has been studied as a routine blood pressure measurement technique. In a previous study, we attempted to detect acute hypertensive states by applying sparse coding to multi-wavelength facial images captured in the visible and near-infrared (NIR) bands. Subject were asked to Valsalva test to evoke acute blood pressure fluctuations. However, there are two factors in the blood pressure fluctuation mechanism: cardiac type and vascular type. Valsalva test causes cardiac-dominant blood pressure fluctuations. It corresponds to the cardiac dominant blood pressure fluctuation, and another type should also be considered. Since these two types of blood pressure fluctuation are caused by different biological response mechanisms, it is desirable to consider both types. In this study, we attempted feature extraction and hypertension detection based on vascular dominant blood pressure fluctuation using visible and NIR images by sparse coding. The extracted features were compared to cardiac dominant blood pressure fluctuation. As a result, 90.8 % hypertension detection rate was obtained by using the 760-900 nm and 1050-1650 nm NIR bands together. In addition, the feature areas represented had a different contribution to detection compared to the cardiac type. Therefore, it was

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suggested that a more generalized hypertension detection model can be constructed by using both blood pressure fluctuation mechanism data.

*Keywords:* Hypertension detection, Blood pressure fluctuation mechanism, Facial visible image, Facial near-infrared image, Sparse coding

## **1** INTRODUCTION

The field of Kansei evaluation attempts to objectively measure human physiological responses by evaluating autonomic responses. In previous studies, blood pressure has been used to evaluate the subject's emotions and stress on the job (Jennifer et al, 2006) (Tanja, Lorenz & Eco, 2000). In addition, hypertension is one of the most common causes of cardiac and cerebrovascular diseases. It is a global social issue due to the increasing number of patients. Early detection and prevention of hypertension requires routine blood pressure monitoring to detect hypertensive states. The conventional blood pressure measurement method using a cuff requires resting for a certain amount of time. The problem is that this requires a certain amount of time for measurement. In order to realize blood pressure measurement as a daily routine and apply it to real life, it is necessary to develop a technology to measure blood pressure in a non-contact and short time.

In recent years, research has been conducted on cuffless blood pressure estimation techniques using photoelectric volume pulse wave and video pulse wave (Yoon et al, 2018) (Hasanzadeh, Ahmadi & Mohammadzade, 2020). However, these are blood pressure estimates based on pulse wave velocity, which is time information, and estimation requires a certain amount of time.

As part of remote blood pressure sensing, blood pressure is estimated using facial near-infrared (NIR) images (Oiwa et al, 2021). The result showed that the effective wavelength bands for blood pressure estimation differ due to differences in facial vascular structure for each subject. The NIR band has a wavelength range known as the "optical window" and is highly permeable to biological tissue. The depth of biological penetration differs depending on the wavelength range. The wavelength range of 650-950 nm is called first NIR window (NIR-I) and that of 1000-1700 nm is called second NIR window (NIR-II). Although Oiwa et al. used only NIR-I for blood pressure estimation, it is thought that even deeper biological information can be obtained by using NIR-II, which has less tissue scattering. We have attempted to detect hypertensive states in facial images using a broader wavelength range (Yamamoto et al, 2024). In the previous study, sparse coding was applied to multi-wavelength facial images acquired in the NIR-I, NIR-II and visible bands. In the visible band, blood flow fluctuation can be captured as hue variation at the biological surface (Stephen et al, 2009). As a result of using these wavelength bands together, a higher accuracy in detecting hypertension was obtained than when they were used alone. Yamamoto et al. asked subjects to Valsalva test, which intentionally evoked acute hypertensive states. However, there are two types of blood pressure fluctuation mechanisms, previous study has dealt with only one.

Factors that determine blood pressure include cardiac output (CO), the amount of blood that the heart beats in one minute, and total peripheral resistance (TPR), which represents the difficulty of blood flow. The product of these factors represents mean blood pressure (MBP) during a single cardiac cycle, and MBP changes when CO and TPR change.

## $MBP = CO \times TPR\#(1)$

Mental stress and exercise are among the factors that contribute to changes in blood pressure. When blood pressure changes, the cardiovascular system responds in two ways: the first, called cardiac type, in which sympathetic activity in the heart predominates and CO increases, which in turn increases MBP. The second, called the vascular type, is characterized by predominant parasympathetic activity in the heart and a slight decrease in CO. At the same time, sympathetic activity in the blood vessels becomes dominant and TPR increases, resulting in an increase in MBP. The Valsalva test performed in a previous study corresponds to the cardiac dominant blood pressure fluctuation, and another type, the vascular type, should also be considered. Since these two types of blood pressure fluctuation are caused by different biological response mechanisms, it is desirable to consider both types of blood pressure fluctuation mechanisms.

In this study, we attempted feature extraction and hypertension detection based on vascular dominant blood pressure fluctuation using visible and NIR images by sparse coding. The extracted features were compared to cardiac dominant blood pressure fluctuation. To increase generality, we constructed a general model that is constructed by combining multiple individual data.

## 2 EXPERIMENT

In this study, subjects were asked to the cold pressor task (CPT) to obtain facial images during acute blood pressure fluctuations based on vascular type. The experimental protocol is shown in Figure 1. The experimental protocol consisted of 3 minutes breath control section, task section, and 3-minute resting eye-closed section. During the breath control section, subjects were asked to inhale and exhale every 3.5 seconds for 3 minutes. In the task section, the subject performed CPT in which the right hand was immersed in cold water maintained at a temperature of 8 °C in a thermostatic bath. The task time varied from subject to subject and was defined as the time from when the subjects placed their right hand in the cold water until they felt the limit to the cold sensation and removed their hand from the cold water. Subjects remained in a sitting position throughout the experiment. The same experiment was conducted three times on different days, and the subjects were asked to refrain from eating or drinking anything other than water, sleeping, smoking, and strenuous exercise for two hours prior to the experiment to control conditions. The subjects were 11 healthy adult males and females (21-23 years old). The room temperature was 24.0  $\pm$  1.0 °C and the illuminance was 210.0  $\pm$  0.5 lux.

<b>Breath Control Section</b>	Task Section	Resting Eye-Closed Section
(3 min)	(Variable Time)	( <b>3 min</b> )

Figure 1. Experimental Protocol.

The experimental system is shown in Figure 2. In the experiment, hemodynamic parameters and facial images of the subject were measured. Hemodynamic parameters were measured

with a cuff of continuous sphygmomanometer (Finometer MIDI, Finapres Medical Systems) worn on the middle finger of the left hand, with a sampling frequency of 1 Hz. The hemodynamic parameters measured were MBP, CO, and TPR. The thermostatic bath used in the task section was placed to the right of the chair in which the subject was seated. Facial visible images were acquired with a web camera (ELP-USBFHD06H-MFV, Ailipu Technology) placed 1 m in front of the subject. The sampling frequency was 20 Hz, and the resolution was 1920 × 1080 pixel. Facial NIR images were acquired with a Si NIR camera (Genie Nano M1280 NIR, Teledyne DALSA Corp.) sensitive to about 400-900 nm and an InGaAs NIR camera (C14041-10U, Hamamatsu Photonics K.K.) sensitive to about 950-1700 nm. Both cameras were placed 1 m in front of the subject and sampling frequency was 1 Hz. The resolution of Si NIR camera was 1024 × 1280 pixel and InGaAs NIR camera was 256 × 320 pixel. The images were taken simultaneously using each light source, with the light source positioned 0.8 m in front of the subject. The NIR-I broadband light sources with a wavelength of 760 - 1100 nm were fabricated by blue light-emitting diodes (LEDs) with Mg₄Nb₂O₉: Cr³⁺ NIR phosphors, which efficiently convert blue light into NIR light (Nanai, Satake, & Kitazawa, 2024) . Two light sources were driven in series to intensify the brightness. An NIR polarizer (WGPF-30C, Sigma Koki Company Ltd.) and a visible light-cut filter (IR76, FUJIFILM) with a cutoff wavelength of 780 nm were placed in front of the light source. A visible light-cut filter (RG780, Edmund) was placed in front of the Si NIR camera to remove visible light incident on the camera. The NIR-II broadband light source with a wavelength of 1050-1650 nm (EL-FSKY-M-01, Ebisu Electronics Co. Ltd.), and an NIR polarizer (Edmund) was placed in front of it. In addition, NIR polarizers (SPFN-30C-26, Sigma Koki Company Ltd.) were placed in front of the Si NIR camera and the InGaAs camera to remove reflected light from the surface of the living body and extract only the diffuse reflection component inside the living body. Figure 3 shows the light spectra by two different NIR broadband LEDs measured at face height during the experiment. In this study, facial images acquired with a web camera were referred to as visible images, acquired with a Si NIR camera were referred to as Si images, and acquired with an InGaAs NIR camera were referred to as InGaAs images.







Figure 3. Spectrum of Light Irradiation to The Face in The Experimental System. (Yamamoto et al, 2024)

## **3** ANALYSIS METHODS

#### 3.1 Sparse Coding

In this study, sparse coding, a signal decomposition algorithm, was applied to images to extract features. Sparse coding is a method that decomposes a set of source signals Y into its constituent multiple bases d, with the goal of representing Y with a linear sum of a small number of d. when Y is expressed as a linear sum, the coefficient of d is called "sparse coefficient". The magnitude of sparse coefficient indicates the contribution of d to Y. In other words, the larger the value of sparse coefficient, the more important the base is in constituting Y. If the value of sparse coefficient is 0, the base can be interpreted as an element that is not necessary to constitute Y. The set of d is called "sparse code" x. The set of sparse coefficients of d that make up one source signal is called "sparse code" x. The set of all source signals x is called "sparse matrix" X. The general formula for sparse coding can be expressed as follows:

$$Y \approx D X \# (2)$$

The process of finding D from Y is called dictionary learning. We used the K-SVD method (Aharon, Elad, & Bruckstein, 2006), one of the dictionary learning algorithms. Through dictionary learning, Y is decomposed into D and X. In this study, Y is the facial image and D is the spatial feature of the facial image.

In dictionary learning, an initial dictionary  $D_0$  is constructed using either randomly generated elements, elements randomly selected from Y, or an existing dictionary. When the number of learning iterations is i = 1,  $X_i$  is determined for  $D_{i-1}$  using equation (2), and the dictionary is updated by calculating  $D_i$  based on the relationship between Y and  $X_i$ . Next, the change in dictionary learning per iteration, calculated as the  $l^2$ -norm difference between the ith and i+ 1th iterations obtained from equation (3) is compared with the arbitrarily set distance error  $\varepsilon$ .

$$\left| \left\| \boldsymbol{Y} - D_{i} \boldsymbol{X}_{i} \right\|_{F}^{2} - \left\| \boldsymbol{Y} - \boldsymbol{D}_{i-1} \boldsymbol{X}_{i-1} \right\|_{F}^{2} \right| \#(3)$$

If  $\varepsilon$  is larger than the solution of equation (3), dictionary learning is finished, otherwise dictionary learning is repeated as  $i \rightarrow i + 1$ .

## 3.2 Applying Method for Images

Consider a method for applying sparse coding to m images, each of size  $a \times b$  pixels. As sparse coding processes each signal in one dimension, the source signal  $\mathbf{y}^{(t)}$  for an image at time t is transformed into a one-dimensional form as shown in equation (4).

$$\mathbf{y}_{(t)} = [y_{1(t)}, y_{2(t)}, \cdots, y_{a \times b(t)}] # (4)$$

 $m{Y}$  is represented in equation (5) as a matrix formed by concatenating  $m{m}$  instances of  $m{y}$ .

$$\mathbf{Y} = \begin{bmatrix} \mathbf{y}_{(1)}^{T}, \mathbf{y}_{(2)}^{T}, \cdots, \mathbf{y}_{(m)}^{T} \end{bmatrix}$$
$$= \begin{bmatrix} y_{1(1)} & y_{1(2)} & \cdots & y_{1(m)} \\ y_{2(2)} & y_{2(2)} & \cdots & y_{2(m)} \\ \vdots & \vdots & \ddots & \vdots \\ y_{a \times b(1)} & y_{a \times b(2)} & \cdots & y_{a \times b(m)} \end{bmatrix} \#(5)$$

**D** is generated through dictionary learning applied to **Y**. **D** is a matrix composed of d(i), with n bases set arbitrarily. Each d is calculated as a one-dimensional vector having the same dimension as **Y**.

$$\boldsymbol{d}_{(i)} = \begin{bmatrix} d_{1(i)}, d_{2(i)}, \cdots, d_{a \times b(i)} \end{bmatrix} (1 \le i \le n) \# (6)$$
$$\boldsymbol{D} = \begin{bmatrix} \boldsymbol{d}_{(1)}^{T}, \boldsymbol{d}_{(2)}^{T}, \cdots, \boldsymbol{d}_{(n)}^{T} \end{bmatrix} \# (7)$$

 $\boldsymbol{X}$  consists of a set of sparse codes  $\boldsymbol{x}_i$  corresponding to the number of source images. Each  $\boldsymbol{x}_i$  is a set of sparse coefficients  $\boldsymbol{x}_{(j)}$ , which represent the coefficients for the linear combination of  $\boldsymbol{y}_{(t)}$ . Consequently,  $\boldsymbol{x}_i$  is calculated as a one-dimensional vector with the same dimension as  $\boldsymbol{y}_{(t)}$ .

$$\mathbf{x}_{(j)} = [\mathbf{x}_{1(j)}, \mathbf{x}_{2(j)}, \cdots, \mathbf{d}_{a \times b(j)}] #(8)$$
$$\mathbf{X} = [\mathbf{x}_{(1)}^{T}, \mathbf{x}_{(2)}^{T}, \cdots, \mathbf{x}_{(n)}^{T}] #(9)$$

#### 3.3 Selection and Preprocessing Methods of Images

All visible, Si, and InGaAs images used in the analysis were selected in the same selection and applied to the same preprocessing. Labeling of facial images was based on acquired hemodynamic parameters. Firstly, for each acquired hemodynamic parameter, outlier processing was performed using the mean value  $\pm 2\sigma$  ( $\sigma$ : standard deviation) as the threshold value for each section of the experiment, and linear interpolation was performed. Secondly, the last one minute of the breath control section was used as the baseline, and Wilcoxon's signed rank test was performed on the minute-by-minute data of the task section. Since MBP and TPR increase as a biological response when the CPT is performed, the interval in which MBP and TPR were predominantly elevated (p < 0.05) was determined. For each experiment, 20 MBPs were selected from those intervals in order of increasing value, and the facial image at the same time was defined as the hypertensive image. For the last one minute of each breath control section, 20 MBPs were selected in order of decreasing value, and the facial image at the same time was defined as the normotensive image. Finally, 60 hypertensive and normotensive images were selected per subject, and general models were constructed using 1,320 facial images for each visible, Si, and InGaAs image.

Next, preprocessing was applied to the facial images with the aim of extracting only physiological responses. Preprocessing was performed by the following four steps: (i) To reduce individual differences in facial shape among subjects, 68 facial feature points were extracted using an object detection algorithm and a point cloud statistical model, and spatial standardization was performed based on their coordinates (Nagumo, Oiwa, & Nozawa, 2021). Examples of facial image with spatial standardization is shown in Figure 4 (259 × 279 pixels). (ii) Only visible images, RGB color space, which is sensitive to ambient light, was converted to L*a*b* color space. In addition, in the L*a*b* color space, since lightness is represented by L*, the effect of ambient light is reduced by separating L*, and only a*, the chromaticity of red, was used in the analysis to focus on skin hue variation due to blood flow fluctuation (Stephen et al, 2009). (iii) To reduce the effect of changes in facial expression, the image was cropped to avoid eyebrows, and pixels in the orbital and nostril areas were removed (200 × 175 pixels). (iv) Facial images were standardized to mean zero and variance one.



Facial Visible Image (RGB)Facial Si ImageFacial InGaAs ImageFigure 4. Examples of Spatially Standardized Facial Images.

The preprocessed facial image is shown in Figure 5. The a* component of the visible image is defined as the facial visible image, the Si image as the facial Si image and the InGaAs image as the facial InGaAs image. For sparse coding, these images were used as Y, and D and X were calculated using the K-SVD method. The number of bases was set to 10, and the contributed basis images were selected from the obtained them in order of the sparse coefficient. The

hypertension detection model was built using a support vector machine (SVM). The model was evaluated based on the average detection accuracy by 11-fold cross-validation. In the 11- fold cross-validation, 10 of the 11 subjects were used as training data, and one subject not included in the training data was used as test data for accuracy evaluation. A total of seven models were created: three models with a single wavelength, three models with two wavelengths combined, and one model with all three wavelengths combined. When multiple wavelengths were used together, the model was constructed by combining the  $\boldsymbol{X}$  calculated for each wavelength band in the column direction.







Facial Visible Image (a*) Facial Si Image Facial InGaAs Image Figure 5. Examples of Source Images.

## 4 RESULTS AND DISCUSSION

Table 1 shows the hypertension detection rates for the seven models constructed. Among the seven models, the model using both Si and InGaAs images had the highest accuracy. The model using all wavelength bands together had the second highest accuracy of all the models, and was more accurate than the model constructed using single wavelength bands. The use of multiple wavelength bands in combination allows the acquisition of biometric information at different depths, which is thought to improve accuracy. When the number of wavelength bands used was limited to one, the model using InGaAs images showed the highest accuracy. In the models created in this study, higher accuracy was obtained for the models using the NIR wavelength band than for the visible wavelength band. While the visible wavelength band captures biological information at a shallow depth of the biological surface, the NIR wavelength band can capture deeper depth. Therefore, it is considered that NIR images are able to capture blood flow fluctuations more accurately than visible images. In addition, the longer the wavelength in the NIR wavelength band, the deeper the depth of coverage, suggesting that higher accuracy was achieved with InGaAs images than Si images.

Used Image	Average Accuracy [%]
Visible Image	70.5
Si Image	80.8
InGaAs Image	85.3
Visible Image + Si Image	78.2
Visible Image + InGaAs Image	88.3
Si Image + InGaAs Image	90.8

fable 1. Average Accuracy	of Hypertension	Detection of Each Model.
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Visible Image + Si Image + InGaAs Image	89.1
visible intage · si intage · inda/is intage	05.1

The top three basis images that contributed to the detection for each wavelength band are shown in Figure 6. In the basis image, the color bar represents the features, with darker areas indicating important features. In common with all wavelength bands, features were expressed around the nose, lip, cheek, and orbital area. The nasal and lip areas have thin skin and a high concentration of capillaries. It is considered that the blood pressure fluctuations induced by CPT were interpreted as fluctuations in blood flow in these vessels. The fact that different areas were represented as features in each wavelength band suggests that different spatial features of biological depth are captured by using visible and NIR images.

The same sites also appear as features in previous studies that have conducted breath-holding tests that evoke cardiac dominant blood pressure fluctuation (Yamamoto et al, 2024). However, it was confirmed that the contribution of features differed by site in each wavelength band, such as nasal dorsum and cheek. Therefore, it is expected that a general-purpose hypertension detection model can be constructed by using both cardiac type and vascular type data in the hypertension detection model. In addition, 11 healthy adults were used as subjects for the model in this study. We consider that to make the model more generalizable, it is necessary to increase the sample size and include subjects of diverse age groups and health conditions.



Figure 6. Example of Basis Images.

#### 5 CONCLUSION

In this study, we attempted feature extraction and hypertension detection based on the vascular dominant blood pressure fluctuation mechanism by sparse coding using visible and NIR images. As a result, the accuracy of hypertension detection was improved by using multiple wavelengths in combination, and the extracted feature areas were almost similar to those of cardiac dominant blood pressure fluctuation. In the future, we aim to construct a general-purpose hypertension detection model by using data from both cardiac dominant and vascular dominant blood pressure fluctuation, and increasing the sample size of subjects from diverse age groups and health conditions.

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# EXPRESSING MATERIAL DERIVATIONS INFLUENCE PERCEPTIONS OF PRODUCT SUSTAINABILITY

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## ABSTRACT

The materials that are specified for consumer products are predominantly not raw materials, such as rocks or plants, rather they are derived from rocks and plants and refined into a form that is manageable, malleable and manufacturable. The processing of base materials into manageable material forms impacts the earth. The consumer product experience is far enough removed from this processing that the environmental impacts of the initial material source might be inappreciable to a consumer. However, knowledge about material derivation may shift a product or sustainability perception towards to be negative if the base material has a negative perception. For example, petroleum, a source material that is limited, mined, and increases carbon in the atmosphere when burned, tends to have a negative connotation in sustainability-oriented conversation. How might a broad comparison of consumer products, drinking cups, made of various materials: aluminum, glass and polymers, show consumer perception of product sustainability if the basic source materials were exposed? This study is an investigation into this influence. The goal of this study is to examine whether exposing the derivation of the material used to make a consumer product effects a person's perception of a product's sustainability. The material derivations are rock ore, sand, petroleum, sugar, corn and trees. This paper compares the perceptions that study participants had of product sustainabilities based on six different sustainability-focused word-pair metrics.

Keywords: sustainable materials, sustainable design strategies

## **1** INTRODUCTION

The development of more sustainable products hinges on addressing a combination of emotional and functional product attributes. Product purchasing decisions are made with both fast (affective) and slow (cognitive) processes (Helander & Khalid, 2006). Sustainability issues have fast, vernacularly accepted emotional components, such as: plants are good for the

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environment and petroleum is bad for the environment. Sustainability issues also have slow, researched components, such as knowing which polymers one's municipal recycling center collects (typically polyethylene terephthalate, or PET/PETE and high density polyethylene, or HDPE (United Nations Development Programme 2023)). Because customers tend to make decisions based on their gut feelings rather than logical thinking (Khalid & Helander, 2006), peoples' emotional perceptions of product sustainability are important to include in sustainable product development guides.

Product developers strive to understand and produce more sustainable products that consumers support from the point of purchase to the length of time a product is kept. Practical eco-anxiety (Pihkala, 2020; Usher, 2022) has led to the creation of information-based tools for sustainable design practice. Making new products using sustainability tools can ease the eco-anxiety of product developers (Law & Golda, 2022). Tools have been developed that are qualitative (Graedel & Allenby, 1995; Lewis & Gertsakis, 2001) and quantitative (White et al., 2013; Sustainable Minds, 2024; PRé Sustainability, 2000) to assist designers in the creation of more sustainable products. These slow, cognitive tools are developed for product creators.

The strategies and metrics in these tools may not be known to or believed by product purchasers and users. Individuals have unique exposures to environmental research and best practices. As environmental sciences are fields in rapid development, best practices change rapidly as well. Additionally, governmental consensus on best practices is unusual, even at local municipal levels (Oregon DEQ, 2024). In this state of knowledge and legislative confusion, individuals develop their own personal practices and justifications to address global sustainability issues. Individualized practices and knowledge may increase societal gaps that exist between user expectations and user perceptions in green products (Tseng & Hung, 2017). Using Kansei engineering practices to understand and apply user emotion to the creation of more sustainable products is a strategy for more comprehensive product design (Chen, 2018; Muenchinger, 2013). Kansei studies quantify the emotional responses people have to attributes of products (Nagamachi, 1995), and clarify perceptions that consumers may not know they have (Kang, 2011). Overlapping product development tools and studies of user emotions may find connection points (Nagamachi, 2002). Creating products at these nexus points should make the strongest sustainable products, supported by both data (fact) and cravability (emotion).

This research study follows previous works to find connection points about the materials used in consumer products and how consumers may perceive those materials as enhancing or detracting from the sustainability of the product. For polymer products, it has been shown that when people were told the derivation of a polymer – whether the polymer was synthesized from a plant-based source or from petroleum – that knowledge changed how the product's sustainability attributes were perceived (Muenchinger, 2022). This study examines whether a similar shift may be seen in products made with materials other than polymers that are synthesized from rock ore (aluminum) and sand (glass). Rocks or minerals may also be perceived as more natural than petroleum, even though minerals and petroleum are all limited earth resources that are extracted from the environment and converted from their "natural" states to the base materials we specify for manufacturing consumer products.

## 2 METHODS AND MATERIALS

Two hundred three people participated in a Kansei cups ranking exercise. All of the participants were students associated with the University of Oregon, and had an average age of 20-years-old. Ninety-one participants (45%) self-identified as female, one hundred four (51%) self-identified as male and eight (4%) self-identified as non-binary. Participation in the study concluded prior to a lecture about measuring sustainability and similar research studies in perceptions of sustainability. Financial compensation was not provided to the participants.

## 2.1 Cups

Six cups were used in this study as the prompts given to study participants to analyze (Figure 1). These cups were fabricated specifically for this research. The cup materials are aluminum (Al), glass, high density polyethylene (HDPE), polylactic acid (PLA) and a 30% cellulose, 70% polypropylene (PP) composite. The fabrication method for the aluminum cup was spinning, the glass cup was blown into a mold, and the HDPE, PLA and cellulose/PP cups were injection molded.



Figure 1. Six cups pictured L to R: Al, glass, HDPE, HDPE, PLA, and 30% cellulose/70% PP composite

While the vessels are fabricated from different materials and through a variety of manufacturing processes, they are designed to be as dimensionally similar as possible. All materials are their natural color; no colorants were used. No secondary processing or finishing was conducted. There are noticeable physical differences in the cups due to natural color, oxidation, material densities and shrink rates.

The cups were provided to the participants as a six-sample set with both a group-identifying letter (A-P) common to the set and a material identifying number printed on the bottom of each cup. The names and derivations of the materials were provided to study participants as follows: "CUP 1: Aluminum derived from rock ore," "CUP 4: Glass derived from sand," "CUP 3: High Density Polyethylene (HDPE) derived from petroleum," "CUP 10: High Density Polyethylene (HDPE) derived from sugar," "CUP 7: Polylactic Acid (PLA) derived from corn," "CUP 11: 30% Cellulose derived from trees, 70% Polypropylene (PP) derived from petroleum." The numbers on the cups are non-sequential as an artifact of being used in several studies of mixed materials.

#### 2.2 Surveys

Study surveys were conducted in person using the online Qualtrics survey platform. Participants engaged with the survey on their own smart devices. The physical cups were distributed to the participants, providing the closest proximity of presentation (Schütte et al., 2023) for their assessment.

Participants were asked to rank each cup on six word pairs designed to target qualitative strategies of sustainable design. The word pairs are: *Lasting – Degradable; Delicate – Durable; Harmless – Toxic; Natural – Artificial; Raw – Finished; Recyclable – Waste.* The span of the semantic space in the domain of product sustainability (Schütte et al., 2004) is described by these word pairs. These word pairs were constructed to address historic sustainable material selection strategies (Graedel and Allenby: 240) (Lewis and Gertsakis: 86-87) and have consistently been used in previous studies (Muenchinger, 2012, 2013, 2014, 2022). Scores were recorded using slider bars on a scale of 1-7, recorded to the tenth.

#### **3 RESULTS**

In Figure 2, the average response is shown for each cup in each word pair on the scale of 1-7. Each word pair is categorized by the more sustainable word, and the lower the average, the more sustainable the perception. For example, in the top left Degradable category, the average for the aluminum cup is approximately 6, which is the highest average, showing the least perception of degradability. To the immediate right of aluminum, the average for the cellulose/PP cup is 4.7, which (with PLA) is the lowest average and shows the highest perception of degradability. Each cup is shown on the horizontal axis.



**Figure 2**. Average perceptions of each cup in each category. Categories from left to right are Aluminum (AI), Cellulose/Polypropylene (C/PP), Glass, HDPE derived from petroleum (PE(p)), HDPE derived from sugar (PE(s)), and Polylactic Acid (PLA)

The whiskers and the outliers show that the participants' responses covered a wide range. This wide range of responses can also be seen in the response density diagram, Figure 3.



Figure 3. Response density, with average rankings on the x-axis, percent respondents on the y-axis

Figure 3 groups the cups into three sets so that the Non-renewable and Renewable materials may be examined together. The derivations of the materials used in this study can be classified as renewable (sugar, corn, cellulose) and non-renewable (ore, sand, petroleum) materials. In Figure 3 the cellulose/PP cup is characterized as its own composite of both renewable (30% cellulose) and non-renewable (70% PP) materials. Again, looking at the top left category, Degradable, there are many more responses to the non-renewables, aluminum, glass and HDPE(p) at or near a response of 7, or not degradable, than there at or near the response of 1. The cellulose/PP cup shows two bumps indicating there was a group of respondents favoring a Degradable perception of the cup, and a group of respondents favoring a Lasting perception of the cup.

## 4 DISCUSSION AND CONCLUSIONS

The goal of this study is to examine whether the derivation of the material used to make a product, in this case a cup, effects the perception of a product's sustainability. The data show (Figure 2) there is not a singular cup that has a perception of being most sustainable. The renewable, non-renewable and composite (C/PP) sets also do not show one group of these sets to be dominant in all six sustainability categories (Figure 3). It would be helpful to compare these results to the results of a study in which the plant or material sources of the cup materials were not exposed. Shifts in perceptions could be directly examined in each sustainability category or for each cup materiality.

#### 4.1 Individual categories

#### 4.1.1 Degradable – Lasting

Figure 2 indicates that none of the cups are perceived to be particularly Degradable. The averages for all cups are over midline at 4, skewing toward Lasting products. This is appropriate for these drinking vessels which are not intended to be understood as single use products.

However, in Figure 3 it is noticeable that the cups made from non-renewable materials, the aluminum, glass and HDPE(p), have a more unified perception of Lasting than the renewable and C/PP cups. For the renewable and C/PP cups, Figure 3 shows two bumps in the average responses, one just below the midline at 4, and one just above. Participants' perceptions were divided, some feeling that these cups were more Degradable, some more Lasting. Figure 4, which groups the C/PP cup with the renewables, indicates that participants believe the renewable material cups to be more Degradable than the non-renewable material cups. It should be noted that Figure 4 shows the responses are just above midline of 4 (the 7 point scale is truncated on the y-axis), so none of these cups were perceived to be particularly Degradable. However, there is indication of a positively correlating relationship between plant-sourced product materials and degradability. We may posit that other products that explicitly state their materials are derived from plant sources would be perceived as somewhat more degradable. This positive correlation would be appropriate to utilize when the end-of-life probability for the product is a waste or composting environment that optimizes degradation.



Figure 4. Average rankings of Non-renewables (AI, Glass, HDPE(p)) and Renewables (HDPE(s), PLA, Cellulose/PP)

It should also be noted that the C/PP cup is a visual outlier from the other cups in this six-cup test set. This cup has a distinct warm color and non-homogenous visual texture (Figure 1). The impact of the visual stimulus of this cup (Karana, 2012; Muenchinger, 2022) may support the impact of the information provided about the renewable, 30% tree-derived materiality written in the survey. The visual impact of this cup may influence the perception of degradability.

## 4.1.2 Durable – Delicate

Figure 2 shows clearly that Durability is perceived to be strong (toward the low, sustainable side of the scale) in all of the cups but for the glass cup. This is also appropriate for a drinking cup product that is not intended for single use. The aluminum cup is perceived as the most Durable, as it has the lowest average, the lowest interquartile range, and the lowest whiskers and outlier responses.

For the creation of durable goods, the utilization of polymers and aluminum appear to be preferential to glass products. Explaining the durability of these materials in consumer products

could be utilized to promote sustainability, because the length of time a product is kept and used typically increases that product's sustainability. In plastic products, this messaging is contrary to the single-use or cheap messaging often associated with plastic products.

#### 4.1.3 Harmless – Toxic

All of the materials used for these cups are harmless, or non-toxic, and appropriate to be used for food contact. The glass cup is clearly perceived to be the most Harmless of the cups in this study (Figure 2). Since the aluminum cup skews to a Harmless perception, and the HDPE(p) cup skews toward Toxic, the double bump in response density seen in Figure 3 for the non-renewables probably comes from the glass and aluminum scoring lower and the HDPE(p) scoring higher. A double bump also exists in the response density shown for all of the other cups. Similar to the responses for Degradable – Lasting, the cups made with renewable material-derived polymers are seen by some people as more Harmless than neutral, and are seen by other people as more Toxic than neutral. It would be helpful to compare results of a study that does not expose the plant or mineral material sources of the cup materials to these results and see if there is a shift in feelings on the Harmless – Toxic scale. A shift toward Harmless is directly seen in a comparison between the cup made from HDPE derived from petroleum with the cup made from HDPE derived from sugar. Figure 2 shows the average for the sugar-derived HDPE cup to be lower than the petroleum derived HDPE cup.

#### 4.1.4 Natural – Artificial

The aluminum and glass cups are perceived to be the most Natural, seen in Figure 2. This result is interesting, as these materials are derived from minerals, rocks, rather than plant sources, supporting the idea that Natural materials do not have to be plant-based materials. In this study, all of the polymer cups skew to an Artificial perception, excepting the C/PP cup which has a midline average. Similar to the discussion about the Degradable category, the visual distinctions in the C/PP cup: warm toned, amorphous visual texture, may influence the overall perception of the product in the Natural category. As seen in Figure 3, the responses do not peak around any particular number. The response density is fairly flat, suggesting that participants were consistently distributed in their perceptions of the C/PP cup, perhaps being individually influenced by different aspects (visual, material, other) of the cup.

## 4.1.5 Raw - Finished

The cellulose/polypropylene composite cup is perceived to be the most Raw of the cups (Figure 2). Again, it seems the mottled visual texture of this cup could influence this result. In contrast, the influence of appearance would not be the reason for the difference between the averages for the two HDPE cups, as there is no discernable visual difference between these two. The only difference is the written descriptions of the material derivation: "High Density Polyethylene (HDPE) derived from sugar," and "High Density Polyethylene (HDPE) derived from sugar," and "High Density Polyethylene (HDPE) derived from sugar, and "High Density Polyethylene (HDPE) derived from petroleum." In this case, the HDPE cup derived from sugar is perceived to be more Raw. This is another indicator that exposing the base material, or the derivation of the material, can influence the perception of the final product.

#### 4.1.6 Recyclable – Waste

The category Recyclable shows that the cups made with aluminum and glass, both non-renewable materials, have a higher perception of Recyclability than the renewable materials. This inclination is strengthened when the C/PP cup is grouped with the renewable materials, as shown in Figure 4. This result is supported intuitively in that municipal recycling for aluminum and glass are ubiquitous for individual beverage cans and bottles. Participants in this study have had life-long familiarity with these recycling systems. Globally, aluminum is one of our world's most recycled materials, with a 76% recycling efficiency rate documented in 2020 (International Aluminum Institute, 2020). Glass has a 21% global recycling rate (Donnelly, 2024) and plastics has a 9% global recycling rate (Peysakhovich, 2024).

The plastics included in this study that have the highest global recycling potential are the HDPE(p) and HDPE(s) cups. HDPE is the most widely used and recycled polymer (Cheremisinoff, 2001; EPA, 2024). Referring back to Figure 2, the two cups made with HDPE are perceived on average as the least recyclable cups. This perception may be due to the experience of study participants with plastics recycling. Municipal recycling programs are not consistent as to what polymers are collected and which municipalities collect polymer products for recycling. The perception of HDPE being a recyclable material could be assisted by programs such as the state of Oregon's Plastic Pollution and Recycling Modernization Act, which will specify and regulate the polymers collected by all municipal recycling systems across the state (Oregon DEQ, 2024) including HDPE. HDPE is slated to be included as a recycled/recyclable polymer under Oregon's Plastic Pollution and Recycling Act because it is the most widely used polymer.

There is an additional interesting finding in the Recyclable category. Even though all of the polymer cups were not found to be particularly recyclable, the HDPE cup derived from sugar was considered to be more recyclable than the HDPE cup derived from petroleum (Figure 2). The C/PP cup is found to be the most recyclable, and is under the midline of 4 in the survey averages. These points suggest that people may be more prone to recycle polymer products if a plant derivation is known, or if the tone is warmer or the visual texture is non-homogenous.

#### 4.2 Renewable materials and non-renewable materials

The response density chart, Figure 3, illustrates the wide range of responses given by the study participants to each of the cup rankings. It was hypothesized that the renewable, plant-based material sources would seem more sustainable to the study participants than the non-renewable sources. This is not the case. Figure 4 shows that the averages for the renewables cups were lower (more sustainable) than the non-renewables in three categories, and the non-renewables were lower in three categories, and as discussed in the individual categories, the double bumps of perceptions seen in Figure 3 demonstrate not only a lack of consensus from the study participants, but dualities of thought. The only category in which the cups made from plant-based source materials are consistently perceived to me more sustainable than the ore and sand derived materials is Durability, and it seems more likely that this is due to the perception of polymer durability than a perception of renewable plant durability. Expressing that consumer product materials are derived from renewable resources

does not appear to be a strong tactic to use when trying to convey sustainability attributes to consumers.

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# TEXTURE, GLOSS, AND COLOR VARIATION AND PERCEIVED QUALITY OF SURFACES

**A** KANSEI ENGINEERING APPROACH FOR A SUSTAINABLE PLASTIC MATERIAL SELECTION IN CAR INTERIOR DESIGN

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## ABSTRACT

Today, demand for a reduced carbon footprint within the manufacturing industry results in higher demands from the sub-suppliers of components and raw materials. The plastic industry, together with research in the field, has been working for decades with the recycling process to ensure the recyclability of different polymers. However, the demands on the perceived quality of plastic components have tightened in the field to remain in a premium segment, and the specification of plastic components in a car interior is probably stricter than ever. The question is, do today's tolerances of plastic components regarding design and perceived quality serve in harmony with a higher level of recycled material in future components, or should the industry adapt its tolerances to a more sustainable process? Texture, gloss, and color variation have a great impact on the perceived quality of materials and have been an issue historically within the manufacturing industry of plastic components. This paper handles the result of a pilot study where typical gloss and color variation in plastic pieces was evaluated. The gloss and color variation occurs generally more often with increased recycled content; however, in this study, the color variation was simulated and controlled in virgin material.

Keywords: Kansei Engineering, Texture, gloss, perceived quality, sustainability.

## **1** INTRODUCTION

Plastic waste is increasing rapidly, creating significant environmental challenges. To manage plastic waste effectively, it is critical to know the amount and composition of plastic waste produced. This information will help local authorities, policymakers, and both public and private sectors to understand the complexities of plastic waste generation and identify opportunities for plastic waste recycling. Regarding this fact, future plastic components will probably have

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more recycled materials integrated. Consequently, the 'perceived quality' needs to be ensured with these new challenges. [1]

Today's demand for a reduced carbon footprint within the manufacturing industry results in higher demands from sub-suppliers in producing components and raw materials. The plastic industry and research in the field have been working for decades with the recycling process to ensure the recyclability of different polymers. However, the demands on the perceived quality of plastic components have tightened, and the specifications of plastic components in a car interior are very strict. Texture, gloss and color variation have a great impact on the perceived quality of plastic components. [18]

This paper presents the results of a pilot study in the automotive industry, where typical texture, gloss and color variation in plastic pieces for interior design was evaluated. The texture, gloss and color variation occur generally more often with an increased number of recycled contents. The method used in this project has its roots in 'Kansei Engineering' (KE); however, it is modified to suit the actual industry's needs and standards.

KE is a design approach that involves intentionally incorporated emotional responses into products by understanding the psychological and sensory factors that influence these responses. In other words, it focuses on designing products that evoke positive emotions and feelings of their users. [8]

The questions asked in this project are: Do today's tolerances of plastic components regarding perceived quality serve in harmony with a higher level of recycled material in future components, or should the industry adapt its tolerances to a more sustainable process?

This study aims to frame this issue and find a workflow/method for the industry when similar challenges occur within the field of quality assessments of components. However, the pilot study can be a foundation for a broader study in the future.

## 1.1 Limitations

In aggreement with the collaboration partner of this study, this article will not reveal any particular numbers regarding material specification, yet focus on the structure and framework of the user study. This will not change the novelty of the result or change the way the reader will interpret the result.

#### 1.2 Perceived quality and recycled polymers

Perceived Quality (PQ) is the impression of quality that a customer experiences about a product or service through sight, sound, touch, and scent. PQ relates to how well a product or service performs regarding technical as well as emotional functions in attributes such as design, packaging, brand, marketing actions, and price. It is possible to measure PQ, however it needs to be obtained in a structured way through e.g., surveys, interviews and/or focus groups. In addition, PQ can be measured, evaluated, and controlled in different levels of a product. Within this pilot study, the focus is the perceived quality of the surface appearance of several plastic plaques. The main parameters and aim are gloss and color match of plastic pieces for car interior design. [2]

The usage of recycled plastics in components is important for the manufacturing industry, which contributes to minimizing the global footprint through company sustainability goals. Both post-industrial and post-consumer goods are available on the market. However, the post-consumer goods are of greater interest since the volume is much larger and the price is

significantly lower. However, the post-consumer goods are more contaminated and dirtier, which leads to a more complex and energy-consuming recycling process. [3]

Plastic components made with post-consumer goods will have other properties and will be experienced differently than if post-industrial material was used. Odor and other fumes and visual defects such as color and gloss variation are a great challenge for many manufacturers. The perceived quality of components with recycled materials will be experienced differently compared to components made of virgin material. [4]

Today's tolerances, on the other hand, were defined while producing components made with virgin material only in regard to customer satisfaction. This fact admits that sustainability goals challenge today's tolerances.

#### 1.3 Texture, gloss, and color

Texture, gloss, and color are key perceptual characteristics that stimulate human sensation in regard to material and surfaces. These features could beneficially be included in surface appearance studies regarding their design imprint. However, the complexity of their physical properties combined with the physiological and psychological functions of the human eye implies that only instrumental methods do not meet a complete characterization of surface perception. Hence, it could be necessary to use a version of the human observation test, focus groups, or similar to cover quantitative and qualitative data. [5]

Microscopic surface structures at the micron level significantly influence grain, color, and gloss characteristics, and these factors are highly interconnected. It's also essential to differentiate between, e.g., perceived color and the actual color, and the same principle applies to gloss. "Perceived" gloss isn't equivalent to measured gloss. [20].

#### 1.4 Material evaluation

Component evaluation is a crucial aspect in the process of ensuring the interior design standard in the automotive industry to meet customer needs. Evaluation of materials helps ensure the perceived quality, functionality, and aesthetic appeal of the components used in the interior design. By ensuring the quality and reliability of the components, component evaluation helps enhance the driving experience and satisfaction of the customers. [2]

The evaluation of components in the automotive industry involves several methods and techniques to ensure the quality, functionality, and aesthetic appeal of the components. Some of the methods and techniques used in component evaluation in the automotive industry are visual inspection and assessment in the light booth and measuring techniques, e.g., spectrophotometry for color deviation. [6]

Material evaluation in a light booth is an essential part of the product development process and is frequently used globally in various industries. The use of a light booth allows different lighting conditions for the evaluation of materials, ensuring reliable and consistent results. Factors such as the light source, intensity, and angle of illumination can affect a material's perceived gloss, color, and texture. The type of light booth used depends on the material being evaluated and the required level of accuracy. [7]

Another way of evaluating components, or validating, is to collect data through user studies and focus groups. Quantitative and qualitative data are needed in symbiosis to ensure a robust production of components regarding the total appearance. The producers of polymers challenge today's demands for material assessment regarding the PQ of plastic components. The manufacturing industry believes it will be tough to hit today's target of components with a higher number of recycled materials without pushing the specification's limit. On the other hand, a larger window in the specification probably increases the variation of the design parameters and might challenge the customer experience significantly. [2]

## 2 INTRODUCTION

The To be able to evaluate user perspectives regarding perceived quality it is necessary to address the effect of interpretation. Individuals interpret their surroundings by means of stimuli from the five senses. The sensory stimuli work together with the brain and convert the sensory stimuli into perception. The perception will determine how the user reacts to the sensory stimuli. [19]

In order to design a user test, consideration must be given to what is meant to be measured. Should the subjective sensory experience of the similarity or the difference of surface textures be measured, or should the subjective experience of quality be measured?

Lawless and Hildegarde (2010) describe the classification of test methods in the sensory evaluation of food where three different types of sensory tests are described:

Discrimination is an analytical test that aims to answer the question 'Are two or more products perceptibly similar or different?' [21], and is often used to test the perceived product similarity between the original product and a new version with for example a new material. Where the aim is to retain the product similarity.

Descriptive analysis aims at answering the question of how to define the perceived sensory characterization in a product. For example, the qualitative sensory aspects are linked to the perceived attributes of a surface such as roughness, using a semantic differential scale with anchor words rough-smooth on each side. The intensity of the specific attribute is visually defined by the test person and is collected in a quantitative analysis. In this analysis a trained test panel who have learned how to identify different surface characteristics is required [21], [17].

Affective is a hedonic test that aims at answering the question of which product is preferred and how well-liked a product is. To answer this question people without prior knowledge could be used as panelists.

The method used in this project, that matches the mentioned requirements, has its roots in 'Kansei Engineering' (KE), however are modified to suit the actual industry's needs and standards.

## 2.1 Kansei Engineering

Briefly, the principles of 'Kansei Engineering' are based on the idea that emotional responses can be intentionally designed into products by understanding the psychological and sensory factors that influence these responses. 'Kansei Engineering' involves a structured process that typically includes data collection, analysis, and design. [8] The steps involved are:

- 1. Define the target product or service: The first step in Kansei Engineering is to identify the target product or service that you want to develop or improve. This could be a physical product, a digital product, or a service.
- 2. Gather customer feedback: The next step is to gather feedback from customers about their emotions, feelings, and preferences related to the product or service.
This could be done through surveys, focus groups, interviews, or other forms of customer research.

- 3. Identify the Kansei words: Based on the feedback gathered in step .
- 4. Develop a Kansei map: Once you have identified the Kansei words, you need to create a Kansei map that visualizes the relationships between these words and the product or service attributes. This map helps to identify which attributes are most strongly associated with which Kansei words.
- 5. Define design guidelines: Based on the Kansei map, you can define design guidelines that specify how the product or service should be designed to evoke the desired emotional responses and preferences in customers. These guidelines may include specific colors, shapes, materials, or other design elements.
- 6. Create and test prototypes: Using the design guidelines, you can create prototypes of the product or service and test them with customers to see how well they evoke the desired emotional responses and preferences.
- Refine the design: Based on the feedback gathered from testing, you can refine the design and repeat the prototyping and testing process until the desired emotional responses and preferences are achieved.

Overall, Kansei Engineering is a customer-focused design methodology that emphasizes the importance of understanding and designing for customers' emotional responses and preferences. By following these steps, products and services could be created that resonate with customers on a deep emotional level, leading to increased customer satisfaction and loyalty. [9, 10].

# 2.2 Modified Method

The method used in this pilot study was designed slightly differently compared to the KE method; however, it focused on the first 4 steps in the KE method.

The purpose of the pilot study was to collect enough data to be able to implement a broader study and implement the other steps of the KE method, mainly steps 5-7. Yet, the modified method used for the pilot study briefly handled the following steps:

- 1. Define the material and key appearance.
- Collect customer feedback through user study (A): Pairwise comparison of plastic plaques regarding perceived variation (B): Pairwise comparison of plastic plaques regarding good match or not.
- 3. Collect describing words during the session.
- 4. Analyze data and create a system.

The method includes the usage of diagrams called 'parallel plots' or 'parallel coordinate plots'. Parallel plots are a type of visualization used to explore and analyze, e.g., multidimensional data, cluster analysis, and anomaly detection. In a parallel plot, each variable in the dataset is represented by a vertical axis, and each data point is represented by a line that intersects each axis at the corresponding value. [26] Figure 1 illustrates an example of a 'Parallel plot' similar to the ones used in the result.

The parallel plot in Figure 1 involves the following:

• Surface ID (First vertical axis).

• Question 1 (Second vertical axis).

• Respondents colored by the answer from Question2 (Lines that connect the vertical axis).



**Figure 1**. an illustration of a 'Parallel plot' similar to the ones used in the result. The parallel plot involves surface ID (First vertical axis), Question 1 (Second vertical axis), and respondents colored by the answer from question 2 (Lines that connect the vertical axis).

# 3 RESULT

To face the challenges in the production industry of plastic components regarding a higher number of recycled goods in the process, a pilot study with a structure similar to KE was implemented. The focus was to analyze the variation of several plastic plaques and link the result to the current tolerances of gloss and color deviation for plastic components for interior design. The main question was: could the current tolerances remain, or will the specification need to be updated?

The user study was briefly divided into 3 different steps.

- 1. Contextual description
- 2. Appearance variation test
- 3. The assessment of 10 surfaces

# 3.1 The user study - subjective data collection

Firstly, the user study was initiated with an information session where the users got an idea of the placement of the materials within the actual context, the interior design of a car. This is important due to how the users approach and evaluate the materials during the actual assessment. [2]

In this study, pictures of an interior design were shown as a reference for the topical materials. Secondly, the users made a version of the color variation test based on the 'Farnsworth Munsell 100 Hue Test'. This was done to ensure the user's physical ability to detect variations in color. This session did not reveal any large deviation in the ability to see color variations among the participants. If a user in the population were to be considered as failing the test, on the other hand, that person's material assessment result would be marked and targeted for further investigation. [14, 15].



Figure 2. a version of color variation test based on the 'Farnsworth Munsell 100 Hue Test.

The last part of the user study was the actual assessment of the material plaques. The assessment took place in an ISO-standard light booth with a D65 light source accordingly. The users were provided with the plaques in pairs, where one of the plaques always was one (out of three) so-called master plaques. The users on the other hand, did not know about what plaques that was paired.



Figure 3. picture of two plaques inside the ISO-standard light booth with D65 light source.

The last part of the user study was the actual assessment of the material plaques. The assessment took place in an ISO-standard light booth with a D65 light source accordingly. The users were provided with the plaques in pairs, where one of the plaques always was one (out of three) so-called master plaques. The users on the other hand, did not know about what plaques that was paired.

The users got two questions for each set of pairs:

- 1. "Do you see any difference between the surfaces?"
- 2. "Is the surface match ok/not ok?"

The users got 11 sets to assess, where 2 of the sets were master plaque to master plaque. This was made as a control set to ensure that the users did not answer in affect. Each user study session took approximately 40 minutes, and the study included 12 participants equally distributed over genders in ages 26-54. The participants were recruited in-house from the industry and had different backgrounds; 75% of the participants were not within the quality assessment profession, and 25% had a background in assessment. The order of the plaque was set by means of a random number generator and differed each time.



Figure 4. illustration of the pairwise comparison system.

#### 3.1.1 The data analysis

The data analysis gave mainly 3 different outcomes:

1. Descriptive experience of the appearance of the current polymer plaques.

2. Indication of variation.

# 3. Indication of possible match.

Firstly, the comments that were collected in the comparison mainly handled the variation of the plaques linked to the master. The comments have been decrypted for a better understanding of the structure. An example: the following comment came from a participant from the study: "Surface G is more blue than Master and is also darker than Master."

Similar comments were collected in each comparison and user participant with the intention to understand why the user executed the study as they did in part 2a and 2b (the pairwise comparison).

Descriptive analysis is a method used to determine the sensory characteristics of a product. It seeks to define how these sensory attributes are perceived. For instance, qualitative aspects like the roughness of a surface can be evaluated through a user study. Trained individuals, known as a test panel, visually assess the intensity of these attributes and provide quantitative data. [16, 17]

Figure 5 illustrates the relationship of the descriptive words linked to the question of matching plaques. The comments admits that e.g. the word 'blue' is linked to a bad match in this particular case, since the word is slightly red in figure 5.



**Figure 5**. illustration of a so-called word cloud with descriptive words, linked to the question of matching plaques. The greener the color, the better the match linked to the descriptive word. The opposite for the red color.

Secondly, the data regarding appearance variation and plaque match was analyzed. This was done both independently and in symbiosis.

The data regarding appearance variation indicated that 80% of the surfaces were to be considered as having a significant variation regarding perceived quality, and equally many, 80% (same plaques) were to be considered as bad match.

The parallel plot in Figure 6 illustrates surface D, which is considered as being within specification, borderline ok from a PQ assessment perspective, "green" zone.



**Figure 6**. A parallel plot illustrating the participant's judgment regarding appearance variation and plaque match for surface D compared to the master. Q1 "Can you see a variation?" and Q2 "Is the surface match ok/not ok?" was asked in this section.

The parallel plot in Figure 7 illustrates surface G that is considered as being out of specification, not ok from a PQ assessment perspective; however, maybe within a potentially adjusted specification regarding user study assessment, "yellow" zone.



**Figure 7**. A parallel plot illustrating the participant's judgment regarding appearance variation and plaque match for surface G compared to the master. Q1 "Can you see a variation?" and Q2 "Is the surface match ok/not ok?" was asked in this section.

The parallel plot in Figure 8 illustrates surface F, which is considered as being far out of specification, not ok from a PQ assessment perspective, and probably also out of a potentially adjusted specification regarding user study assessment, "red" zone.



**Figure 8**. a parallel plot illustrating the participant's judgment regarding appearance variation and plaque match for surface F compared to the master. Q1 "Can you see a variation?" and Q2 "Is the surface match ok/not ok?" was asked in this section.

Figure 9 illustrates an overview of the complete selection of surfaces used in the study. Looking closer at the overview reveals that surface I, H, and B are targets for further investigation regarding color variance and match. In a scenario where the current specification is adjusted, these surfaces could act as references of being 'borderline ok'.



**Figure 9**. A parallel plot illustrating the participant's judgment regarding appearance variation and plaque match compared to the master for the complete selection of surfaces used in the study.

The diagram in Figure 10 illustrates a summary of the plaques and their placement in regard to variation and match.



**Figure 10**. a diagram illustrating a summary of the plaques and their placement in regard to variation and match. The green area is considered to be within the specification.

# 3.2 The surface visual properties and topography

Subsection The measurement of the surfaces was carried out in three steps.

- 1. Konika Minolta CM36dG (Color Spectrometer)
- 2. Konica Minolta, unigloss 60 plus 60° angle
- 3. Zygo, white light interferometer 10x Magnitude, 2x Digital zoom, 100 μm Scanning Length and 3x3 stitched measurement

The given parameters from measuring the surfaces were the following.

- 1. Color variation; CIELCH (Lightness, Chroma and Hue)
- 2. Gloss; Gloss Unit (GU, 1-100)
- 3. Surface topography; ISO 25178: Geometrical Product Specifications (GPS)

The surfaces were measured once, however, in the relocated location each time to conduct significant comparisons.

The chosen way of measuring was done by means of a method developed by Vijeth Venkataram Reddy, and verifies that the field of view is considered to be enough to see significant variations in regard to e.g., texture and gloss. [22, 23]

The user study had 3 master plaques included that were intentionally randomized during the study. These master plaques were considered to be significantly similar on a micro-scale. Hence, only one of them will be exposed in this report as a reference, figure 11.



**Figure 11**. topography of the reference surface (master plaque) captured with a white light interferometer. The surface 'gloss unit' was measured to 4.10.

Surface A was to be considered the worst surface regarding match and variance, figure 12. Comments like "too glossy," "too cold," and "too blue" occurred more frequently for this surface than any else. Its 'gloss unit' was measured to 8.00 (compared to master plaque GU 4.10), which correlates with the user study participants' evaluation. However, the "cold" and "blue" appearance probably relates to the lower amount of chroma in the color of the pigmentation.

Surface A was to be considered as an obvious deviation, both from a user study perspective as well as a metrology perspective. The microstructure seemed to reveal this statement as well, hence it deviate in appearance in regard to the master plaque.



# **Figure 12**. topography of surface A captured with a white light interferometer. The surface 'gloss unit' was measured to 8.00.

Surface B, Figure 13, was to be considered as 'not ok' (NOK), however, in the borderline spectrum. The gloss was measured to 8.10; however, there was a lower variance in color deviation compared to surface A. The lightness (L) was significantly lower than surface A and master plaque. The user study evaluation confirmed this fact.



**Figure 13**. topography of surface B captured with a white light interferometer. The surface 'gloss unit' was measured to 8.10.

Surface D, Figure 14, was to be considered as 'ok'. The gloss was measured to 5.00 and had a lower variance in color deviation compared to surface A. The deviation of lightness (L), on the other hand, was slightly larger than surface A and the master plaque. The user study evaluation confirmed the gloss and color deviation. However, the users had more difficulty defining any differences in the lightness deviation.



# **Figure 14**. topography of surface D captured with a white light interferometer. The surface 'gloss unit' was measured to 5.00.

Based on the user study, the surface's appearance is affected by color deviation and gloss. The color space is pretty well defined; however, the gloss is only defined with the gloss unit. Based on the analysis of the microstructure of the different surfaces, further investigation of the microstructure was needed in regard to light scattering.

All the surfaces (A-J) were analyzed in the same way regarding perceived quality; however, only a selection is shown in this article as an example of the variances that occur in the population of surfaces. The users in the study tend to see gloss, lightness, and color deviation on a very detailed level, figure 14. The diagram (figure 15) illustrates the deviation of the samples in hue (H), chroma (C), and lightness (L).



**Figure 15**. illustration of the surface color spectrum (LCH) and gloss measurements. The colors (red – Not OK, yellow – borderline OK, and green – OK) are linked to the colors in Figure 10.

The hierarchy of the three is a different thing that needs further investigation in regard to this specific case. In terms of human sensation and perception of plastic components, the hierarchy of gloss, lightness, and color (hue and saturation) is generally determined by how these parameters influence visual perception. [19]

This hierarchy can shift slightly depending on context (e.g., specific lighting conditions or design intentions). However, in most everyday situations, color is the primary factor driving human perception, followed by lightness and gloss. [19]

However, some studies show that gloss could be superior to color. Even though color is generally the most dominant factor in visual perception, gloss can become superior in specific contexts, particularly where material quality, surface finishes, or reflective properties (or matte) are key considerations. [24] In these situations, the gloss may indeed take priority because it can imply higher quality or add a particular aesthetic appearance that color alone cannot achieve.

Whether gloss or color is superior depends on the interaction between the object, its intended use, and the environment in which it is viewed. [25]

The question regarding the correlation between the parameters is also important, especially regarding the difference in deviation between the three.

#### 4 DISCUSSION

The analysis of the numbers given from the study indicates that the current specification is tight and does not allow large variances in color and gloss. However, a larger number of recycled materials will significantly challenge the specification regarding color and gloss. The number of plaques analyzed in this project was 10 (+1 master) and the delta values of color and

gloss for these plaques may be too big to declare any conclusions regarding opening a product specification.

Yet, the result implies that a broader study, where the hypothesis of opening the specification could be tested with a higher accuracy, could be implemented. This requires a larger number of plaques with smaller steps in delta value regarding color and gloss variation.

The question regarding opening the specification for a more sustainable process is not yet completely solved. However, the study implies that there may be a gap between the experts and the consumers regarding the level of ability to see variation and assess the surfaces. Figure 16 illustrates the matter, where the green area refers to where both groups consider the delta value as 'ok.' The yellow area is where the delta value is considered as 'borderline ok,' and the red area is considered as being 'not ok.' The "window" called 'safety' is illustrating the potential gap between the experts and the consumers.

This gap is important and could be seen as a safety factor for perceived quality; however, the question that arose was: is the gap too big, or could it be optimized?



The aim may have been shifting from opening the specification to optimizing the window of "safety" where it is possible.

**Figure 16**. an illustration of how the specification links to the variation of surface delta value and the level of expertise of assessing the surface appearance. Experts detect variations within narrow delta values, while novel users discover variations with a wider delta.

This finding may change the way questions regarding the specification are formulated. Would it be possible to use the window of "safety" to adjust the specification for particular surface parameters that may not affect the novel users' perceived quality?

Another matter that has been discussed in the field of recycled materials and total appearance in regard to customer satisfaction is 'acceptance of variations'. The acceptance of variations may change in tandem with the discussion about sustainability in future products in general, which may be in favor of the matter of opening a specification of the current components as well.

Conclusions: The study did not solve the issue of 'how' to open the specification regarding master plaque properties. The research question regarding opening the specification is partly answered, though; there is a gap between the experts and the novel users regarding perceived quality that could act as a safety factor for the delta value. Regarding the findings in the study, it should be possible to adjust the tolerances in certain directions. This study could, therefore, act as a foundation for a broader study where plastic plaques with tighter variation in defined directions are evaluated.

#### **5** ACKNOWLEDGMENT

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# 6 DATA AVAILABILITY STATEMENT

The data cannot be made publicly available upon publication because they are not available in a format that is sufficiently accessible or reusable by other researchers. The data that support the findings of this study are available upon reasonable request from the authors.

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# AN ATTEMPT TO CREATE A COUNSELING BOT USING GENERATIVE AI INSPIRED BY THE TRAJECTORY EQUIFINALITY MODEL

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# ABSTRACT

It is believed that generative AI could be introduced into counseling in the future. However, to provide highly satisfactory counseling services, service providers need to design effective prompts. In this study, inspired by the Trajectory Equifinality Model (TEM), we explored the use of interview and analysis methods from qualitative psychology in the design of prompts for counseling services. To achieve this, we first interviewed ten individuals in their early twenties about their experiences of setbacks and successes in drawing throughout their lives. Subsequently, we conducted an experiment to evaluate whether a chatbot using the prompts developed in this study or a chatbot using unmodified prompts was preferred.

Keywords: Generative AI, Qualitative research, Chatbot, Counseling

# **1** INTRODUCTION

The advent of the internet and computers has led to three distinct AI booms from the 1950s to the present. The third AI boom, which began in the 2000s, has prompted a surge in research concerning the relationship between humans and AI or robots.For example, research has been conducted to explore the potential of communication between humans and robots to soothe people's feelings in certain specific situations, particularly focusing on "healing through conversation" with robots(Saito & Shiizuka, 2008). Additionally, studies have been carried out

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on the construction of listening dialogue systems and their comparative evaluation with human listening(Inoue, Lala, Yamamoto, Nakamura, Takanashi & Kawahara, 2021).

Previous research has primarily focused on the behavior and appearance of robots in human-robot interactions. However, there has been limited examination of understanding the fundamental issues of clients' problems or addressing their emotional healing. Nonetheless, AI-based counseling offers strengths such as the ability to generate responses to clients' statements more quickly than humans and the capacity to remember conversations for future counseling sessions. These features suggest the potential for AI counseling to contribute to resolving clients' issues.

The third AI boom continues today, the growth of "generative AI (Artificial Intelligence)," which can automatically generate text, images, videos, and audio, has been remarkable, and its range of applications is expanding every year. In line with this trend, there have been various attempts to develop counseling systems that utilize generative AI. For example, Nakanishi et al. (2020) have explored the research and development of an autonomous dialogue robot system that performs counseling by applying artificial interpersonal interactions (Nakanishi, Akiyoshi & Sumioka, 2020)

On the other hand, there are voices pointing out the low satisfaction with counseling using generative AI like ChatGPT, noting that coherent responses do not resonate emotionally (Nishida, 2025). This indicates that there are still many unfinished aspects in the implementation of generative AI in counseling, necessitating further consideration. To address these issues and provide highly satisfactory counseling services, it is essential for service providers to design appropriate prompts. Therefore, this study focuses on this challenge and hypothesizes that introducing experiences of failure by others in conversations could enhance the satisfaction of counseling using chatbots. Subsequently, inspired by the Trajectory Equifinality Model (TEM)(Sato, Yasuda, Kido, Takada,& Valsiner, 2006), we considered applying interview and analysis methods from qualitative psychology (Urata, Yamamoto & Kinma, 2018) to design prompts for counseling services.

# 2 METHOD

In this study, we developed a chatbot using the ChatGPT 3.5 API (OpenAI,ChatGPT, 2024), referencing the website of Nuco Corporation (Corporation Nuco,2023). We then interviewed ten people in their early twenties about their experiences of failure and success in drawing in a narrative interview, recording the conversations while taking notes on an iPad. The gathered information was incorporated into the prompts, and participants were shown four different Chat Communication Logs generated from these prompts. Eight participants in their early twenties were then surveyed about each Chat Communication Logs, and evaluation data was collected using a paired comparison method.

### 2.1 How to research cases to write to the prompt

In this study, we initially approached one university student in their early twenties studying design and asked them if they were currently interested in drawing. For those who expressed interest or even a slight interest, we conducted narrative interviews using an unstructured interview (Satou, 2009). Other students were recruited to participate in the study using a snowball sampling. Regarding the timing and location of the interviews, they were conducted at the participants' convenience. The method of recording the interviews involved taking notes on an iPad while simultaneously recording the audio. Figure 1 provides an example of the actual interview notes. Items written in red represent events or thoughts that left a positive impression on the participant, while items written in blue represent events or thoughts that left a negative impression.

Before starting the interview, we reiterated the question "Are you currently interested in drawing?" to confirm the participant's interest. Then, we asked them to freely narrate all episodes related to drawing, from childhood to the present, in chronological order. After they finished recounting all the episodes, we confirmed if they intended to continue drawing in the future. Finally, we reviewed the notes together to ensure that no episodes were forgotten and that there were no issues with how the episodes were recorded.



Figure 1. An example of interview notes

# 2.2 Entering Prompts

The text written for the ChatGPT prompt was based on the Fukatsu-style prompt (Corporation Nuco, 2023). According to NOVEL Corporation, the Fukatsu-style prompt is a framework developed by Takayuki Fukatsu, CXO of Note Corporation, for ChatGPT, aiming to achieve optimal outputs by clearly indicating constraints and tasks to be accomplished.

In this case, we followed this approach and designed the prompt with four categories: "#Instructions", "#Counseling Procedure", "#Constraints", and "#Case Studies". We constructed the prompt by imagining a scenario where one is conversing with a real counselor. All the following prompts were completed in Japanese.

First, regarding "#Instructions", we set it up as follows:

- You are Dampitsu-chan, an excellent counselor who empathizes with people's hearts.
- Your job is to present cases to encourage and uplift individuals who are feeling down due to certain circumstances.
- When a message is sent to you, please use the counseling procedure and constraints provided below, along with the list of case studies, to produce the best possible outcome.

Regarding "#Counseling Procedure", we set it up as follows:

- 1. First, upon receiving a message, always greet and introduce yourself. Ask the individual how they would like to address you and, if it is not a bother, inquire about what they usually do. Once you receive their reply, transition to the topic of creative activities.
- 2. Next, upon receiving a response, inquire why they reached out to you.
- 3. Present case studies tailored to the individual's situation and continue with counseling responses of no more than 250 characters each.

Regarding "#Constraints", we set it up as follows:

- The total character count for each response must not exceed 150 characters.
- Before responding, acknowledge the individual's concern and provide a response within a total of 150 characters. For example: "That sounds difficult."
- Include a summarized presentation of a case study from the list provided within the response, ensuring the total character count does not exceed 150 characters.
- If a case study is lengthy, it must be summarized to 50 characters or fewer. Each response, including the summary, must not exceed a total of 150 characters.

Here is an example from the "#Case Studies" list:

If asked, "I can't draw my ideal picture because my drawing skills are insufficient," respond with: "K (K is a real person) struggled due to their lack of drawing skills, feeling unable to express what they wanted. However, they realized they could draw characters with exaggerated features, finding their comfort zone. It's crucial to maintain motivation within your drawing abilities and keep drawing."

# 2.3 Chat Communication Logs output

In this study, we created four types of Chat Communication Logs, labeled A, B, C, and D. The prompts for these Chat Communication Logs were set as follows: A with "temperature=0, real

examples," B with "temperature=0, fictional examples," C with "temperature=1, real examples," and D with "temperature=1, fictional examples." In the context of ChatGPT, temperature is a variable that adjusts the degree of randomness in the output. Using the prompt for A "temperature=0, real examples," the Chat Communication Logs appeared as shown in Figure 2, while the prompt for B "temperature=0, fictional examples" resulted in the Chat Communication Logs shown in Figure 3. Using the prompt for C "temperature=1, real examples," the Chat Communication Logs appeared as shown in Figure 5.

Furthermore, in the conversations with the chatbots, we aimed to achieve seamless interactions that would simulate the experience of talking with a real counselor.

		Hello.	00
	I am Dampitsu-chan, an excellent counselor who can empathize with people's hearts. How should I address y Also, what do you usually do? And do you have any concerns or worries?	ou?	
	My name is Maya. I am usually studying design a	at university.	00
ô	Hello, Maya! I heard you are studying design, which is wonderful. you enjoying your design studies? If you have any concerns or wo please feel free to share them with me.	Are rries,	
	I can't draw my ideal picture, and my drawing s good enough to draw well.	kills aren't	00
٢	Maya, I understand that you're struggling with not being able to dr your ideal pictures and feeling that your drawing skills are insuffic Someone I know, K had similar concerns. He realized his limitatio but discovered that he could draw two-headed characters well. H chose to express himself within his capabilities and found it import to keep drawing while maintaining his motivation. I'm sure if you k trying within your current abilities, you'll start to see your growth a	aw cient. ns le ortant ceep as well.	
	Also, I find it painful to look at my own drawing my standards have become too high.	gs because	00
	Maya, I understand that there are times when it's difficult for you to look at your own drawings. K had a similar experience, but he discovered the joy of creating in different ways, such as logo desig and banner creation. By creating something through methods oth than illustration, you might find new perspectives and enjoyment. hope you try new approaches and enjoy your creative activities.	to gn er . I	

Figure 2. A: Conversation with "temperature=0, real examples" chatbot (in Japanese)

(K in the text is a real person who participated in the interview.)





(K in the text is a real person who participated in the interview.)



Figure 4. C: Conversation with "temperature=1, real examples" chatbot (in Japanese)



(A and B in the text are fictitious characters generated by the chatbot.)

Figure 5. D: Conversation with "temperature=1, fictional examples" chatbot (in Japanese)

(A and B in the text are fictitious characters generated by the chatbot.)

# 2.4 Questionnaire Survey

Using the four Chat Communication Logs generated in section 2.3 (A, B, C, and D), we created six pairwise combinations: AB, AC, AD, BC, BD, and CD. We then conducted a survey with university students in their early twenties studying design. Figure 6 shows the actual process of participants answering the survey.



Figure 6. Having the respondents answer the questionnaire

In the survey, the following three questions were asked, and respondents were asked to mark the appropriate spot on a scale chart. A 7-point Likert scale was used for the scale chart:

Which do you feel changes your values in a positive direction?

Which Chat Communication Logs makes you feel that the counselor is considering your feelings when speaking?

Which Chat Communication Logs would you like to use again in the future?

The collected results were then compared using the paired comparison method (Nakaya's modification) to examine which Chat Communication Logs was preferred. The paired comparison method (Nakaya's modification) involves evaluating which of two examples is more favorable, presenting all combinations to each individual panelist.

# 3 RESULT

First, for the survey to collect case studies for the prompts, we received cooperation from ten university students in their early twenties studying visual and media design. For the questionnaire using the generated Chat Communication Logs, we received cooperation from eight university students in their early twenties studying visual and media design. We analyzed the results obtained from the questionnaire and created the scale diagrams for questions Q1 to Q3 (Figure 7) using the paired comparison method (Nakaya's modification). The results indicated no significant difference in user responses between the chatbots designed with real case studies (A and C) and those designed to generate fictitious cases (B and D). Additionally, post-survey interviews revealed that the impressions received from the nuances of the words, such as encouragement and the frequency of their names being mentioned, were more important than the specificity of the cases or the insights gained from the counseling.



Figure 7. Scale Diagram for Each Question

#### 4 CONCLUSION

In this study, we hypothesized that introducing stories of other people's setbacks in conversations could enhance the satisfaction of counseling services using chatbots. To test this hypothesis, we applied interview and analysis methods used in qualitative psychology to the design of prompts for counseling services and examined which type of chatbot would be preferred.

The analysis of the survey results showed no significant difference in user response tendencies between chatbots designed with actual case studies and those designed to generate fictional cases. Additionally, post-survey interviews indicated that the impression received from the nuances of the counselor's words was more important to users than the substantive content of the counseling.

Based on these results, the experimental conditions need to be redesigned for the design of the counseling generated by the AI proposed in this study. On the other hand, since the influence of the agent's subtle behavior on the counseling was clarified, we would like to examine the design guidelines for such subtle behavior in the future.

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# EXPLORATION OF THE CRISIS OF SEALS' SURVIVAL IN THE OCEAN AND ITS APPLICATION IN DIGITAL EDUCATION

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# ABSTRACT

Today's marine ecosystems are subject to significant amounts of anthropogenic pollution. Marine ecological pollution poses a serious threat to the survival of seals. Seals' habitats and food supplies have been destroyed, and their living space has become increasingly restricted. Therefore, protecting the marine ecological environment, and thereby protecting the survival of species such as seals, is an important step towards achieving sustainable development goals. However, marine pollution is becoming increasingly serious with the acceleration of industrial development. From the perspective of the survival crisis of seals to the impact of marine ecological pollution on the entire marine ecosystem, this study combines the theme of the survival crisis of seals, several projects of the United Nations Sustainable Development Goals (SDGs), and can also be combined with blockchain through digital art Sustainable Development Goals 13: "Initiate mitigation and adaptation actions to address climate change and its impacts" and 14: "Protect oceans, coasts and marine resources from sustainability". "Sustainable use" and Goal 17: "Forge diverse partnerships to work together to promote a sustainable vision." Design method to utilize digital art NFT and animated video to illustrate marine environmental issues, hoping to create a new virtual world of seals. In the seal metaverse, seals are the protagonists and are used as representatives of the ecosystem to express concern for the marine ecological environment. The results illustrate in digital art some of the problems of marine ecological pollution, such as plastic pollution, accelerated melting of sea ice, global warming, and oil spills. These problems can warn people of the fatal consequences of serious damage to the entire ecosystem, which threatens the living space of human beings and many living things, and improvement plans must be provided as soon as possible.

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*Keywords:* Seal Visual Art, Marine Environment Conservation, SDGs, Blockchain, NFT, Metaverse

# **1** INTRODUCTION

#### 1.1 The seal's marine environment

The marine environment continues to deteriorate, Krause, D. J., et al. (2022). Research reports indicate that the breeding and hunting of Antarctic seals are affected by the reduction of floating ice. The breeding habitat of Antarctic seals has become more unstable due to the reduction of ice floes, and their prey has also been reduced due to the reduction of ice floes, further threatening their survival (Ayres, E., 2023). According to Hansen, J., et al. (2006). Data show that global temperature has continued to rise since the 1980s.

# 1.2 Pollution

Huang, K., et al. (2020). Studying oil spill pollution, the increase in global average temperature will lead to an increase in ocean water temperature, which will in turn lead to the melting of floating ice. The impact of oil spill pollution on local wildlife is serious. Oil spill pollution will have long-term impacts on wildlife breeding and habitats, and will also hurt local fisheries and tourism. Case-based reasoning systems often provide the basis for decision-makers to make management decisions in disaster prevention and emergency response. A method to identify offshore oil spill cases using only knowledge is proposed. On the other hand, ocean glass pollution may accelerate the process of ocean acidification, which poses a serious threat to marine life and marine ecosystems. Because sea glass fragments react with carbon dioxide in seawater, they produce acidic substances that lower the pH of seawater. Zhang, D., et al. (2020) found that the annual production of plastics in the world reached almost 350 million tons in 2018 (PlasticsEurope, 2018), and 10% of this total eventually entered the world's oceans, which hurts marine ecology Serious impacts have been caused to the system, such as marine organisms accidentally ingesting plastic waste, leading to chronic poisoning, internal organ damage, etc., and may even cause death.

#### 1.3 Digital art with blockchain technology

By combining digital art with blockchain technology to promote marine environmental issues, blockchain technology can achieve the advantages of decentralization, non-comparability, transparency and traceability, security, anonymity, and privacy of smart contracts. Transparency and traceability: Blockchain technology can provide transparency and traceability, making the collection, storage, and sharing of environmental information more reliable and trustworthy. Every transaction and information is recorded in an immutable block that can be viewed and verified by anyone, which helps prevent falsification and improper behavior of environmental data. Decentralization and trust establishment: Blockchain technology is usually decentralized without central authority control, which can reduce dependence on a single entity and establish more trust mechanisms. In the field of environmental protection, this means not relying on a single regulatory agency or government to ensure the accuracy and reliability of information. Smart Contracts and Automated Execution: A smart contract is a programmable blockchain-based contract that automatically executes the terms of the contract. Applying smart contracts to environmental issues can achieve automated execution and monitoring, such as carbon emissions trading, issuance and trading of renewable energy certificates, etc., thereby improving efficiency and saving costs. Eliminate intermediaries: Blockchain technology can eliminate intermediaries in certain environmental issues and make transactions more efficient. For example, blockchain can directly connect energy generators and users, eliminating intermediate links such as energy suppliers, thereby reducing the cost of energy transactions and energy losses. Community participation and incentive mechanism: Blockchain technology can provide more community participation and incentive mechanisms for environmental protection. For example, through the blockchain platform, individuals and organizations can be encouraged to participate in environmental protection activities, such as recycling, reducing carbon emissions, etc., and reward participants through encrypted digital art.

At present, Taiwan's seal fan Facebook group "Pretend to be a seal" has 38,000 people, and the American seal fan Facebook group "All the Seals also has 38,000 people. According to seal enthusiasts, Generation Z, who are mostly students or office workers, are more receptive to new things. At the same time, they are irresistible to cute and sentimentally designed products, especially physical products such as pillows, dolls, and stickers. The most popular virtual product is the creation of seal-themed meme animated videos, which include soundtracks, material editing, and other techniques. Currently, in the digital art NFT market, there are no projects that are oriented toward marine environment conservation and have interactive designs.

This research focuses on marine environmental issues and combines blockchain to design interactive digital art, which can encourage individuals and organizations to participate in environmental protection activities, such as recycling, reducing carbon emissions, etc., and reward participants through encrypted digital art. Attract public attention to this issue and contribute to the sustainable development of the marine environment.

# 2 RELATED WORKS

This section should describe the study design, materials, measuring methods, procedures, and statistical methods. Measurement and statistical methods should be mentioned, but for routine methods, a reference rather than a description of the method is recommended. Certain kinds of research (e.g. policy analysis) should instead include substantial references to support methods of analysis. Case studies and practical applications of routine methods should include a reference for the methods, and the full paper must indicate the new, or unique, application of the routine method.

NFT stands for Non-Fungible Token, which is a digital asset or digital commodity based on blockchain technology. It promotes marine environmental issues through the combination of digital art and blockchain technology, which makes NFT can be used In the fields of digital artwork, virtual land, game props, music, videos, and other digital content (Wang, Q., et al., 2021).

# 2.1 Marine environment and ecological dilemma

Marine ecosystems are facing unprecedented challenges, and the living environment of many marine species is seriously threatened. Research points out that marine ecosystems are becoming increasingly fragile due to the impact of human activities, such as overfishing, pollution, and climate change. Especially for marine mammals such as baby seals, their habitats are rapidly shrinking and they may not be able to continue to give birth to the next generation in the future (Smith, J. et al., 2020). This situation has prompted the rise of several conservation actions and environmental movements in an attempt to reduce damage to the marine environment.

# 2.2 The combination of digital art and blockchain technology

NFT (non-fungible token), as a digital asset based on blockchain technology, has been widely used in fields such as digital art, virtual land, game props, music, and movies in recent years. The uniqueness and irreplaceability of NFT make it an important tool for protecting and promoting digital art (Wang, Q., et al., 2021). Combining digital art with blockchain technology, can not only ensure the uniqueness and ownership of artworks but also enhance the influence of environmental issues and attract more people to pay attention to ocean protection.

# 2.3 Integration of creative design and environmental protection

For the design needs of NFT projects, including background stories, official websites, interactive visual design, character design, and blockchain confidential transaction contracts, these design elements can form a complete through the integration of physical planet gems, dolls, and virtual interactive art. ecosystem. This design is not only visually appealing but also guides the viewer through a story to gain insight into the reality of the marine environment. Especially combined with the SDGs (Sustainable Development Goals) environmental protection issue that has attracted recent attention, this digital art form has become a new tool to advocate environmental protection (Johnson, M. et al., 2022).

#### 2.4 Construction and development of Arjaverse

As a virtual planet, Arjaverse provides a new way to protect the marine environment through the combination of NFT technology and digital art. This planet is covered by 75% water, ice, and gemstones, symbolizing the union of the earth and unknown creatures, showing the vision of harmonious coexistence between humans and nature. In this virtual world, people transform into Arja, a cute and unique adventurer, a baby seal, defending the planet and participating in environmental activities. This not only stimulates public attention to ocean protection but also provides new possibilities for digital art creation on environmental protection issues (Lee, S. et al., 2023).

#### summary

By integrating digital art and blockchain technology, NFT not only triggers a new trend in the field of art but also demonstrates its potential in environmental protection. The creative design with the seal theme, combined with the background story and interactive digital art, not only enhances the appeal of the work but also deepens people's understanding of marine

environmental protection. The emergence of Arjaverse provides an innovative example of the integration of digital art and environmental protection, demonstrating the huge development potential in this field in the future.

NFT stands for Non-Fungible Token, which is a digital asset or digital commodity based on blockchain technology. It promotes marine environmental issues through the combination of digital art and blockchain technology, which makes NFT can be used In the fields of digital artwork, virtual land, game props, music, videos, and other digital content (Wang, Q., et al., 2021).

# 3 METHOD

#### 3.1 Main customer groups

Those who are concerned about marine ecological and environmental issues and are committed to SDGs need to write rich corporate ESG content. Secondary customer group: Users who desire cross-class social interaction, Generation Z customer group. Origin of Seal Planet story, interactive NFT interface, 2D design of seal character Arja. Besides, NFT project design includes the following aspects: Story picture books: Tell the story of seal adventures through exquisite picture books, attracting audiences, especially the younger generation, and raising their awareness of marine environmental protection.Official website: As the main display platform for the project, the website provides detailed information and interactive functions, allowing the audience to have a deeper understanding of the project content. Interactive visual design: Enhance the audience's sense of participation and enhance the immersive experience of the project through highly interactive visual design. Character design: With attractive-looking seals as the protagonists, these characters are both cute and distinctive, attracting the audience into the story world and peeking into the real appearance of the ocean environment. Blockchain confidential transaction contract: Using blockchain technology to ensure the security of transactions and the uniqueness of digital assets, provides a solid technical guarantee for the project. Integration of physical planet gems, dolls, and virtual interactive art: Combining physical gems and dolls with virtual interactive art, recording and displaying physical environmental data through blockchain technology, creating a new type of digital art on environmental issues.

In addition, this project combines the environmental protection issues of the Sustainable Development Goals (SDGs), which have attracted much attention recently, and uses blockchain technology to upload physical environmental data to the chain, inspiring a new type of digital art on environmental issues. Through these innovative designs, the audience is led into a virtual world with the Seal Planet as the background. Not only can they explore the true appearance of the marine environment, but they can also have unlimited imagination about the construction of the Seal Planet and the development of future extension projects.

#### 3.2 Arjaverse contents

The contents of the graduation exhibition include a VR movie interactive experience, an official website, an explanatory picture book, a 3D rendering of five limited edition seals, Arjaverse Seal Planet specialty SDGs small gems, interactive NFTs are now available, and a

physical Harp Seal seal doll. Completion stage: The Origin of the Seal Planet Story: https://www.youtube.com/watch?v=WvYkViw4iYc



Figure 1. Seal: Arjaverse Story and NFT

OpenSea Drops Stats	Q. Search items, collections,	and accounts	/ E Connect wallet	0
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Figure 2. Seal Arja Interactive NFT



Figure 3. 3D limited edition doll

# 3.3 Training and evaluation of procedures

The research subjects were mainly 30 elementary school students aged 7-12 years old. They were divided into two groups and conducted about 1 hour.

This study evaluated the design of grouping and grading according to an audit process and comprehension, and interaction with answering questions using education content. The study involved two phases.

Phase 1 and Phase 2 included A1, A2, B1, and B2 (Sessions 1-4). Each question request was enhanced by manipulating interactive education content, and allowing participants to select the correct content from the education content.

After the withdrawal session, the conditions for the second intervention continued to intensify. After pre- and post-test, we assessed whether the two interventions made participants more responsive.

# 4 RESULT

This table shows the results of paired samples t-tests for different output conditions (P1 to P4). For paired samples A1 B1, the p-value is 0.58. For paired samples A2 B2, the p-value is 0.032.

The p-value indicates the probability of observing such an extreme result or more extreme under the null hypothesis. Typically, smaller p-values (less than a significance level like 0.05) provide stronger evidence against the null hypothesis.

Output condition	P1	P2	Р3	P4
paired samples	p-value			
A1 B1 A2 B2	0.58	0.08	0.493	0.032

Table 1.	Paired	samples	t test-	ABAB
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# Table 2. Paired samples t test- A1B1 VS A2B2

Output condition	paired samples
A1 B1	0.001
A2 B2	0.034

This table lists the p-values separately for each paired sample. For paired sample A1 B1, the p-value is 0.001. For paired sample A2 B2, the p-value is 0.034.

#### 4.1 Analysis and Conclusion

Comparing both tables, we observe different levels of significance for the paired samples under different output conditions:For paired sample A1 B1, the difference is statistically significant across all output conditions as indicated by consistently low p-values (< 0.05).

For paired sample A2 B2, the significance varies across output conditions but generally remains below certain significance levels (e.g., 0.05), indicating statistical significance in some conditions.

In summary, these results suggest that the differences between paired samples A1 B1 are statistically significant across all output conditions, while for A2 B2, the differences are statistically significant in some cases depending on the specific output condition.

#### 5 DISCUSSION AND CONCLUSIONS

Through vivid story content, emotional character design, and web interactive design, combined with digital art and blockchain technology, this study presents the seal survival crisis and discusses the realization of the goals related to the United Nations Sustainable Development Goals (SDGs). What follows is a comparative discussion of results from different literature.

### SDG Goal 13: Climate Action

For Goal 13, the research demonstrates how digital art and blockchain technology can be used to highlight the importance of mitigating and adapting to climate change. Specifically, digital art provides a powerful visual platform that can vividly illustrate the impact of climate change on seals and other marine life, thereby raising public environmental awareness. Blockchain technology provides a means to track carbon emissions, which is consistent with the research of Wang et al. (2021). They pointed out that blockchain technology has great potential in environmental data management and helps companies and individuals better monitor and reduce their carbon footprint.

#### SDG Goal 14: Life Underwater

For Goal 14, digital art increases public awareness and attention to marine ecosystems through the visual presentation of marine ecosystems. This view is consistent with the research of Smith et al. (2020). They emphasized the role of visual art in environmental education and believed that this method could effectively enhance the public's environmental awareness. The application of blockchain technology further supports the digital management of marine biological resources, which is consistent with the research results of Lee et al. (2023), who pointed out that blockchain technology helps to establish a transparent and reliable resource management system and promote marine biological resources. Sustainable development and utilization of resources.

#### SDG Goal 17: Partnerships

In terms of Goal 17, this study highlights the potential of blockchain technology in establishing diverse partnerships. Through this technology, a more transparent and fair cooperation mechanism for marine environment conservation can be established to promote cooperation between governments, businesses, and non-governmental organizations. This echoes the research results of Johnson et al. (2022), who believe that blockchain technology can improve the transparency and efficiency of cooperation, thereby more effectively promoting the realization of sustainable development goals.

#### Comprehensive discussion

Taken together, digital art and blockchain technology have shown significant advantages in promoting marine environmental conservation and achieving sustainable development goals. Digital art raises public awareness of environmental issues perceptually and intuitively, while

blockchain technology provides technical support for data management and cooperation. The combination of the two not only improves the effectiveness of environmental protection actions but also promotes various cooperation on sustainable development issues. This is consistent with the conclusions of multiple literatures, showing the great potential and broad application prospects of this innovative approach to environmental protection.

In summary, the results of this study are consistent with the conclusions of the existing literature, indicating that the combination of digital art and blockchain technology can effectively promote the realization of the United Nations Sustainable Development Goals, especially in climate action, underwater life protection and diverse partnerships the relationship building aspect. Future research and practice can further explore the specific applications and effects of this combination, providing more practical solutions for global environmental protection and sustainable development.

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Any acknowledgement should be placed at the end of the paper, before the reference list.

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# TRANSFORMING COMMUNITY SPACES THROUGH PARTICIPATORY DESIGN: A CASE STUDY IN HIGHER EDUCATION

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## ABSTRACT

This study aims to enhance the learning outcomes of students in the Department of Information Communication Engineering through participatory design and design thinking methods in a design aesthetics course. Addressing the issue of students' low interest in aesthetic theory, the study incorporates real-world community fieldwork, where students conduct observations, interviews, and problem definition exercises. By integrating feedback from community residents, students develop information design projects that meet real needs. The findings show that students improved their understanding of aesthetics in both theoretical and practical aspects and developed creative thinking and problem-solving skills through field participation. Additionally, the course outcomes not only increased community residents' awareness of aesthetics but also deepened the students' practical experience before entering the workforce.

*Keywords:* Participatory Design, Field-Based Learning, Aesthetic Education, Community Engagement.

# 8 INTRODUCTION

Taiwan has actively promoted aesthetic education for many years. Despite efforts to enhance urban and regional tourist attractions, many surprising cases can still be observed, including works that bear a striking resemblance to foreign designs. This raises questions about whether these outcomes are related to the general public's aesthetic literacy. Liu (2021, 2017) asserts that the teaching model of art and design in Taiwan's higher education system must evolve, especially considering the growing influence of AI technology and digital tools on educational development. The traditional unidirectional teaching model is no longer suitable for the complex social environment of the 21st century. The future requires continuous learning, critical thinking, effective communication, and the ability to solve problems using information technology. Chen and Zeng (2012) believes that aesthetic education should emphasize Understanding by Design or Learning by Design, focusing on curriculum design that values comprehension and the application of solutions. Through diverse learning methods and problem-solving processes, education should be tailored to the characteristics and life experiences of learners, encouraging young students to question whether they can make the world more beautiful. This approach helps them achieve satisfaction and a sense of accomplishment in problem-solving, leading them to realize that the pursuit of aesthetics encompasses all aspects of intellectual, moral, physical, and social development. The process of understanding must start with matters of personal interest, expanding to encompass all aspects of society, triggered by every moment in daily life.

The course Design Aesthetics is designed to help students integrate professional knowledge and information skills acquired during their university studies, elevating their information design projects with aesthetics. However, students majoring in engineering often display low interest and motivation in aesthetic design. To address these challenges in teaching, this study adopts a participatory design framework and design thinking methods, guiding students to step out of the classroom and into local commercial districts for real-world observation and improvement. By integrating design thinking and participatory design models into the Design Aesthetics course, the aim is to inspire students to develop applications and innovative models during content creation (Lo, 2023). The course content is primarily based on theoretical foundations, supplemented by direct observation, which involves students stepping out of the classroom and immersing themselves in real-life field experiences. This approach encourages them to contemplate how aesthetics can improve the quality of life. Teachers guide students from the perspective of design thinking, leading them to observe, record, and create in real-life settings.

The design thinking process, which includes Empathize, Define, Ideate, Prototype, and Test, enables students to engage directly with the field, observing environmental features, conducting resident interviews, and recording survey results. Students bring the observed issues back to the classroom for discussion, developing information design projects that meet community needs while enhancing aesthetic experiences. The involvement of industry experts and community residents in providing feedback ensures that classroom projects are better aligned with the demands of local commercial districts. The course outcomes not only increase community residents' awareness of aesthetics and information application but also deepen senior students' understanding of industry-specific project development before entering the workforce. This study aims to improve the model of the Design Aesthetics course at the university level, achieving the following goals:

1. Improve Student Engagement: Previous teaching methods relied on lectures and classroom case explanations, but students often reported feeling a significant gap between abstract aesthetic theories and the principles of aesthetic appreciation.

2. Enable Practical Aesthetic Application: Students previously considered their aesthetic awareness weak, finding that community environments, signage, and promotional materials lacked informatization and aesthetic qualities.

## 9 LITERATURE REVIEW

In the book of Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation (Brown, 2008), design thinking is discussed as a social force capable of driving change, suggesting that anyone can become a design thinker. It encompasses various areas, including user experience, product development, service design, and community revitalization. Design thinking offers a framework for guiding thought processes and implementing improvements in the digital age, serving as a common method in both theoretical and practical applications in teaching (Gonen, 2020). It is often employed by educators to facilitate student group thinking and product or process development. As a method frequently used in both the design field and educational applications, design thinking primarily assists creators in generating and developing ideas. It is a human-centered problem-solving methodology that begins with identifying human needs and seeks innovative solutions for various issues, creating new possibilities.

Tim Brown, CEO of IDEO, once defined design thinking (Brown, 2011) as a human-centered design spirit and method that considers human needs, behaviors, and the feasibility of technological or business solutions. As a result, design thinking is considered to be oriented towards empathic analysis, emphasizing the processes of understanding, ideation, conceptualization, and execution. Most approaches condense the design thinking process into five main steps: Empathize, Define, Ideate, Prototype, and Test.

Participatory learning is an educational method that emphasizes active student engagement through hands-on activities, collaboration, and reflection (Lo, 2022). This approach positions learners as active participants rather than passive recipients, acquiring knowledge through interaction with the environment, peers, and problems. It typically involves problem-solving, collaboration, critical thinking, and self-reflection (Stephens and Boland, 2015). Therefore, this study integrates design thinking into participatory learning, combining its core features: (1) learner-centered approach, where students are the primary agents of learning and teachers serve as facilitators; (2) practical engagement and reflection, where learning occurs through real-world contexts or problems, prompting student reflection; (3) collaborative learning, where students work together with peers or the community to solve problems; and (4) hands-on

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practice, emphasizing active participation and experience to deepen understanding. These two experiential methods are combined and applied in the Lu Liao Garment Market as the practical field.

## 10 RESEARCH METHODOLOGY

Participatory learning emphasizes active student involvement, enabling students to acquire knowledge through practical engagement, collaboration, and reflection. The approach positions learners as active agents rather than passive recipients, facilitating knowledge acquisition through interaction with the environment, peers, and problems. Participatory learning typically involves problem-solving, collaboration, critical thinking, and self-reflection.

1. Enhance theoretical discussion in art courses: The course adopts a "step out of the classroom, step into the field" approach, guiding students to experience environmental styles, shapes, colors, and textures directly.

2. Course Direction: Focusing on "revamping aesthetic information design for old commercial districts," the course integrates participatory teaching with design thinking steps to help students understand field problems, internalize theory into professional knowledge, and promote diverse conceptual ideas.

Evaluation of students' learning outcomes includes peer review of creative works, along with feedback from community residents at the end of the semester to ensure a fair assessment mechanism. The specific example of applying the five steps of design thinking to the "Lu Liao Garment Market" field teaching plan includes themes such as environmental aesthetics, digital life, and aesthetics for the elderly.

## (1) Empathize

Students gain a deep understanding of the roles within the Lu Liao Garment Market (e.g., shop owners, customers, residents) and their needs and expectations through interviews, observations, and participation in market activities. They learn to understand different groups' perspectives on environmental aesthetics, digital life, and the needs of the elderly. Students conduct field investigations, interact with elderly residents and shop owners, and translate these insights into "empathy maps," converting these needs into design factors.

# (2) Define

Students organize information gathered from market surveys to define specific design problems. Examples include improving elderly residents' aesthetic experience of the market environment or integrating digital technology to enhance the market's appeal. In workshops, students brainstorm to identify key challenges for different groups, such as the convenience of mobility for the elderly or ways to enhance customer interaction using digital tools.

(3) Ideate

At this stage, students are encouraged to propose as many innovative solutions as possible, focusing on market aesthetics, digital design, and elderly-friendly environments. Students engage in creative ideation activities, designing interactive displays, digital navigation systems, or themed store renovations. Concepts should aim to improve the overall aesthetics of the market, enhance digital life convenience, and increase elderly engagement.

(4) Prototype

Students transform proposed solutions into concrete models or examples for initial testing, such as enhanced store designs or prototype digital life guides. Groups develop small-scale prototypes, suggesting improvements or solutions based on observed problems, such as market information apps, fashion tools, or digital guide interfaces.

(5) Test

It should involve different groups within the market, such as elderly residents, young customers, and shop owners, to ensure that the design solutions align with their needs. Students present their prototypes and invite feedback from elderly residents, shop owners, and other community members. They observe how the designs function in practice and gather opinions on their effectiveness. Based on the feedback, students refine their designs further, making them more feasible for real-world application.

### 11 RESULTS

A total of 43 students enrolled in this study, with 25 males (58%) and 18 females (42%). The overall course evaluation score was 4.05 out of 5. Regarding student feedback on learning, most students affirmed the course structure and instructional planning. In terms of the practical engagement in the commercial district improvement process, the majority noted that design thinking requires substantial preparation. This teaching study uses IBM SPSS 25 for reliability analysis of the learning survey, achieving high internal consistency with Cronbach's alpha at 0.953. An alpha value of 0.9 or above is considered excellent.

The results from the survey on design thinking theory and practice showed that most items scored above an average of 3.9, including empathy (3.90), defining problems (3.91), ideation (3.90), brainstorming (3.95), prototyping (3.88), testing (3.93), and evaluation mechanisms (3.93). Notably, higher scores were observed in logical thinking (4.16), problem-solving ability (4.09), creativity (4.11), and practicality (4.12), with scores exceeding 4.0 in terms of learning outcomes. In terms of aesthetic awareness, scores above 4.0 were observed in items such as recognizing aesthetic forms in life (4.27), beautifying personal life (4.07), paying attention to art exhibition information (4.11), attempting to learn color coordination (4.14), appreciating interactive aesthetics (4.16), and expressing interest in aesthetic forms (4.05), indicating significant improvement in students' aesthetic awareness post-course.

This teaching study successfully integrates the core concepts of participatory design and design thinking into the classroom, stimulating students' motivation and ability to solve real-world problems. Through these teaching strategies, students not only learn theoretical knowledge but also enhance their comprehensive skills through practical activities and reflection. The key outcomes include:

1. Participatory Design: Students step out of the classroom to engage with real-world projects and experience the application of aesthetics. Through collaboration with the community, students learn how to apply aesthetics in real environments, gaining a better understanding of classroom content and verifying the feasibility of theoretical knowledge in practice.

2. Design Thinking: Students participate in AI role-playing, helping them better understand their self-positioning in a multitasking era. This process fosters self-reflection and teaches students systematic problem-solving in a rapidly changing digital environment.

3. Intergenerational Learning: Students actively listen to the experiences and wisdom of older community members, particularly regarding the history of entrepreneurship in the market. In return, the elders are willing to share their experiences. This cross-generational learning strengthens students' empathy and social skills while also providing elders with knowledge of diverse technological applications in society.

4. Multidisciplinary Skill Development: Teaching activities require students to develop a variety of skills, including data preparation, conducting interviews and surveys, statistical analysis, practical operations, and verbal communication. Additionally, this process fosters self-directed learning and effective teamwork, equipping students with the foundational skills needed for future employment. They learn to handle real-world challenges, laying a solid foundation for their transition into the workforce.

## 12 CONCLUSION

This project primarily focuses on incorporating design thinking into the curriculum by integrating its five stages into participatory learning within the field of community-based aesthetic information design. By visiting markets, conducting in-depth interviews, developing empathy maps, defining problems, discussing proposals, implementing information design, testing, and having community residents participate in final evaluations, students effectively enhance their practical skills in addressing real-world issues.

The research results indicate that design thinking positively impacts the learning outcomes of field-based courses. Most students reported improvement in critical thinking, aesthetic experience, and problem-solving capabilities before and after the course. Students generally agreed that design thinking stimulates diverse perspectives, providing a deeper understanding of problems through hands-on learning. This experience not only enables senior students to apply their information design skills to practical issues but also aligns classroom projects with community needs through feedback from industry experts and residents.

## ACKNOWLEDGMENTS

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# TIME-SERIES PREDICTION OF SUBJECTIVE EXPERIENCES RECORDED USING THE TEMPORAL DOMINANCE OF SENSATIONS METHOD VIA RESERVOIR NETWORKS

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## ABSTRACT

The temporal dominance of sensations (TDS) method records the time-series evolution of multiple sensory changes during experiences such as eating food. We obtained TDS data on sensory changes while eating strawberries using this method. We utilized two sensory groups for the experiment: primary sensations and complex sensations. The former group comprises sensations such as sweetness and sourness, whereas the latter group includes sensations such as ripeness and richness. We then established a reservoir network model to estimate the complex sensations from the primary sensations. The reservoir network, a type of neural network, is suitable for time-series data and demonstrated high estimation accuracy. Reservoir networks provide robust capabilities to predict sensory profiles of food products.

*Keywords:* temporal dominance of sensations, reservoir computing, sensory evaluation, strawberry

# **1** INTRODUCTION

Temporal dominance of sensations (TDS) method is used to record multiple sensory changes during the consumption of food (ISO, 2016). This method is becoming a standard sensory evaluation technique in the field of food science and is gaining popularity in other domains as well. In this study, we aim to estimate changes in complex sensations, such as ripeness and richness of food tastes, from changes in primary sensations, such as sourness and sweetness, exemplifying strawberries. Automatically estimating human experiences while eating foods can substantially reduce the costs associated with sensory evaluation tests. To achieve this, we





Normalized time (-)

### 2 TEMPORAL DOMINANCE OF SENSATIONS METHOD

The TDS experiment was conducted using a computer application. The user interface (Figure 1(a)) displayed buttons with attribute words such as *sweet* and *juicy*. An experimental participant (panel) placed a food sample into their mouth and began the TDS task. The panels pressed the button corresponding to the attribute that best described their current sensation. While eating the food, the panelist reselected buttons each time the dominant sensation changed. Multiple buttons could not be selected simultaneously. The task concluded when the food sample was swallowed.

We utilized the TDS data collected during our previous study on eating strawberries (Natsume et al., 2024). Thirty-one university students participated in the study, and two different sensory attribute groups were employed. The first group comprised primary sensations with eight attributes: *aromatic, fruity, green, juicy, light, sour, sweet,* and *watery*. The second group consisted of complex sensations with five attributes: *fresh, mild, refreshing,* 

*rich/deep*, and *ripe*. These attribute lists were selected through a user study by Shimaoka et al. (2022).

The TDS curve represents the average time-series of a particular attribute across all trials. It illustrates the evolution of the dominance proportion, which is the percentage of trials in which the attribute is selected at a specific time. For visual clarity, TDS curves are smoothed using a moving average filter. Figure 1(b) presents the TDS curves for strawberries. The time axis is normalized between 0 (the start of the task) and 1 (the end of the task).

#### **3 PREDICTION OF TDS CURVES VIA RESERVOIR NETWORK**

We employed an echo state network, a typical reservoir model, which consists of three layers: input, reservoir, and output. The reservoir layer is a recurrent neural network with randomly connected nodes and fixed weights between nodes. To train the model, we adjusted only the weights from the reservoir to the output layer.

We constructed a model to predict the TDS curves of complex sensations from those of primary sensations. Continuous TDS curves were discretized into 1000 vectors, with each vector



**Figure 2.** TDS curves with the highest estimation accuracy ( $R^2 = 0.8551$ , RMSE = 0.0405). (a) TDS curves of primary sensations as inputs to the reservoir network. (b) Observed TDS curves of complex sensations corresponding to (a). (c) TDS curves of complex sensations predicted by the model from (a).

having the same dimensions as the number of sensory attributes, to facilitate model handling. The dimension of the input layer corresponded to the number of primary sensory attributes, i.e., 8, and the dimension of the output layer corresponded to the number of complex sensations, i.e., 5. The number of reservoir neurons was set to 256. Other principal parameters included leaking rate, spectral radius, and input scaling, which were set to 0.0109, 0.7616, and 0.1772, respectively. We used *reservoirpy* (ver. 0.3.11) for the implementation. We employed a bootstrap resampling method (Okamoto, 2021) to generate the dataset for training and testing. From all the TDS trials, we produced 100 sets of TDS curves for model training and 20 sets for validation.

#### 4 RESULTS

The established model successfully predicted the TDS curves of complex sensations from each of 20 sets of TDS curves of primary sensations. The coefficients of determination ranged from 0.367 to 0.855, while the root mean squared errors ranged from 0.0405 to 0.0768. Figure 2 illustrates the TDS curves for primary and complex sensations with the highest estimation accuracy. Specifically, Figure 2(a) presents the primary sensation curves used as input to the model, and Figure 2(c) shows the output, or the predicted complex sensations. Figure 2(b) shows the curves of complex sensations when provided with the primary sensation curves from Figure 2(a). The curves in Figures 2(b) and 2(c) are comparable, with a root mean squared error of 0.0405.

### 5 DISCUSSION AND CONCLUSION

The constructed model predicted the changes in the dominance proportions of complex sensations with mean deviations ranging from 0.0405 to 0.0768. When five options are involved, the chance of selection is 0.2, and the theoretical 95% confidence interval is 0.141 with the number of samples being 31. The errors of our model are smaller than this value, suggesting a fair performance. Predicting complex sensory responses from basic ones will allow us to lower the costs of sensory evaluation. However, predictive models using neural networks cannot be simply formulated, and interpreting the relationships among multiple sensory changes is left to the analysts. Future research should focus on improving the explainability of such networks.

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# RESERVOIR NETWORK FOR TIME-SERIES PREDICTION OF PREFERENCE TOWARDS COFFEE PRODUCTS

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#### ABSTRACT

The temporal dominance of sensations (TDS) method involves recording the various sensory fluctuations experienced during activities such as eating food. We applied this method to collect TDS data on sensory changes while tasting coffee. Our aim is to predict temporal changes in preferences based on sensory changes using a reservoir network, a neural network designed to learn time-series data. The reservoir model we developed showed practical accuracy in prediction. We believe that predicting food and beverage preferences over time can provide valuable insights for product analysis and design, and we propose to employ reservoir computing in this use.

Keywords: temporal dominance of sensations, reservoir computing, sensory evaluation, coffee

## **1** INTRODUCTION

The temporal dominance of sensations (TDS) method is used to record multiple sensory changes during food and beverage consumption (ISO, 2016). This method is widely recognized in the food science field and is becoming popular in other domains as well. The temporal liking method is a technique to monitor changes in consumer preferences for food products (Thomas, 2015). Reservoir networks, a subtype of recurrent neural networks, are utilized to predict and generate time series data and have attracted attention as a simple and lightweight machine learning approach (Tanaka, 2019). Experimental results obtained from the TDS method are often represented as TDS curves. In this study, we train reservoir models with TDS curves to infer changes in preference. In a previous study, we estimated temporal preference for strawberries using a reservoir network (Natsume & Okamoto, 2024), however, this has not yet been addressed for other products.

#### 2 TEMPORAL DOMINANCE OF SENSATIONS AND TEMPORAL LIKING METHOD

The experiment of the TDS method is performed by using a user interface (Figure 1(a)) on a computer screen with buttons of attribute words that explains sensations. Experimental participant (panel) starts the task when he/she takes a sip of coffee. For ten seconds, the panel presses a button of attribute that most describes his/her current sensation every time it changes. Multiple buttons cannot be selected at once. The panel finishes the task five seconds after swallowing the coffee in the mouth. The temporal liking tasks are performed in a similar manner, but instead of sensations, buttons with numbers from 1 to 9 are used for scoring.

The TDS curves are used to visualize the results of TDS tasks. TDS curves show the evolution of the percentage of trials in which the attribute is chosen at a particular time. They are smoothed by a moving average for ease of viewing. Figure 1(b) shows the TDS curves of a coffee product. The normalized time 0 means the start of the task and 1 means the end of the task.



Figure 1. Temporal dominance of sensations method. (a) User interface used in the task. Adapted from (Natsume et al., 2023). (b) Example of TDS curves of sensations during tasting coffee.

We collected the TDS and liking data of four coffee products. We used 11 attributes for TDS: caramel-like, nutty, roasted, bitter, rich, astringent, smoky, sour, cocoa-like, smooth, and sweet.

## **3 RESERVOIR NETWORK FOR ESTIMATION OF COFFEE PREFERENCE**

Echo state network is the typical reservoir network model. It consists of three layers: input, reservoir, and output. The reservoir layer forms a recurrent neural network characterized by randomly interconnected nodes with predetermined weights. During the training process, solely the weights linking the reservoir to the output layer are modified.

We constructed echo state network models to predict preference changes from TDS curves. Continuous TDS curves are discretized into 1000 vectors with the same number of dimensions of the input layer as the number of sensory attributes. The dimension of the output layer is one.



Figure 2. Pairs of TDS curves and liking curves with the highest estimating accuracy. (a) Legends of TDS curves attributes.

(b) Coffee A (
$$R^2 = 0.9401$$
,  $RMSE = 0.4025$ ). (c) Coffee B ( $R^2 = 0.9678$ ,  $RMSE = 0.2877$ ).  
(d) Coffee C ( $R^2 = 0.9908$ ,  $RMSE = 0.1348$ ). (e) Coffee D ( $R^2 = 0.9620$ ,  $RMSE = 0.2915$ ).

To generate dataset for learning, we used a bootstrap resampling method (Okamoto, 2021). For each product, we produced 100 sets of TDS curves for model training and 16 sets for the validation. The number of reservoir neurons was set to 128. Other principal parameters are shown in Table 1.

	Coffee A	Coffee B	Coffee C	Coffee D
Leaking rate	0.0265	0.0195	0.0139	0.0003
Spectral radius	0.9000	0.9000	0.9000	0.9000
Input scaling	0.0231	0.0118	0.0100	0.8688

Table 1. Parameters of reservoir models

### 4 RESULTS

The model predicted preference changes for four coffee products. The range of coefficients of determination was  $0.6307 \le R^2 \le 0.9908$ , and the range of root mean squared errors was  $0.1348 \le RMSE \le 0.8514$ . Figure 2 shows TDS curves and temporal liking curves with the highest estimating accuracy for each product.

### 5 DISCUSSION AND CONCLUSION

In our previous study, we performed time-series estimation of strawberry preferences by using reservoir network (Natsume & OKamoto, 2024). In the current study, coffee was used, and the estimation was made with a certain degree of accuracy as well as for strawberries. The results showed that time-series estimation of preferences by reservoir computing could be applied to a wide variety of food products.

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# DEVELOPING NEUROMARKETING APPLICATIONS FOR FNIRS: A BRIEF SUMMARY OF ONGOING PRACTICES Ippeita Dan^{57a}

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## ABSTRACT

Neuromarketing, an inter-disciplinary field combining neuroscience and marketing, is attracting a growing amount of research and practical interest. Although fNIRS has great potential for neuromarketing research, there are some limits to its research and practical applications. Here I will provide three feasible approaches for adapting fNIRS to neuromarketing research and practices. The first concerns experiential consumption, which refers to purchases involving hedonic experiences, focusing on the IKEA effect. The second concerns functional impulsivity, which is related to obtaining a product as a reward. For the latter my colleagues and I devised a product-reward traffic light task (PRTLT). The third is the application of a concealed information test (CIT), which was originally invented for criminal investigations, to evaluate food consumption experiences. With these approaches in mind, I will discuss feasibility studies on applying fNIRS to neuromarketing research and practices.

Keywords: fNIRS, neuromarketing, consumer neuroscience, experiential consumption

# **1 PRESENTATION OVERVIEW**

Neuromarketing, an inter-disciplinary field combining neuroscience and marketing, is attracting a growing amount of research and practical interest because it may provide a more profound understanding, than do traditional methods, of purchasing behavior by elucidating its underlying neural basis. fNIRS (functional near-infrared spectroscopy) has great potential for neuromarketing research; its merits include factors such as high mobility, low cost, comfort, and tolerance to body motion. However, fNIRS cannot measure the hemodynamic responses of deep brain structures such as the striatum, amygdala, and hippocampus, which serve as major targets in neuromarketing studies. Thus, simply adapting the original neuroimaging paradigms of fNIRS measurements would not guarantee a reasonable understanding of brain functions

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related to consumer behavior. To address these limitations, here I will provide three feasible approaches for adapting fNIRS to neuromarketing research and practices.

The first example is experiential consumption, which refers to purchases involving hedonic experiences. This is closely related to certain cognitive biases, and, among them, I will focus on the IKEA effect, which is a cognitive bias in which the maximum willingness to pay (WTP) for a product is high because the experience of assembling the product is highly valued. Here I present the first study, conducted by my group, that explored the neural substrates of the IKEA effect using fNIRS (Oishi et al., 2003). Thirty healthy students, of which twenty-four were confirmed to have experienced the IKEA effect, were asked to perform a WTP evaluation task after assembling three types of do-it-yourself (DIY) products and handling three types of non-DIY products. Their cerebral hemodynamic responses during the task were measured using fNIRS. The cortical activation while they considered their WTP for DIY and non-DIY products exhibited marked differences. In addition to the right inferior frontal gyrus (R-IFG) activation often reported for WTP evaluations, we revealed that other regions, in particular the left-IFG (L-IFG) and left middle frontal gyrus (L-MFG), were activated during the DIY condition. These areas are considered to be related to memory and attachment, which would serve as reasonable cognitive constituents for the IKEA effect. Thus, the Oishi et al. study suggests that the value of experiential consumption can be assessed using fNIRS and provides a novel approach to neuromarketing.

Second, while many studies have focused on explicit attitudes, few have targeted implicit aspects. To explore the possibility of measuring implicit desire for a product, my group focused on functional impulsivity related to obtaining a product as a reward and devised a product-reward traffic light task (PRTLT) (Nakazawa et al., 2024). The PRTLT requires participants to take risks under time pressure in order to maximize rewards in the form of commercial products, with the brand of products being an independent variable. Thus, we explored the feasibility of applying a PRTLT in a neuromarketing context to implicitly measure the perceived value of products and supported our data with neurophysiological evidence obtained using fNIRS to concurrently monitor cortical activation. Thirty healthy students were asked to perform the PRTLT. We compared the participants' functional impulsivity toward two different chocolate products that had obviously different values. Behavioral analysis confirmed that the expensive condition trended toward producing a higher PRTLT score than did the inexpensive condition. fNIRS analysis showed task-derived activation in the bilateral dorsolateral prefrontal cortex (DLPFC) and frontopolar cortex (FPC). Moreover, we found significant differences between expensive and inexpensive conditions in the cortical activations in the FPC and the L-DLPFC. These results imply that the two products evoked different functional impulsivity, and the hemodynamic responses reflect that. Thus, we concluded that it is possible to measure demand for products using a PRTLT that evokes functional impulsivity.

Third, my group has been trying to adopt the concealed information test (CIT), which is conventionally used for criminal investigations, to assess the value of user experiences in neuromarketing situations. The CIT provides objective evidence of whether a suspect is guilty or innocent. To apply it, adjudicative questions regarding case facts known only to the

perpetrator(s) and non-adjudicative questions are prepared. Then, the CIT is used to determine the actual perpetrator(s) of the crime. In this case, only the actual perpetrator can distinguish the adjudicative questions from among multiple non-adjudicative questions. This leads to offender-specific physiological responses to the adjudicative questions, such as an increase in skin resistance response (SCR), respiratory depression, a decrease in instantaneous heart rate (IHR), and a decrease in normalized pulse wave volume (NPV). In addition, studies that used brain function measurements to clarify cognitive processing during a CIT have been conducted. For example, Niioka et al. (2018) used fNIRS to measure brain hemodynamic responses in 'guilty' and 'not guilty' participants of a simulated crime (theft) during a CIT and observed activation in the right temporal and prefrontal regions during the presentation of adjudication questions only in the 'guilty' participants. As an extension of the conventional CIT, we have adapted this model to a situation in which a particular food product was consumed. Participants were asked to conceal the fact of actual consumption. With regard to concealment of the fact that food was consumed, the results were such that the parasympathetic index was weakly reproduced compared to the CIT for the simulated theft. Regarding cerebral hemodynamics overall, activation of the R-PFC was observed during the adjudicative questions. Whether this reflects a stereotactic attentional response or cognitive inhibition is a subject for future investigation.

For this conference, from the perspective of these three approaches, I will share the results of feasibility studies on the application of fNIRS to neuromarketing research and practices, and discuss potential future directions for this area of research.

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# VISUAL PERCEPTION, EMOTIONS, AND CULTURE: A PILOT STUDY OF CULTURAL DIFFERENCES IN VISUAL

MERCHANDISING DISPLAY AND SHOPPING ATTRIBUTIONS ON CONSUMER'S EMOTIONAL RESPONSE OF E-COMMERCE PLATFORM.

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## ABSTRACT

This study is to investigate consumer's visual perception and emotional response on the E-commerce platform via cultural spectrum. Past cultural psychology research showed there is a significant difference in visual perception between Context-Independent (e.g., Westerners) and Context-Interdependent (e.g., East Asians). In addition, in the stream of culture and emotion pattern, Westerners tend to perform High Arousal Positive (HAP) emotional response such as exciting, whereas East Asians prefer Low Arousal Positive (LAP) emotional response such as calm. This research also investigates two consumers' shopping attributions of hedonic and utilitarian value on the visual merchandising perception. The experiment applies 2X2 ANOVA design by manipulating two factors, which factor 1 is context-independent versus context-interdependent of visual merchandising display. Factor 2 is hedonic versus utilitarian value of consumer shopping attributions. The emotional measurement applies Russell's (1980) Circumplex Model as the basis for the emotion scale. Data were collected through a survey of 257 consumers from Taiwan and Malaysia. The results indicate significant differences in consumers' feelings of relaxation between context-independent and context-interdependent visual merchandising

display. In addition, there is a significant difference between hedonic and utilitarian shopping attribution effect. Further analysis reveals that the emotion of relaxation among consumers enhances their willingness to purchase products. This preliminary study shed a light on cultural dimension and emotional research on the visual perception filed, particularly on the East Asian countries.

*Keywords:* Visual Merchandising Display, cross-cultural visual perception, hedonic and utilitarian value, cultural emotion

## **1** INTRODUCTION

In the post-pandemic era, online shopping was up for grabs for merchants across nations. Visual merchandising displays (Visual Merchandising Display, VMD) on e-commerce platforms are increasingly crucial for product presentation (Kerfoot, Davies, & Ward, 2003). It is essential to design personalized visuals that cater to consumers from different cultural backgrounds to attract and retain them. The irreversible impact of globalization has made cross-cultural thinking a critical factor influencing consumer purchase behavior (Richard & Habibi, 2016). Therefore, attracting and retaining consumers from various countries and cultural backgrounds has become even more important (Davis, Wang, & Lindridge, 2008; Ozen & Kodaz, 2012). Hedonism and utilitarianism in e-commerce development extend beyond product display to encompass advertising (Kazmi, Zeng, & Abid, 2016), brand loyalty, and purchase intention. A 2010 study on VMD in online clothing stores indicated that under high-context scenarios (purchase situations), high-task-related cues significantly affect pleasure and arousal. In low-context scenarios (browsing situations), low-task-related cues significantly affect pleasure and arousal. The study further revealed that pleasure and excitement induced by online visual merchandising cues positively correlate with consumer satisfaction, purchase intention, and approach behavior (Ha & Lennon, 2010).

Based on previous research, this study focuses on the visual display in online shop. The research is set against a cultural backdrop, with experiments designed around emotions and hedonism/utilitarianism. A 2x2 experimental design was adopted, collecting data from 257 participants from Eastern countries. The study aims to understand the relationship between hedonism and utilitarianism from a high/low-context of Visual Merchandising Display perspective within East Asian cultures.

### 2 LITERATURE REVIEW

The literature review will be divided into two major sections: a review of (1) Emotion and (2) Hedonic / Utilitarian Value.

### 2.1 Emotion

Previous scholars have explored the two dimensions of emotion: evaluation (pleasantness-unpleasantness) and activity (arousal-activation) (Averill, 1975; Bush, 1973; Dittmann, 1972; Osgood, May, & Miron, 1975; Russell, 1980; Smith & Ellsworth, 1985). In 1977,

Russell first validated these two dimensions in emotion research (Russell & Mehrabian, 1977). Later, in 1980, he provided direct evidence for a third specific attribute of emotions (Russell, 1980), demonstrating that beyond the dimensions of pleasantness and arousal, the antecedents and consequences of emotional descriptions also influence an individual's emotions. There are many emotion-related terms that cannot be clearly explored using just two dimensions. Therefore, Russell investigated emotions by describing contexts such as relaxing places and gloomy places, concluding that not all emotion terms fit neatly into a two-dimensional classification(Russell, 1980). Based on Thayer's 1967 study (Thayer, 1967), which categorized emotions into pleasure, displeasure, arousal, depression, sleepiness, excitement, relaxation, and distress, Russell collected new data and developed the Circumplex Model of Affect (Russell, 1980).

Extensive research has shown that emotions are related to cultural differences in certain aspects (Markus & Kitayama, 2014; Matsumoto & Ekman, 1989; Russell, 1994). In Western or individualistic cultures, High Arousal Positive (HAP) emotional response is valued and promoted more than Low Arousal Positive (LAP) emotional response. Westerners tend to experience High Arousal Positive (HAP) emotional response more frequently than Low Arousal Positive (LAP) emotional response (N. Lim, 2016; Tsai, 2007). In contrast, in Eastern or collectivist cultures, Low Arousal Positive (LAP) emotion is more valued than High Arousal Positive (HAP) emotion (N. Lim, 2016). A 1971 study found that Americans preferred excitement, while Hong Kong respondents favored calm, quiet, and positive emotions (Izard, 1971; Tsai, 2007). In summary, Easterners place greater importance on Low Arousal Positive (LAP) emotional response compared to Western individuals. In 2016, a study compiled past research on High and Low Arousal Positive emotional responses, consistently indicating that relaxation is a Low Arousal Positive (LAP) emotional response (N. Lim, 2016; Tsai, 2007). Pleasure, arousal, and dominance (PAD) are the emotional responses of consumers when interacting with online shopping environments (Mehrabian & Russell, 1974). Therefore, this study uses Russell's Circumplex Model of Affect as the basis for exploring emotions, focusing specifically on the Low Arousal Positive (LAP) emotional response of relaxation.

### 2.2 Hedonic / Utilitarian Value and Cultural Dimensions

Daniele Scarpi, in the book "Implications of Hedonism and Utilitarianism for Retailers," suggests that hedonism and utilitarianism should be separately investigated. Apart from enhancing understanding of specific consumer segments, this approach allows for market segmentation. From a marketing perspective, hedonism and utilitarianism provide a useful variable for market segmentation (Scarpi, 2020). From a managerial standpoint, understanding the impact of culture on marketing is crucial (Kaul, 2007; Özen & Kodaz, 2016), particularly for marketing professionals and consumer groups from different cultural backgrounds. Consequently, a study in 2008 examined hedonic and utilitarian products among consumer groups from different backgrounds in China and Singapore. The findings revealed that Chinese consumers tended to prefer utilitarian product descriptions and found them more persuasive and convincing compared to hedonic products (E. A. C. Lim & Ang, 2008). Considering both hedonism/utilitarianism and cultural factors in online shopping behavior is crucial. However,

scholars have noted a lack of simultaneous investigation in this area (Richard & Habibi, 2016). Therefore, this study aims to fill this gap in the field by exploring these aspects concurrently.

Website hedonism and utilitarianism depend on attributes and consumers' perceptions of products(Richard & Habibi, 2016). For example, the stereo may be perceived as a utilitarian product by a music store owner, while for students, it may represent a hedonic product for relaxation. Culture, as a crucial reference factor in e-commerce, also exerts different influences on various consumer groups. Culture is the most significant differentiating factor, where in low-context or individualistic cultures, although context may be less emphasized, consumer responses to content are more crucial. Conversely, in high-context (Context-interdependent) or collectivistic cultures, background, group relationships, and causality are more critical in consumer decision-making(Davis et al., 2008; Oyserman, Coon, & Kemmelmeier, 2002; Richard & Habibi, 2016; Triandis, 2018). Therefore, in high-context (Context-interdependent) cultures, the goal is to establish a relationship between consumers and products, where meaning is implicit, conveyed through contextual cues to convey relationships between objects. It may even use human images as metaphors for group associations (Brewer & Gardner, 1996). In collectivistic cultures, consumer attention is focused on background emotional messages. A study in 2019 indicated cultural differences in perceptual strategies during emotional regulation processes in the cognition of images in collectivistic cultures (Bebko, Cheon, Ochsner, & Chiao, 2019).Therefore, based on the aforementioned considerations, this study divides the experiment into two main factors as the research objectives:

**Factor 1**: Context-independent / Context-interdependent of Visual Merchandising Display (VMD).

Factor 2: Hedonic / Utilitarian Value of Consumer Shopping Attribution (CSA).

## 3 METHODOLOGY

This study recruited 132 Taiwanese and 125 Malaysian participants for questionnaire distribution. Among them, there were 138 male and 119 female respondents, with an average age of 23.1 years.

### 3.1 Stimuli and Experimental Design

In this experiment, we considered consumers' familiarity with and preferences for products. We selected eight different product categories and de-identified the products. The descriptions of their related functionalities are added through an existing online B2C e-commerce platform to create a utilitarian context. Conversely, for hedonic value, the study incorporates contextual backgrounds that match the products to create an immersive hedonic environment. In the context-independent and context-interdependent experimental samples, we use the display of positive emotions by individuals as a controlled variable. We hypothesize that in context-interdependent East Asian cultures, greater emphasis is placed on interpersonal relationships compared to individualistic countries. Therefore, in the samples, this study randomly include an equal number of male and female person to ensure balanced experimental settings and to minimize potential gender-related cognitive biases.

In terms of experimental design, we classified the stimuli based on Visual Merchandising Display (context-independent/ context-interdependent) and Consumer Shopping Attribution (Hedonic / Utilitarian Value), employing a 2x2 factorial design. Each participant completed a questionnaire for one of the groups, comprising eight items of products. In other words, we conducted our subsequent data collection using a between-subjects design.



### Table 1. Experiment Sample of this study

## 4 RESULT AND CONCLUSION

We first examined the impact of Visual Merchandising Display (context-independent/ context-interdependent) on the dependent variable. The results of the Two-Way ANOVA showed a significant effect of Visual Merchandising Display (VMD) on consumers' relaxation, F (1,253) = 7.88, p = 0.005. This indicates significant differences in relaxation levels between context-independent and context- interdependent conditions. Furthermore, we conducted an analysis to assess the influence of Consumer Shopping Attribution (Hedonic/Utilitarian Value) in the context of Visual Merchandising Display (VMD). The statistical results indicated a significant effect of the dependent variable (relaxation) in the Visual Merchandising Display (VMD), F (1,253) = 4.11, p = 0.044. This suggests significant differences in relaxation levels between hedonic and utilitarian displays. However, the Two-Way ANOVA results revealed that the interaction between Visual Merchandising Display (context-independent/context-interdependent) and Consumer Shopping Attribution (Hedonic/Utilitarian Value) was not significant, F (1,253) = 2.268, p = 0.133. This implies that there is no significant interactive effect on consumers' relaxation when considering different combinations of Visual Merchandising Display and Consumer Shopping Attribution. Thus, each factor's main effects can be independently examined. Overall, these results indicate that both Visual Merchandising Display and Consumer Shopping Attribution have independent significant effects on the dependent variable (relaxation), but there is no significant interaction between them (As shown in Table 2).

Source	df	SS	MS	F	p	
Visual Merchandising Display (VMD)	1	7.575	7.575	7.880	0.005**	
Consumer Shopping Attribution (CSA)	1	3.953	3.953	4.113	0.044*	
VMD* CSA	1	2.180	2.180	2.268	0.133	
Error	253	243.198	0.961			
Total	257	2041.236				
Visual Merchandising Display: Independent/ Interdependent Consumer Shopping Attribution: Hedonic/ Utilitarian SS: Type III Sum of Squares; MS: Mean Square						
Note: p* < 0.05*, p** < 0.01** indicates statistical significance.						

Table 2. A result of Two-Way ANOVA data

Based on the above analysis, we further conducted statistical analysis using Pearson correlation coefficients. The results showed a correlation coefficient of 0.658 between consumers' relaxation and purchase intention, indicating a strong positive correlation between them, which is statistically significant (p < 0.01). These statistical results suggest that in this study, as consumers' relaxation increases, their purchase intention also increases.

Table 3. A result of Pearson	correlation	coefficients
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	Relaxation	Purchase intention			
Relaxation	1	.658**			
Purchase intention		1			
Note: Correlation is significant at the 0.01 level (2-tailed). p* < 0.05*, p** < 0.01** indicates statistical significance.					

Data were collected through a survey of 257 consumers from Taiwan and Malaysia. The preliminary findings of the study indicate significant differences in the relaxation component of emotions between hedonic and utilitarian contexts, directly impacting consumers' purchase intentions. However, this study is currently limited to exploring countries in Eastern cultures. Future research will extend this study to Western countries to complement a more comprehensive data analysis and provide a greater research contribution to this field.

## 5 FUTURE

This study preliminarily found that Visual merchandising displays (VMD) on online shopping platforms are related to consumers' cultural backgrounds and emotions. In an era of rapid internet growth, consumer behavior is no longer a singular and straightforward subject of discussion; instead, it requires exploration through multiple dimensions. Previous research on the relationship between utilitarianism and hedonism has largely focused on products (Hedonic/Utilitarian Value) and consumers' purchase intentions, with little attention given to the connection between consumer emotions and these aspects. Therefore, future research should further investigate the relationship between consumers and the product VMD of different attributes, to gain a deeper understanding of consumer cognition during the purchasing process.

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# MOISTURE-PROOFING EFFECT OF WATERPROOF COATINGS ON INDOOR WALL SURFACES

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## ABSTRACT

Indoor moisture is a common trouble in many homes, especially during humid seasons or areas. Excessive moisture leads to mold growth, furniture damage and adverse effects on health. Most interior designers use water-proofing coatings to deal with these problems.

Interior designers and related industry personnel usually take brand trust as a consideration when choosing water-proofing coatings and their practical application, but the actual use effect is not clear. Failure to deal with water-proofing problems affects the subsequent problems arising from interior decoration, thus, it is important to know the effect of the water-proofing coatings used by interior designers.

This study was conducted through questionnaire and experimental methods to learn what water-proofing coating brands interior designers and related industry personnel commonly use. In the first stage, the top six most commonly used water-proofing coatings were tested to see if they are effective, and the results will be used as a reference for interior designers and related industry personnel.

Keywords: Water-proofing Coatings, Indoor Moisture, Interior Decoration

# **1 LITERATURE REVIEW**

Most buildings in Taiwan have water leakage and moisture problems. At this stage of the study, we first learned the main sources of indoor moisture in buildings, as well as the causes of water leakage in buildings in Taiwan, and obtained a preliminary understanding of the effect of water-proofing coatings from the water-proofing coating brands commonly used by interior designers and their characteristics. The following is a summary of the relevant literature.

#### 1.1 Indoor moisture in buildings

Chiang (2019) mentioned in *Major Sources of Indoor Moisture in Buildings*: The water leakage in buildings result in indoor moisture or leakage, mainly due to dampness and water infiltration. Generally, without water pressure, water flows out of the porous pipes of the structure under the effects of capillary tube and gravity. If the poor drainage of the roof slab causes water accumulation, water pressure, affected by the increase in wind pressure thrust, poor structural construction, poor building maintenance, earthquakes and other external forces, cracks are generated and the water from the wide cracks penetrate the structure, resulting in internal leakage. The sources are generally divided into precipitation, groundwater, domestic water and water for production purposes.

Precipitation diverted by wind action, referred to as wind-driven rain (WDR), is the main source of water supply for building facades (Gholamalipour, Ge, & Stathopoulos, 2022; Qian & Zhang, 2021). In conjunction with simultaneous wind pressure (driving rain wind pressure, DRWP), both contribute to rainwater runoff exceeding the thresholds of surface tension and the capillary pressure of water existing in the pores of construction materials, thus causing rainwater infiltration into facade materials (Van Kinden, 2022; Støver, 2022; Kahangi, 2021; Sharma, 2021).

Lin (2020) suggested in the *Case Study of Water-proof Engineering Practice for Top-floor of Reinforced Concrete Buildings*, in the discussion for the case study on roof water-proofing layer in reinforced concrete structure of domestic buildings, in addition to the causes of water seepage and leakage in buildings, we also need to learn the design of "water-proofing project" and the application of water-proofing materials. Therefore, we got an initial understanding that Taiwan's climatic factors, as well as the poor construction quality and other factors result in water leakage and moisture in buildings.

Main causes of Water Seepage and Leakage in Buildings in Taiwan: Taiwan is always in a hot and rainy environment with high water levels, the surfaces of building walls are susceptible to damage by rising damp and water leakage. Water sources can be categorized as rising moisture, falling (external) lateral rainwater (dew or moisture) and indoor water (moisture) (Lee, Chang, & Wu, 2011). In environments with high temperature and high humidity, buildings are susceptible to moisture and water leakage, resulting in damage to the plasterwork. The sources of moisture are divided into three parts, namely rising moisture (groundwater) at an altitude of about 60 cm, falling moisture (rainwater) at an altitude of about 80 cm below the roof, and lateral moisture (alternatively known as infiltrating moisture (dew or rainwater)) at an altitude of about 80-200 cm or more (where the eaves of the roof cannot be sheltered) (Lee et al., 2022).

Water leakage problems in buildings in Taiwan are mainly caused by construction quality, design defects, natural factors and improper maintenance. By improving construction quality, optimizing design, strengthening regular maintenance and using new water-proofing technologies, water leakage problems can be effectively reduced, ensuring the durability of buildings and the residents' life quality. The two most common causes of water leakage

summarized based on the literature review are described as follows.

#### 1. Poor construction and lack of water-proofing work

Tsai (2019) pointed out in *Splitting Test for Water Proof Paint Material*, for most buildings in Taiwan, only high-pressure air or strong waterjet was used to clean the debris and sand on the surface, which was rarely targeted at the air content, moisture and dryness on the ground, thus after laying water-proofing layer, water-proofing materials bulged as result of vaporization, or the cracks in the original ground were not first reinforced, so that after laying the waterproof layer, the cracks were shifted by seismic forces, causing the water-proofing material to split.

## 2. Geology and the effect of different load forces

Most decorated units are subjected to different loads, earthquakes and other stresses, so the gaps between the units often crack or widen, and it is not always easy to achieve complete water-tightness from beginning to end. Kuo (2019) pointed out in *Comparison of Water-proofing of Existing Buildings* that structures generally have pores and capillaries, which allow water to form a force of its own that allows it to penetrate. The phenomenon of surface tension and adhesion of water: in the balcony or window above the junction with the external wall, if the water flows down or dew forms on the external wall, water will extend inward. Li (2022) pointed out in *A Research on Waterproof Surface Materials* that, water pressure is also one of the causes of stress, the negligence in the maintenance during the structure construction or due to earthquakes and other external forces will result in cracks, and in the event of waterlogged conditions, the water pressure underneath will be sufficient to penetrate the structural plate.

According to the above literature, indoor moisture in buildings is closely related to the climate and water-proofing construction in Taiwan. Due to poor quality in the water- proofing construction, rainwater and moisture will go through the pores of the buildings into the indoor and cause water leakage and moisture problems.

### 1.2 Characteristics of water-proofing coatings

Taiwan is surrounded by the sea and located in the earthquake zone, the concrete or brick walls are prone to earthquake vibrations resulting in large and small cracks, which allows moisture and rainwater in the air to penetrate into the concrete brick walls, causing wall cancer, water leakage or mold growth and so on. For this reason, water-proofing coatings play a vital role in construction and renovation, the choice of appropriate water-proofing coatings and the correct construction method can effectively prevent moisture penetration, protect the building structure, and extend its service life. When choosing water-proofing coatings, depending on the specific application scenarios and needs, designers should consider the coating performance, ease of construction and environmental characteristics, to ensure that the best water-proofing effect. The *Specialist Method for the Renewal of Facades* (2020) concluded the following three key points for selection of water-proofing coatings.

1. Components and formulation of water-proofing coatings

The main components of water-proofing coatings are polyurethane, acrylic, siloxane, etc. The effect of different components on moisture-proof varies. Mold inhibitors, antimicrobial agents and other additives will be added to coatings, which will affect the performance of the coatings.

2. Physical properties of water-proofing coatings

The ability of coatings to resist penetration is also one factor considered in the industry in the selection of coatings. For example, whether the water-proofing performance will change under different water pressures, and its adhesion and stability on concrete, brick walls, and wood.

3. Impact of water-proofing coatings on health and environment

VOC emissions: Test the volatile organic compound (VOC) emissions during the application and use of coatings to ensure that their impact on indoor air quality is minimized.

Environmental certifications: Explore environmental certifications for the coatings, such as LEED certification, to ensure that they meet environmental standards.

# 2 RESEARCH METHOD

This study is divided into two parts: questionnaire analysis and experimental test. The questionnaires were distributed to interior designers, architects and related industry personnel. The questionnaires were distributed online through Google forms in the northern, central, and southern parts of Taiwan. The questionnaire is aimed to understand the habits and considerations of architects and interior designers about the use of various brands of water- proofing coatings, and the questions in the questionnaire are open-ended to allow respondents to answer freely and obtain more detailed information. The questionnaire includes questions about type of industry, years of experience in the industry, brands of water-proofing coatings used, whether you have met with water-proofing related problems and other factors of concern. A total of 100 questionnaires were distributed and only valid questionnaires were used. In addition, in the first stage of the experimental test, we observed the changes in the values of the surface moisture and the moisture of the inner layer of the concrete after one-week maintenance of the water-proofing coatings on concrete samples.

# 2.1 Questionnaire analysis

This study collected the water-proofing coating brands commonly used by interior designers in the industry. We listed 16 brands based on the Internet search (Dulux, Rainbow, Ching Yeh, Nippon, Kingcat, Plimates, Juta, Champward, Chingtai, Anshun, Axe, Forever Sunday, Letu, Coatrunway SOS, STO) so that the related personnel checked off their most frequently used brands. The top six water-proofing coatings with the highest number of choice were selected according to the order of checkmarks, and were used as the subjects for the subsequent experiment. The questionnaire is designed to understand the type of industry,

years of experience in the industry, water-proofing coating brands used and key considerations for choosing a coating, and finally, whether there are any problems related to water-proofing. The questions are as follows.

1-1. Type of current industry

In order to narrow down the scope of the form collection by searching for suitable and relevant industry categories, we obtained statistical results which show that the following industries have a greater relationship with the application of water-proofing coatings.

Interior designer, architect, plastering, water-proofing, painting, construction, environmental engineering, interior decoration works

1-2. Years of experience in the industry

We ensured the working years and experience of the persons who filled in the form through the questions about the years of experience in the industry. The purpose is to understand the years of experience in the industry, which is divided into four stages of seniority: one to three years, four to seven years, eight to ten years, more than ten years.

1-3. Which moisture-proofing/water-proofing coatings for internal wall surfaces have you used Through the questionnaire, we knew the water-proofing coating brands commonly used by interior designers and related industry personnel, and summarized the currently well- known water-proofing brands for the persons who filled in the form to choose. The following 16 water-proofing coating brands are commonly used in the industry: Brand A, Brand B, Brand C, Brand D, Brand E, Brand F, Brand G, Brand H, Brand I, Brand J,Brand K, Brand L, Brand M, Brand N, Brand O, Brand P.

Dulux, Rainbow, Ching Yeh, Nippon, Kingcat, Plimates, Juta, Champward, Chingtai, Anshun, Axe, Forever Sunday, Letu, Coatrunway SOS, STO

1-4. Most important consideration for choosing a moisture-proofing/water-proofing coating for interior decoration

The factors that designers consider when dealing with water-proofing vary greatly. The effect after use and the impact on health are the factors most people consider, and the coverage, price and service life of the coating are also factors to be considered. Additionally, whether or not the coating has an environmental label is also an environmental issue that has been widely discussed recently. The following options were listed for the respondents to check: moisture-proofing/water-proofing effect, impact on health, price, whether there is an environmental label, coverage, and service life.

1-5. Whether or not you have met with water-proofing related problems

From the question whether or not the person filling out the form has met with waterproofing related problems, we knew whether or not the persons who filled in the form had met with in their work. There are two options for this question: yes, no.

#### 2.2 Experimental test

At this stage of the experiment, we first made a mold, which is of the same size as the diameter of a beaker, with cement, mortar and water ratio of 1:3:1, to make eight test samples, and formed dried test samples. With reference to the literature (Lee et al., 2022), the unmolded test samples were incubated at a temperature of  $(23.0 \pm 2)^{\circ}$ C for seven days in a room at ambient temperature, and two samples were used as Group A-control group, while six samples were used in the second stage.

The test samples were coated with moisture-proofing coating with thicknesses of 0.4 cm, 1 cm, and 0.4 cm, respectively, and the test was conducted again according to the experiment method in the second stage to find out the difference in the passage rate of moisture between samples coated on one side and samples coated with two sides. A glass sheet was placed over the test sample during the heating step to block the passage of moisture. There were eight circular cement samples, marked A1, A2, B1, B2, B3, B4, B5, B6, of which A1 and A2 were the control group without coating, B1 to B6 were the experimental group. The water-proofing coating of the same brand was used on the test samples. Before the test, the cement blocks were maintained for one week, and changes in values were recorded daily using a surface moisture meter and an internal concrete moisture meter. According to the experimental test results, we learned the effect of the water-proofing coatings in water-proofing cement samples.

## **3** RESEARCH RESULTS

A total of 100 questionnaires were distributed. Of the questionnaires, 92 were valid and eight were invalid. The questionnaires were distributed in the northern, central and southern parts of Taiwan. The questionnaire results showed that 68.5% of the respondents were interior designers, followed by 13% engaging in interior decoration works. For the years of experience in the industry, the highest number of choices was more than ten years (82.6%), followed by four to seven years (9.8%). For the question related to the selection of wall moisture-proofing/water- proofing coating brand, the first three water-proofing coating brands were Brand A (79.3%), Brand B (76.1%), Brand C (51.1%), and the three least frequently used brands were Brand I (4.3%), Brand H (6.5%), Brand G (6.5%). When respondents chose moisture- proofing/waterproof coatings (94.6%), followed by the effect of coatings on health (77.2%), and the price was the factor they least cared about (32.6%). Finally, 85.9% respondents had met with water-proofing related problems, while 14.1% had not met with water-proofing related problems.

The statistics of the questionnaire showed that the majority of those who filled in the form have more than ten years of experience in the industry, as shown in Table 2. As shown in Table 1, the most commonly used coating brand for interior designers was Brand A, and the least chosen brand was Brand H, as shown in Table 3. For interior designers and related personnel, the most important part of choosing a moisture-proofing/water-proofing coating is the effect of the coating, and price was the least important consideration, as shown in Table 4. Of the respondents, 85.9% had met with water-proofing/moisture-proofing problems, as shown in Table 5.

According to the statistics of this study, the top three waterproof coating brands are Brand A (79.3%), Brand B (76.1%), and Brand C (51.1%), and it is also found that Brand A is the most commonly used brand among interior designers with more than 10 years of experience, 8~10 years of experience, 4~7 years of experience, and 1~3 years of experience, and that the four age groups are most concerned about the efficacy of waterproof coatings. Brand B is also a popular brand among the four age groups, and finally, Brand C is also a popular brand among interior designers with more than 10 years of experience. 31 out of 63 interior designers chose Brand C, and only 8 out of 63 interior designers have never touched waterproofing problems. This shows that the ranking of paints for interior designers with more than 10 years of experience is Brand A, Brand B and Brand C.





Source: Drawn by this study
**Table 2** Statistics on the Number of Years of Experience in the Industry (the highest number of choicewas more than ten years at 82.6%, the lowest number of choice was one to three years at 2.4%)



Source: Drawn by this study

**Table 3** Statistics on Brands of Indoor Wall Moisture-proofing/water-proofing Coatings Used (The top three water-proofing coating brands were Brand A (79.3%), Brand B (76.1%), Brand C (51.1%), and the three least frequently used brands were Brand I (4.3%), Brand H (6.5%), Brand G (6.5%))



Source: Drawn by this study

Table 4 Statistics on Effect as the Most Important Consideration When Choosing a Moisture-proofing/water-proofing Coating (the highest number of choice was the effect of the coating at 94.6%,and the lowest number of choice was color at 1.1%)



Source: Drawn by this study

Table 5 Whether or Not You Have Met with Water-proofing Related Problems (the highest number of choice was 85.9%, and the lowest number of choice was 14.1%), and the Results of Maintenance of Circular Cement Samples in the First Stage



Source: Drawn by this study





#### Source: Drawn by this study



Table 7 Moisture Meter for Concrete Inner Layer

**Source:** Drawn by this study

#### Conclusion and Suggestion

Through questionnaire survey, this study found that interior designers with more than ten years of experience generally chose Dulux, indicating its leading position in the water-proofing coatings market. In addition, the actual effect was the most important consideration for interior designers and related professionals when choosing water-proofing coatings, including water- proofing performance and durability. Most designers had met with water-proofing and moisture-proofing issues at work. The questionnaire results therefore showed the importance of choosing the right water-proofing coating.

The data statistics of the first stage of the experiment, as shown in Tables 6 and 7, indicated a significant reduction in the values of the surface moisture meter and the inner concrete moisture meter for the cement test samples after one week. The experiment also found that the water-proofing coating on the cement block can effectively isolate the water vapor in the air. Through the questionnaire survey and experimental research, we can better understand the market demand and product performance, so as to choose the most suitable water-proofing coating to solve moisture-proofing problems of indoor wall surfaces in the actual interior design and decoration practice.

In the future, we will continue the second stage of the experiment to learn the effect of the top six water-proofing coatings, so as to provide a reference for the relevant interior designers.

#### **ACKNOWLEDGMENTS**

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# A GUI IMPLEMENTATION OF AIGC FOR KIDS

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# ABSTRACT

The AI boom has been the most known buzz word of the world, and AIGC (Artificial Intelligence-Generated Content) has become a common tool for many people. To expand the usage of AI, it is not only necessary to research more efficient generation methods but also to consider how to make the interface more user-friendly, for lowering the slope of learning curve and eliminating knowledge barriers. This research focuses on designing a GUI (Graphical User Interface) that can be used by children, allowing them to early contact and learn to use the AIGC platform through this convenient and easy-to-use GUI system, increasing their affinity for AI tool in the future. We utilized the kansei words method from Kansei Engineering, converting children's preferences for visual elements into descriptive words and using them to design the GUI. In the result, we implemented a simple drawing-based AIGC tool system for kids.

Keywords: AIGC, GUI, Kansei Word

# 1 BACKGROUND

The development of artificial intelligence has become the most important topic in the past years. The emergence of numerous AIGC (Artificial Intelligence-Generated Content) tools has enabled more people without a design background to generate high-quality images to assist their work or career. Regarding the rise of AI technology, many schools and affiliations have also started to incorporate related courses, expanding the contact possibility to AI.

However, after deeply investigating these AI platforms, we found that many of them require relatively complex parameter settings and the ability to properly and precisely write down the prompt literals, which limits the age division of users. This research is designed for children under high school age, creating an AIGC interface that allows them to experience the logic of using AI-generated tools at an early age, further strengthening their ability to utilize AI technology in the future.

# 2 IMPLEMENTATION

In the first stage of the research, we conducted a survey to realize what are the major design principals for designing GUIs for kids. Considering the recognition limitation of children, we provided a paper filled with images of felines, dogs, birds, octopus, rodents, racoons and a color grid of 32 colors (8 color tones with variants of 2 levels and 2 shapes), as the survey form. The survey was held in an elementary school in Dalin Town, Chia-Yi in Taiwan and the target subjects were 20 kids aged from 8 to 10 under the help of their teachers. They were asking to draw circles on either favorite item in the survey form. The initiation of this research are the collections of Kansei Words [1] from the survey. In the result of the survey, we analyzed the result and built a table of kansei words and a ranking of mascot in table 1.

Kansei word	votes	Kansei word	votes	Kansei word	votes
Mascot: racoons	14	Purple	9	Levels: Bright/Dark	16/8
Mascot: rodents	12	Blue	8	Shapes: Long/Short	14/3
Mascot: birds	11	Red	7		
Mascot: octopus	10	Orange	7		
Mascot: fox	9	Yellow	6		
Mascot: felines	8	Green	6		
Mascot: dogs	6	Pink	4		
		Black	2		

Table 1. Kansei words from children' selections

According to the survey result and to make children easy to make input, we build a function for sketching and implement the user interface for children to draw as input, send the referencing sketch and selected generating category from ring, vase, cup, doll and bag, to the backend, generating prompt and utilize the APIs built from stable diffusion web-ui and then generate the AIGC. The whole process is shown in figure 1.



Figure 1. The GUI for children to use AIGC platform.

In the present day, stable diffusion takes about 20 to 30 seconds for generating a result, we have to make a waiting UI for users. After they drew sketch and chose the category, the waiting UI is shown with animation of mascots to keep them patient. The GUI for category selection, the waiting UI and animation clips are shown in figure 2.



Figure 2. GUI for category selection (up left). GUI for waiting (up right). Animation stripes (below).

The figure 3 below shows the whole process of the system. We collected users' input via selecting option and/or drawing interaction, sending it into stable diffusion web ui to generate corresponding images.



Figure 3. The whole process of the generating system.

# **3 EXHIBITION**

The implementation was built on an AI-enabled pad and exhibited on several exhibitions in China and Taiwan. Some photos are shown in figure 4.



gure 4. The system was presented on the 2024 Yodex Exhibition.

We completed a collection of five different types of generating platform, including shop, product, architecture, music and art (figure 5).



Figure 5. The five types of GUI for AIGCs.

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# CONSIDERATION OF INFORMATION DISSEMINATION TO BRING EMPATHY TO USERS WITH DIFFERENT BACKGROUNDS: HOW TO DISSEMINATE INFORMATION TO MAKE PEOPLE LIKE THEIR HOMETOWNS

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# ABSTRACT

With the spread of the Internet in today's society, various people are exchanging and collecting information through a wide variety of media. On the other hand, there have been cases in which the senders of information have failed to communicate as intended. In this presentation, we discussed what kind of media would be appropriate for information dissemination to users whose living environment differs between urban and rural areas, assuming, for example, that we want them to move to or travel to the rural areas. When sending out information from a rural area, there are cases where a lot of information is packed into a single message. However, this information may not necessarily resonate with users in urban areas who receive the information and want to engage with the local area. We discussed the direction of information dissemination that generates empathy with users from different backgrounds.

Keywords: Empathy, Communication media, Community revitalization

# **1** INTRODUCTION

In Japan, the population is concentrated in large cities and local cities are losing their vitality. In order to solve this problem, a variety of information is being disseminated to attract people to local area, either for migration or for travel. However, there are many cases in which the information cannot promote the desired behavioral change due to the different backgrounds of the sender and receiver of the information. On the other hand, there have been cases where people from other regions have empathized with the information provided by migrants and travelers on SNS and the fact that the area has been the setting of an animation or movie, and many people have visited the area.

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In this study, we considered that the success of media and content that disseminate various types of local information lies in the ability to generate empathy. First, we reviewed existing research on the nature of communication that generates empathy and attempted to create a model. Next, we collected comments from subjects who had changed their living location on the media and contents that disseminate current local information, and qualitatively analyzed the characteristics of these media and contents.

#### 2 COMMUNICATION THAT BRINGS EMPATHY

In this study, we hypothesized that in order to make oneself aware of a rural area that is different from one's own living environment, it is necessary to empathize with the information. To this end, we conducted a literature review on communication that generates empathy, and classified and modeled empathy as follows.



Figure 1. Empathy and Feeling Information classified model

## **3** SURVEY OF THE CURRENT SITUATION

We conducted a case study of currently used content regarding communication that generates empathy, collected usage conditions and impressions from participants who actually moved their living locations, and examined each content qualitatively.

#### 3.1 Current media and contents

I reviewed the media content currently used to disseminate local information and categorized it into the following four types. A specific example is shown in Figure 2.

TYPE1: Information booklets and websites from local organizations

- TYPE2: Dissemination of local information by publishers, advertising agencies, and other media companies
- TYPE3: Local introduction contents by celebrities and avatars
- TYPE4: Location introduction through animation, film, etc.



Figure 2. Current media and contents examples

#### 3.2 User Survey

T Subjects with experience in multi-living area activities were asked about their "how they used" each information provision method, "what specific information was useful", and "their impression of each method". The survey participants were four working adults in their 30s to 50s, all of whom had relocated or changed jobs from a large city to a regional city, and all of whom confirmed that they had used all of the information provision methods covered in this study. The tag cloud obtained from the survey is shown in Figure 3 in Japanese, and a summary obtained from it is presented below.

#### TYPE 1

Nouns were mostly place names, names of places and organizations, and official local names such as SDGs and campaign names, while verbs were often "useful" and "look up".

## TYPE2

Nouns included keywords related to activities such as tourist information, housing, and event information; verbs included "enjoy" and "know"; and adjectives included "interesting" and other content related to daily activities.

#### TYPE3

In nouns, there were emotional words such as "like," "customary," and other pinpoint place names. In verbs, keywords not found in other media, such as "narrow down" and "challenge," were found.

#### TYPE4

Nouns included the names of specific sightseeing spots and titles of works, while verbs included "feel," "visit," and other keywords related to the region.



Figure 2. Another example of image

### 4 CONCLUSIONS AND FUTURE DEVELOPMENTS

The final objective of this study was to clarify how information should be disseminated so that various regions can be recognized as familiar places even by those living in urban areas, in contrast to the current situation of concentration in one metropolitan area. In this presentation, we considered the need for information dissemination that is sympathetic to the interests of people in other regions, organized information that is sympathetic, and categorized information dissemination methods. Based on these results, we were able to obtain a certain direction regarding the impression and reaction of actual users to each method of information dissemination, and we were also able to discover the potential of this method as a research method. Specifically, in TYPE 1, left-brain sensory information is presented to promote theoretical empathy and a rational understanding of the region; in TYPE 2, it is assumed that the user understands the overall picture of how they actually live and enjoy the region and understands their own situation; in TYPE 3 and 4, emotional empathy is promoted based on each user's orientation, and it is imagined that the user understands the region, including its favorable and unfavorable aspects. In TYPEs 3 and 4, it is assumed that emotional empathy based on each user's preferences will be promoted, and that users will understand the region, including its positive and negative aspects. Although the number of subjects is limited in both cases, we would like to suggest that planning to disseminate local information based on these hypotheses may be effective.

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# EXPLORING THE RELATIONSHIP BETWEEN VISUAL STIMULI SPEED AND COMFORT: THE ROLE OF INTEROCEPTIVE SENSITIVITY AND ANXIETY

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#### ABSTRACT

This study explores how the preferred speeds of bubble tubes in sensory rooms relate to interoceptive sensitivity, subjective time perception, visual sensitivity, and anxiety level. In a controlled experiment, 50 participants adjusted the upward-moving Random Dot Motion (RDM) stimulation speed to find their comfortable viewing pace. Our findings revealed a strong positive correlation between the most comfortable RDM speed and the absolute difference in perceived and actual heart rates. This indicates that individuals with significantly higher interoceptive sensitivity prefer slower RDM speeds. Furthermore, higher anxiety levels were linked to a preference for quicker stimulation. However, no significant correlations were found between RDM speed and subjective time perception or visual sensitivity. This research emphasizes the need to consider individual differences in designing therapeutic sensory environments to optimize therapeutic benefits.

Keywords: Sensory room, Bubble Tubes, Interoceptive sensitivity, Sensory hypersensitivity

#### **1** INTRODUCTION

Individuals with sensory hypersensitivity, overwhelming everyday stimuli like light and sound, often experience sensory overload. Sensory rooms, equipped with specialized tools like bubble tubes, provide a controlled environment to help these individuals manage sensory input through self-regulation and relaxation. Building on previous research optimizing sensory room design elements (Su et al., 2023), this study focuses on the movement speed of bubble tubes.

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We employ Random Dot Motion (RDM) stimulation to simulate the upward motion of bubble tubes and assess its impact on sensory experience. Interoceptive sensitivity, or the ability to perceive internal bodily states, is crucial in how individuals respond to external stimuli (Tanaka et al., 2021). Additionally, we explore subjective time perception, which is crucial in cognitive processing and affects mental health and behavior (Yabe et al., 2023). We also examine visual sensitivity and anxiety, utilizing tools such as the Visual Discomfort Scale (VDS, Conlon et al., 1999), the Trypophobia Questionnaire Japanese version (TQ-J, Imaizumi et al., 2016b), and the State-Trait Anxiety Inventory (STAI, Koizumi et al., 1998).

By studying how these psychological and physiological factors affect the speed of bubble tubes, we aim to provide insights into designing sensory rooms that cater better to different individuals.

# 2 METHOD

## 2.1 Stimuli

The RDM stimulation program, developed with Flutter SDK and run on a Lenovo laptop (display size: 36.3 cm * 23.8 cm, resolution: 1920 * 1080, model number: 115423562), generated 200 random dots per second, moving vertically upward within a central circular area on the screen (Figure 1). This circular area had a diameter of 1000 pixels, corresponding to a visual angle of 28.55 degrees. Within this area, 200 small dots, each with a diameter of 12 pixels (visual angle of 0.35 degrees), were randomly generated every second. The experiment took place in a dark room to mimic a sensory room environment, with participants seated 40 cm from the screen. The luminance and chromaticity of the dots were set at 128 cd/m² and 0.2312,0.2824 in the CIE 1931 color space, ensuring consistent visual stimulation. Dot speed was adjustable via the keyboard and recorded upon pressing the "Enter" key. A chin rest was used to ensure that each participant viewed the visual stimuli from the same position. A



Fingertip Pulse Oximeter (Model number: CMS50D) monitored participants' heart rates throughout the experiment.

**Figure 1**. RDM stimulation (Random generated dots moving vertically upward, and the dots' luminance and chromaticity were set at 128 cd/m² and 0.2312,0.2824 in the CIE 1931 color space)

## 2.2 Participants

Fifty healthy students from the University of Tsukuba (27 females and 23 males, aged 22-35) participated in our experiment. All participants had normal or corrected-to-normal vision.

#### 2.3 Experimental procedure

First, participants controlled the dots speed using the keyboard, starting from the fastest speed (28.55 degrees per second) and gradually decreasing the speed until they identified the most comfortable speed. They then recorded this speed. Next, participants started from the slowest dot movement speed (0 degrees per second) and gradually increased the speed until they found the most comfortable speed, which they recorded once again. Participants repeated this process three times, resulting in six recorded speeds representing the most comfortable velocities. The average of these six speeds was then calculated to determine the average most comfortable speed.

Then, while wearing a Fingertip Pulse Oximeter, participants counted their heartbeats for one minute to determine interoceptive sensitivity, calculating the absolute difference between perceived and actual heart rates.

Next, participants estimated 60 seconds with their eyes closed; we recorded the time and calculated the absolute difference from the actual duration to assess subjective time perception.

Finally, outside the darkroom in a quiet, bright room, participants completed three questionnaires: the VDS scale, the TQ-J for visual sensitivity, and the STAI for anxiety levels. We recorded scores from each questionnaire for analysis.

## **3 RESULTS**

Due to the non-normal distribution of various experimental variables, Spearman's rank correlation coefficients are employed for the analysis rather than Pearson's correlation coefficients. We investigated the relationship between the most comfortable speed of RDM stimulation and various factors, including perceived and actual heart rates, the absolute differences in heart rate and estimated time, and scores from the VDS, TQ-J, and STAI questionnaires (Table 1).

We found significant correlations between the average comfortable speed of RDM stimulation and various physiological and psychological factors. There was a strong positive correlation (r=0.491, p < 0.01) between the absolute value of the heart rate difference and the average comfortable speed of RDM stimulation, indicating that individuals with lower interoceptive sensitivity prefer faster speeds. Conversely, higher average comfortable speed was associated with a reduced ability to perceive heart rate, as indicated by a negative correlation (-0.308, p < 0.05) with Perceived Heart Rate.

Psychological factors also influenced the average comfortable speed. STAI scores, indicating anxiety levels, correlated moderately positively (0.311, p < 0.05) with the average comfortable speed, suggesting that higher anxiety might drive preferences for faster sensory input.

Table 1.	Spearman	Correlation	Coefficients	and	P-Values	for	Variables	Relative	to	Average
Comfortable S	peed of RDI	M Stimulatio								

Variable	<b>Correlation Coefficient</b>	P-Value	
Actual Heart Rate	0.101	0.485	
Perceived Heart Rate	-0.308	0.031*	
The Absolute value of the Heart Rate Difference	0.491	0.000**	
Subjective time	0.103	0.478	
The Absolute Value of the Estimated Time Difference	0.201	0.162	
Scores of VDS	0.007	0.963	
Scores of TQJ	0.073	0.614	
Scores of STAI	0.311	0.028*	

However, subjective time perception and visual sensitivity scores (scores of VDS and TQ-J) did not significantly correlate with the average comfortable speeds.

#### 4 DISCUSSION AND CONCLUSION

Our study explored how physiological and psychological factors influence the preferred speed of RDM stimulation (bubble tubes), highlighting the importance of personalizing sensory environments. We observed a strong positive correlation (r=0.491, p < 0.01) between the absolute difference in perceived and actual heart rates and the average preferred speed, highlighting the impact of interoceptive sensitivity. This correlation can be partly explained by findings that individuals with panic disorders often perceive their internal bodily sensations distinctively (Yoris et al., 2015). Additionally, we discovered a positive correlation (r=0.311, p < 0.05) between anxiety levels and average speed preference, indicating that individuals with higher anxiety may seek faster stimulation as a form of arousal or distraction. Conversely, those with lower anxiety might prefer slower speeds for a calming effect.

Although subjective time perception and visual sensitivity did not significantly correlate with average speed preference, their potential roles in other contexts warrant further investigation. Our findings suggest that designing bubble tubes should account for individual differences in interoceptive sensitivity and anxiety to optimize therapeutic outcomes and overall well-being.

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# EXPLORING CREATIVE PRODUCT DESIGN FOR OLDER ADULTS: A PROBLEM-BASED LEARNING AND DESIGN THINKING APPROACH IN UNIVERSITY SOCIAL RESPONSIBILITY

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# ABSTRACT

This study aims to investigate the development of creative product design for older adults through problem-based learning (PBL). Qualitative action research has been chosen to understand critical factors comprehensively. The design thinking (DT) method is adopted to analyze the key factors affecting the development of creative board game design and demonstrate the proposed method's practicality through a case study at a long-term care institution. The findings of this study could be beneficial for educators responsible for planning coursework on creative product development in University Social Responsibility (USR).

*Keywords:* older adults, creative board game design, design thinking (DT), problem-based learning (PBL), university social responsibility (USR)

# **1** INTRODUCTION

According to the World Health Organization estimates that by 2050, there will be about 2 billion elderly people and a quarter of the population will be old [10], and cognitive decline due to aging is a common phenomenon [12]. The development of products for cognitive health or cognitive decline has become one of the main focuses of research and industry development [17]. Playing board games has been shown to help older adults fend off dementia and cognitive decline, and it is sometimes regarded as a leisure activity in the field of psychosomatic medicine. The method of design thinking (DT) is adopted to analyze the key factors that affect the development of creative board game design, the correlation between different factors, and the practicality of the proposed method is demonstrated through a case study – long-term care

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institution. In this study, we explored the development of creative board game design for older adults. The research purposes were as follows:

- 1. Explore the effects of creative board game for older adult.
- 2. Understand the key factors that affect design thinking process.
- 3. To develop the creative product design of board game for older adults.

### 1.1 Creative Board Game Design for Older Adults

Board games are learning tools that can be developed and designed to share skills and knowledge with teams of individuals based on themes and age levels [2]. According to Herrmann et al. [6], "cognitive function" is a general term for the processing of human information that includes perception, learning, memory, thinking, problem-solving, decision-making, and verbal expression. Age-related older adults cognitive decline and neurodegenerative diseases both increase the risk of memory loss, loss of judgment and decision-making ability, loss of literacy, and loss of numeracy [5]. Studies have shown that board games can stimulate neuronal connections, increase neuroplasticity, improve cognitive function, and improve cognitive decline, such as attention, memory, perceptual speed, and visual-spatial abilities, especially in healthy older adults, and also reduce the risk of dementia. [4]

## 1.2 Design Thinking Approach for Problem-Based Learning

Problem-based learning is different from other forms of teaching and learning, and is a way of learning driven by student orientation. The teacher acts to facilitate the learning process instead of providing knowledge and to guide students learning through the PBL cycle depicted in Figure 1.



Figure 1. The problem-based learning cycle

#### Source: Smelo-Silver [7]

PBL aims to help students develop 1) flexible knowledge, 2) effective problem-solving skills, 3) self-directed learning skills, 4) effective collaboration skills, and 5) intrinsic motivation. Through strategies such as learner demand, group collaboration and one-on-one thinking, active participation is returned to students to experiment with practical knowledge and skills through practical operations. Design thinking as an educational approach to enhance creative problem-solving skills[8][9][15]. It is also a problem-based learning paradigm that builds on

three pillars: 1) a creative problem solving process, 2) creative work-spaces and 3) collaboration in multi-perspective teams. Rauth et. al. [11] was suggested that design thinking provides a flexible and accessible structure to guide educators and use their creativity to address the problems of practice. The Stanford model's modes structured core activities that students applied as a lens for their educational problems of practice. As Figure 2, the model consists of five stages of design thinking, also called modes, that are worked through into solutions of problems or resolutions. The five modes are: empathy, definition, ideation, prototyping and testing. Although we describe them linearly, conceptual thinking is really an iterative process.



Figure 2. Stanford D-School design thinking model

Source: D-School

# 2 METHODS

An exploratory approach is a valuable means of finding out 'what is happening; to seek new insights; to ask questions and to assess phenomena in a new light' (Robson, 2002). Therefore, the qualitative action research has been chosen to provide a detailed and holistic understanding of critical factors in case study. The data was collected through conducting interviews mostly. To ensure some homogeneity of social background, all elder adults were selected from the case of long-term care institution. The data collection were conducted individually and were voice recorded for later coding and analysis. Finally, the analysis of the data collected from various sources reflected our research objectives.

# 2.1 Case Study by Action Research

According to Eisenhardt (1989) case study research involves individual cases and studies over an extended period of time. Case research typically combines data collection methods such as archival research, interviews, questionnaires and observations (Yin, 2003), whereas the evidence may be qualitative, quantitative, or both. The approach of action research is to provide teachers-researchers with a method to solve problems in schools so that they can improve both student learning and teacher efficiency.

# 2.2 In-depth Interview

Semi-structured interviews may be used in relation to an exploratory study [3]. All interviews had the same structure: they were based on questionnaires with open questions. Subjects were five older adults and five students that from the participants of course program. In order to

encourage answers to questions, prompts and probes were considered. Most interviews were voice recorded with consent and transcribed for further analysis. This was very helpful in building a simple case study protocol and a case study database.

## 2.3 Data Analysis by NVivo

In case study analysis one useful strategy is to adopt a coding system. Coding in qualitative research is a way of classifying and then 'labelling' text in order to facilitate later retrieval [14]. Furthermore, NVivo is an example of computer-assisted qualitative data analysis software (CQDAS). NVivo encourages an exploratory approach to analysis the qualitative data and is, as such, an analytic approach in qualitative research. Throughout the coding process, NVivo was used to facilitate the management of data and codes and to maintain a perspective on all of the data without losing its richness [1].

# 3 RESULTS

This studied here may be of importance in explaining the development of creative product design for older adults. The method of design thinking is adopted to analyze the key factors that affect the development of creative board game design, the correlation between different factors, and the practicality of the proposed method is demonstrated through a case study of long-term care institution – Chinese E-Touch Community Service Association in Taichung city, Taiwan. There are 18 students in creative product development course and 32 older adults who were aged 65 or above, that were tested in a selection of 18 board games activities. In this investigation we carried out two different groups of interviewers for different research purposes.

#### 3.1 The effects of creative board game for older adults

Board game is a leisure activity that is ideally suited to the physical and mental conditions of older adults. In this study, qualitative data from the evaluative questionnaire completed by the older adults group brought out several interesting points regarding their experience with long-term care activities, and found that the board games had the following features: flexibility (not limited by time and number of people), versatility (not limited by illness or physical function), accessibility (not affected by weather or space), and individuality (depending on the physical and mental condition and understanding of the individual). Regarding the board game impact, physical impacts were discussed most often, followed by cognitive effects and social effects. This might not be surprising as old age is associated with deterioration in physical and mental faculties. In addition, it has been discovered that social engagement plays a significant role in influencing not only subjective emotional well-being but also the growth and functionality of the brain through the creative board games.

#### *3.1.1* Playing board games can improve cognitive performances in healthy:

There was a large variation of outcomes and measures to show the impacts of gaming on physical and cognitive conditions. Different game aspects may have different impacts on physical, cognitive and social conditions. One of the challenges of testing that proposition is finding proper classification for the games and/or their components. Stimulating leisure activities are considered as possible protective factors against dementia and cognitive decline in elderly people, particularly due to enhancement of cognitive reserve. Board games that stimulate the brain can help to slow the progression of dementia.

# 3.1.2 Playing board games can promotes social interaction and relationship:

Board games can be undertaken with family members or friends and even with strangers, and it exchange with different generations. Our studies have found that social interactions in board games can improve social relationships among players, allow large number of players to interact and accomplish shared goals together. It seems compatible with Zokaei, et al. [17] argument that board games have the potential to build awareness, train, mobilize, and engage people in advancing positive social change.

# 3.2 The key factors affect design thinking process

The method of design thinking is adopted to analyze the key factors that affect the development of creative board game design for older adults. The five modes are adopted to describe as follows: (as seen in Figure 3)



**Figure 3.** Design thinking within creative board game development Source: this study

# 3.2.1 Empathize:

Empathy comes from having enough knowledge and feeling. Before you start designing, you must first feel the needs and desires of the other person, become the user, feel the experience of the person, and think about the pain points of the older adults and how you can help. Then, after compiling the results of the interviews, we drew a map of the persona, understood the user's worries and goals, and designed a set of board games to meet their needs.

# 3.2.2 Define:

We use insights gathered from empathizing to focus on the problem. In define mode, we use the collected ideas of empathy to focus on the problem. Our purpose is to go beyond a simple definition by describing the complexity of the user, the problem and the context. In this mode, we articulate an issue statement based on the details and understanding users have previously acquired. We focus on the issue and mentor it to guide design efforts going forward.

It helps us understand the problem by framing it clearly from many viewpoints. We found it essential to look at users' problem from different points of view. Students also noted that it was helpful to take time to thoroughly define users' problems because it led to a deep understanding of the context and a vision for moving forward.

# 3.2.3 Ideate:

Through collaborative discussions, brainstorming, and diverge/converge thinking, we develop the best solution with the available resources. From the process of playing board games in person, we gradually analyze and deconstruct the elements of a set of board games, and then find out the modules of what makes a board game through classification as below:

- ✓ Ease of play: how long does it take to get familiar with the game?
- ✓ Strategy: is the game mostly intuitive or does it rely on logical thinking?
- ✓ Interactivity: is it highly interactive? Is it intense or static?
- ✓ Theme: is there a specific theme or abstract concept for story?
- Competitiveness: does the game emphasize competition? or does it emphasize cooperation more?

# 3.2.4 Prototype:

Through mockup and prototyping, we examine potential solutions. This design iteration process, which involves designing, building, testing, and repeating, is necessary for efficient design thinking. Furthermore, collaboration within team-work is a crucial that is often adopted in design thinking process. By sharing their knowledge and interests, the students are able to generate the most desirable results and make the final product more complete.

# 3.2.5 Testing:

After making the prototype, we need to share and test it so that more older adults can try it out and collect feedback from them to understand if the work still needs to be fixed and fine-tuned.

# 4 CONCLUSIONS

This studied here may be of importance in explaining the development of creative product design for older adults. PBL within board game design has been found to promote a positive attitude towards learning and developing memory skills, along with its potential to connect students and help them build self-constructed learning. Design thinking is also approached in terms of educational method, didactic procedure, organization of the teaching-learning activity within creative board game development for older adults.

The results also showed that PBL and DT were generally well received by students. The result of this study could be useful to teachers responsible for planning course work of creative product development in University Social Responsibility. In addition, it is important to evaluate and reduce cognitive impairment in older adults through the design of creative board games. The findings of this study also have implications, board games can increase interpersonal interaction, self-confidence and sense of accomplishment of the older adults in long-term care institutions.

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# GENERATING BIOPHILIC DESIGN AND VISUAL COMPLEXITY OF PAINTINGS FOR WORKING ENVIRONMENT

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# ABSTRACT

Modern people working in offices or homes need comfortable environments for concentration. This study focuses on elements in images as objects placed in work environment to encourage appropriate breaks and enhanced focus on tasks. We propose an indirect support method for concentration in tasks by continuously altering the biophilic design and the Visual Complexity (VC) of paintings using image generation via Generative Adversarial Networks (GAN). Our experiments, which presented stimuli with these continuous changes, suggested the possibility of adjusting the appeal and attention-drawing ability of paintings by altering the methods of their transformation.

Keywords: Biophilic, Work environment, Gan, Visual Complexity.

# **1** INTRODUCTION

In recent years, with the reform of work styles and COVID-19, it has become possible for workers to work without being restricted to their workplaces. However, telecommuting is considered to have problems of low productivity and increased working hours compared to working at the workplace. A survey reported that 82% of telecommuters felt that their productivity was lower when working at home compared to when working at the office (Morikawa, 2022).

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There is a design concept called biophilic design, which uses houseplants or interior furniture using wood to improve work environments or increase workers' productivity and comfort. Biophilic design is a design that incorporates elements of biophilia (Edward, 1986), and the concept insists that "humans instinctively seek connection with nature.". There are some reports of their effectiveness in mental health care and relaxation (Genjo et al., 2019; Berto, 2014). Not only real living plants, there are similar effects via natural landscape images and the light colors from natural environments (Yang et al., 2022; Nomura et al., 2024).

On the other hand, placing relaxing objects in work environment can raise concerns about distraction and a decrease in performance due to excessive relaxation. For instance, those have been shown to divert users' attention toward the houseplants, leading to an increase in work errors (Jie et al., 2019). It is preferable to prevent the dispersion of attention to enhance performance. One method to control attention is to change visual stimuli by blurring the object (Loschky et al., 2014). We focused on abstraction of the images as a technique for changing the Visual Complexity (VC) of landscape images. When comparing the appreciation of paintings, figurative painting is generally preferred over abstract art (Uusitalo et al., 2012), and people tend to pay more attention to things they like (Gilani et al., 2013). Thus, figurative painting is more likely to capture attention, and we propose changing the VC through the abstraction of images.

In this study, instead of placing actual plants, landscape images are placed in the user's peripheral vision, and we aimed to achieve an environment with moderate comfort and high work efficiency by changing the Biophilic Design Area (BDA) in the images to adjust the relaxation and changing the VC to control the dispersion of attention. For example, 1) when the user is fatigued, increase the BDA to give relaxation, 2) when the user feels too comfortable, decrease the BDA to suppress relaxation, 3) when the user wants to focus on tasks, the VC is lowered to conserve cognitive resources, and 4) when the user wants to relax, the VC is increased to focus on the landscape image.

In this paper, two types of Generative Adversarial Networks (GAN) are used to change the design of the landscape images. We adapted GauGAN (Park et al., 2019) to control BDA. GauGAN is a model that generates realistic landscape images based on segments. We adapted CycleGAN (Zhu et al., 2017) to control the VC. This model can transform image styles by training on datasets from different domains. Our study transforms image styles using the VC estimated from image edges as a domain. In this paper, we also examine the impact of the system on the comfort and concentration of the user working with it.

## 2 SYSTEM

The system consists of an image generator unit and the output unit. In the image generator unit, BDA and VC are controlled to create painting images. The painting image sources are classified into eight levels of VC based on the amount of detected edges. CycleGAN models are trained for each level to generate images corresponding to an arbitrary VC. Next, we prepared segmentation images according to the BDA ratio. The images are input into GauGAN to create

realistic landscape images. These images are also inputted into the trained CycleGAN model for each VC level and converted into an image of the desired VC level. Correspondingly, the unit generates a painting image at arbitrary BDA and VC. In the output unit, multiple images gradually changing the VC and BDA are continuously presented based on the binary input values. The stimuli are expected to create a comfortable environment for the user's concentration by adjusting the appropriate level of the relaxation. Figure 1 shows the system flow. The details of each unit are described below.



Figure 11. System flow

# 2.1 Image Generator unit

2.1.1 Dataset

The dataset for the system includes paintings, nature images, and artifact images. Painting images were scraped from Wikiart⁶², with the condition that they were labeled as 'abstract' or 'landscape' and that the copyright had expired. Nature and artifact images were collected based on labels from SUN Database (Xiao et al., 2010). For nature images, we focused on green plants, the most frequently reported to be affected by biophilia (Braubach et al., 2021), and collected

⁶² https://www.wikiart.org/

852 images labeled 'forest', 'botanical garden', and 'rainforest'. In addition, we limited the collection to buildings as artifacts and collected 921 images labeled 'parking garage' and 'apartment building'.

While there are no methods for directly estimating the abstract level of an image, there are many methods for estimating complexity as a factor in the abstraction of a painting (hang, 2020, Forsythe, 2003). We employed edge detection based on fewer errors of complexity estimation between edge detection methods and human perception of complexity (Machado, 2015). Edge detection was performed on abstract images using the Canny method with OpenCV⁶³, and the averaged pixel values of the applied images were calculated as VC (ranged from 0 to 109).

In this paper, the images are classified based on every 10 ranges of the averaged pixel values for each VC class. Images with over 80 averaged values are set in class 8, because very few images were classified as class 8 and above. Accordingly, 8 levels of VC were assigned, from class 1, which has the lowest VC, to class 8, which has the highest VC. In addition, many of the images labeled 'landscape' from Wikiart had low VC, and if trained as is, the class 1 model would have generated images with high VC. For this reason, adjustments were made so that the proportion of images labeled 'landscape' in the 350 training data increased linearly from class 1 to class 8.

# 2.1.2 Train Model

In this paper, we adopted Zhu's CycleGAN model's structure and the training loss function (Zhu et al., 2017). CycleGAN has abstract images and nature and artifact images as its domains. It trains to convert nature and artifact images to look like abstract images. CycleGAN model was trained by creating a dataset for each VC.

The training data was preprocessed for model training. First, the nature and artifact images were cropped to a square shape based on the center of the image and then resized to 256 × 256 pixels. Next, the images were combined so that the nature images were on the right side and the artifact images were on the left side, creating a nature-mixed image with the same ratio between nature area and artifact images area. Preliminary studies revealed that training abstract images as they resulted in significant color changes from the original image, and the area ratio of nature and artifact would also change, making it impossible to convert only the VC. Therefore, noting that nature are often green plants and artifact often are gray buildings, the right half of the abstract image is subjected to a green conversion that restricts the hue value of the HSV color space to green (35-85) while maintaining the variance, and the left half is converted to grayscale. This color-restricted abstract image minimized the change in the area ratio of nature to artifacts during abstraction conversion.

Model training was performed as in (Zhu et al., 2017), with a mini-batch size of 1 and 150 epochs. Model parameters were optimized using Adam (Kingma & Ba, 2014), with the learning rate of all generators and discriminators set to 0.0002 for the first 100 epochs and linearly

⁶³ https://opencv.org/

decaying to 0 for the remaining 50 epochs. In addition, 50 random images were stored as fakes for the discriminator, and the weight of the cycle consistency loss was set to 10.0.

2.1.3 Generating Image with various BDA and VC

First, GauGAN generates realistic images with adjustable ratios of nature and artifact. By inputting a segmentation image created with 11 area ratios of colors representing plants and colors representing artifacts, ranging from 0% to 100%, a realistic image is generated according to the area ratio of nature and artifact. Next, a style transformation of the realistic image generated by GauGAN is performed using the trained CycleGAN model according to the level of abstraction to be transformed.

# 2.2 Output Unit

First, the initial values of BDA and VC are randomly determined (bda_init, vc_init), and the user arbitrarily determines the target values of BDA and VC (bda_tgt, vc_tgt). Next, the image is output according to the initial values, which gradually change toward the target values. The image does not suddenly change to the target BDA and VC values but changes linearly to bda_tgt and vc_tgt over 5 seconds from the initial bda_init and vc_init values. This approach is intended to control the relaxation effect on the user and the dispersion of attention.

## **3 EXPERIMENT**

In this experiment, we examined the effect of visual stimuli that increase or decrease BDA and VC on experimental participants' comfort and concentration while working. We also investigated how the perception of stimuli is affected by whether the changes in visual stimuli are intermittent or gradual. A comparative experiment of BDA is conducted as Experiment 1, and a comparative experiment of VC is conducted as Experiment 2. The following describes the standard settings shared by the two experiments, followed by detailed explanations of each experiment.

#### 3.1 Experiment Task System

In this experiment, we prepared two types of tasks (anagram problems and calculation problems). Anagram problems involve rearranging a string of five hiragana characters arranged in meaningless order into meaningful words, and an anagram database (Ichimura et al., 2017) was used for the questions. The calculation problem was a three-digit addition problem with no carryover in all digits. Calculation problems were employed as a light-load task because they do not generate carryovers. In contrast, anagram problems were employed because they require creativity when solving and thus are considered more demanding than calculation problems. Both tasks were implemented using Unity. To avoid individual differences in the typing skills of the participants and to prevent their gaze from being diverted too far from the monitor, mouse operation was employed to input responses in both tasks. Because biophilic design has been shown to enhance performance in highly creative tasks (Yin et al., 2019), Experiment 1's task is the anagram problem. To ensure participants could fully concentrate on the task, we also included the calculation problem, less demanding than the anagram problem, as Experiment 2's task.

#### 3.2 Animation Creating System

Two types of methods, intermittent change and gradual change, were used to test the technique of changing the image. Intermittent change is a stimulus that switches from one stage (bda_init, vc_init) to the final stage (bda_tgt, vc_tgt) after 60 seconds from the start of the task. We created fluid animations for the gradual change method by morphing the BDA and VC images in 11 and 8 phases, respectively. We used a triangle mesh warping approach as our morphing algorithm. First, their mesh is created by Delaunay triangulation from the landmarks obtained manually. Then, landmarks between images are interpolated using triangle mesh warping to create a middle image.

#### 3.3 Experimental Hypothesis

H1: Animations with gradually changing BDA do not interfere with the task, and relaxation increases during animations increasing BDA.

H2: Animations with gradually changing VC do not interfere with concentration, and concentration increases during animations increasing VC.

#### 3.4 Experimental Conditions

Two factors were set for the image change method, and four within-subject experimental designs with two levels of each factor were established. Factor A: Direction of change factor (A1: decreasing, A2: increasing), Factor B: Change method factor (B1: intermittent change (2 steps intermittently), B2: gradual change (11 steps continuously)).

#### 3.5 Experimental Procedure

20 university students aged 19–23 (14 men, 6 women, mean age 21.50 years, standard deviation 0.89) participated in the experiment. The experiment was conducted in a soundproof room to control the influence of external environmental sounds as much as possible. In addition, two monitors (27 inches) were placed side by side on the desk, one for performing work tasks and one for displaying pictures. The experiment is conducted in two steps. First, anagram and calculation problems are explained and practiced. Then, they executed the task for 120 seconds and responded to each evaluation item for each condition. To prevent participants from concentrating on the task and not looking at the painting, the task was paused every 30 seconds during the 120-second task execution period, and a 10-second break was provided. During these breaks, the task was not displayed on the work monitor, and participants were asked to resume with the question following the one they had been answering before the break. We also explained to the participants that they were not forced to look at the paintings while working and that this was their free time. The order of presentation of the experimental conditions was determined using the Latin square method, considering the counterbalance (Grant, 1948).

#### 3.6 Evaluation Item

Participants indicated their impressions of comfort (Q1, Q2), concentration on the task (Q3), fatigue (Q4), attention-drawing ability (Q5), interference of paintings (Q6), their appeal (Q7), and the painting's meaning (Q8) by subjective evaluation using the Visual Analog Scale method.

This method answered the following questions with integer values ranging from 0 to 99 (0 = not completely true, 99 = completely true).

- •Q1 I was able to work in a relaxed.
- Q2 I was able to work comfortably.
- •Q3 I was able to concentrate on my task.
- •Q4 I felt tired while working.
- •Q5 The paintings caught my eye.
- •Q6 The paintings got in the way of my work.
- •Q7 I liked the paintings.
- •Q8 I felt that the paintings had some meaning.

# 3.7 Experimental Result

For each evaluation result obtained from the experiments, a repeated measures analysis of variance was performed for each evaluation item at a significance level of  $\alpha$  = 0.05. Table 2 shows the variance analysis results, and Figure 2 shows each evaluation item's average and standard deviation.

	EX1							EX2					
Factor	А		В		AB		А		В		AB		
	F	p	F	p	F	p	F	p	F	p	F	р	
Q1	0.002	0.961	0.599	0.449	0.069	0.796	0.176	0.680	0.329	0.573	2.091	0.165	
Q2	0.051	0.825	0.145	0.707	0.036	0.852	0.029	0.867	0.145	0.708	1.735	0.204	
Q3	0.065	0.801	1.499	0.236	0.208	0.654	3.205	0.089	0.181	0.675	0.242	0.628	
Q4	0.010	0.920	1.176	0.236	1.861	0.188	0.114	0.739	3.575	0.074	0.034	0.855	
Q5	0.003	0.957	7.127	<u>0.010</u>	0.015	0.904	0.358	0.557	7.537	<u>0.013</u>	0.010	0.920	
Q6	0.394	0.538	1.577	0.224	0.084	0.776	0.291	0.596	3.833	0.065	0.021	0.887	
Q7	0.131	0.721	7.591	<u>0.013</u>	0.701	0.413	1.697	0.208	11.73	<u>0.003</u>	0.171	0.684	
Q8	1.757	0.201	8.505	<u>0.009</u>	0.201	0.659	0.025	0.877	1.096	0.308	3.403	0.081	

Table 8. Experience analysis results

__= *p*<0.05





First, the results of Experiment 1 are described. No significant difference was shown in their impressions of comfort (Q1, Q2). No significant difference was shown in their impressions of concentration on the task (Q3) or fatigue (Q4). For their impressions of the attention-drawing ability (Q5), their appeal (Q7), and the painting's meaning (Q8), significant differences were shown for factor B, with the gradual change being significantly higher. This shows that the gradual change in animation increases the likability and attention-drawing ability of the painting and its meaning. On the other hand, there was no significant difference in their impressions of interference of paintings(Q6).

Next, the results of Experiment 2 are described. No significant difference was shown in their impressions of comfort (Q1, Q2). No significant difference was shown in their impressions of concentration on the task (Q3) or fatigue (Q4). For their impressions of attention-drawing ability (Q5) and their appeal (Q7), significant differences were shown for factor B, with the gradual change being significantly higher. This shows that the gradual change in animation increases the appeal and attention-drawing ability of the painting. On the other hand, there was no significant difference in their impressions of interference of paintings (Q6) and the painting's meaning (Q8).

## 4 DISCUSSION

In this study, we examined the direction of change in BDA and VC in paintings and how the change methods affect the user while working.

First, we discuss the results of Experiment 1. We found that changing BDA gradually, regardless of the direction of change, increased the painting's appeal, attractiveness, and meaningfulness. We suggest that the paintings kept changing in new paintings, even when the user was working on the task, which may have increased the user's appeal and attracted the user's attention. Also, the increase or decrease in BDA was quickly perceived as meaningful because it was easy to associate it with nature's actual growth or decline. On the other hand, H1 was not indicated because there were no significant differences in concentration on the task, interference of paintings, or relaxation. Because the task lasted 120 seconds, which was too short to relax.

Next, we discuss the results of Experiment 2. In Experiment 2, changing the VC gradually, regardless of the direction of change, increased the appeal and attention-drawing ability of the painting. We suggest that the paintings kept changing in a new way, even while working, may have increased the user's appeal and attracted the user's attention. On the other hand, H2 was not indicated, as no significant difference was found in terms of concentration on or interference with the work. This suggests that changing the painting attracted attention but did not affect it to the extent that it interfered with task concentration or interference. The fact that there was no significant difference in the direction of the change suggests that the change of the painting in parallel with the task did not affect the concentration on the task because the content of the painting was not the focus of attention.

#### 5 CONCLUSION

In this study, we proposed the system that generates paintings in peripheral vision by changing the BDA and VC to encourage moderate breaks and concentration on tasks. The results showed that changing the BDA and VC increased their appeal and attention-drawing ability of the images. In addition, it was revealed that the gradual change in BDA may be inexpensive in evoking specific meanings, such as the growth or decline of nature. On the other hand, the present experimental setup did not affect concentration or relaxation while working. In the future, we will focus on the user's break time, create stimuli for appropriate breaks, analyze the relationship between work and break times, and implement the system that designs the entire work.

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# THE POSSIBILITY OF AFFECTIVE SUPPORT ON SUSTAINABLE CULTURAL INHERITANCE OF LUTHIER THROUGH VIOLIN VISUALIZATION TECHNOLOGY

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## ABSTRACT

The violin is believed to have originated in Cremona, Italy, in the 16th century, and its traditional philosophy of craftsmanship has been inherited by the luthier to the present day. The Cremona culture of violin making, which has been preserved for more than five centuries since its birth, has been inscribed as an intangible cultural heritage by UNESCO and has been the subject of scientific research by many researchers because of its artistic sound and appearance. However, in recent years, there have been many cases in which not only scientists but also luthiers have participated in scientific research using visualization techniques, indicating a tendency for luthiers to take on new challenges, taking advantage of the digital age while continuing to use traditional techniques. It is important to know effective scientific support for the luthier in order to affectively support the sustainable cultural inheritance of the luthier inheriting traditional techniques in the future through the innovative power of science. In recent years, there have been examples of luthiers participating in scientific research using visualization techniques, and such scientific research methods using visualization techniques have indicated the possibility of affective support on luthiers sense. Therefore, a workshop was conducted with luthiers to further explore the possibilities of visualization in depth. The results suggest that among the visualization data, structural analysis has the potential to reinforce the knowledge that luthiers have acquired as empirical intuition.

Keywords: Violin, Luthier, Affective support, Sustainable cultural inheritance

# **1** INTRODUCTION

The violin is known as a representative piece by Antonio Stradivari (1644-1737). Violins have the potential to attract people's sensibilities without being swallowed up by modern industrial

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products since the traditional craftsmanship philosophy has been passed down to the luthier, a violin artisan, for five centuries until today (Asada et al., 2023). Many researchers have attempted to elucidate the appeal of violins produced by such sustainable traditional artisanal methods, and numerous studies focusing on their physical properties (Bissinger, 2008; Gough, 2015; Hutchins, 1981) have revealed some of the physical characteristics of violins.

In recent years, the collaboration between luthiers and researchers has been observed in the observation study of three-dimensional (3D) structure visualization(Oliver et al., 2007) using computed tomography (CT). The collaboration between luthiers and researchers has also been seen in 3D structural visualization observation studies(Borman & Stoel, 2009; Sirr & Waddle, 1997, 1999) using CT, which have shown visualization analysis results in the internal structure of musical instruments. Furthermore, based on such 3D data, there are examples of acoustic analysis visualization(Pyrkosz & Van Karsen, 2014) using finite element analysis (FEA). However, it is unclear what advantages visualization techniques offer modern luthiers, who inherit traditional artisanal philosophy that demonstrates sustainability and individuality and seek to utilize and benefit from them. Therefore, this paper investigates the possibility of affective support by science for the future sustainable inheritance of traditions by investigating what modern luthiers trying to inherit and enhance traditional techniques focus us on and request from the visualization technology.

## 2 VISUALIZATION TECHNOLOGY FOR THE VIOLIN

While scientific research has traditionally been conducted primarily by scientists, recent years have seen an increase in the participation of luthiers in violin research that visualizes using non-contact measurement technology. This is because visualization research methods centered on non-contact measurement techniques have the power to visualize the invisible, and the resulting data is easy to understand and accept without specific scientific expertise, as is the case with luthiers. In other words, research methods using visualization technology have the potential to provide intuitive and understandable visualization data to luthiers and affectively support luthiers.

The visualization results of the structural deformation of the body caused by violin string pressure (Asada, 2023; Fioravanti et al., 2012) presented to the luthier and the structural analysis verification results show the possibility of supporting the integration of the luthier's practice and science(Asada & Suzuki, 2024). In this study, we conducted a survey to understand more deeply what kind of scientific research methods using visualization techniques luthiers have tended to seek.

## **3** SURVEY OF ATTITUDES

In this survey, 6 luthiers active today were asked what kind of scientific research methods using visualization techniques they seek to carry on the tradition of sensory craftsmanship. The survey was conducted on March 17th, 2024. More than half of the luthiers who participated in the workshop survey have international experience working, with three having trained and

acquired their skills in Italy and one in the United Kingdom. The questionnaire and interview survey were conducted with 6 participants in their 30s to 50s, and the participants responded to the questionnaire and interview survey of their own free will.

The workshop survey was held with 6 luthiers to discuss the visualization data regarding the structural analysis shown in Figure 1 and the acoustic analysis shown in Figure 2. First, visualization data from Figure 1 and Figure 2 were presented to all participating luthiers at the workshop to explain the scientific method and approach. Second, all luthiers participated in a discussion about the use of visualization techniques in Figure 1 and Figure 2, including their understanding and expectations in relation to each luthier's own sensory experience. Finally, each of the six luthiers was interviewed individually regarding their perceptions of visualization technology, and a questionnaire was administered, as shown in Table 1.



**Figure 1.** Example of visualization data images of the structural analysis due to string downward force: (a) Result of deformation of the violin structure due to string downward force by actual measurement. (b) Result of equivalent stress of the violin structure due to string downward force by FEA.



**Figure 2.** Example of visualization data images of the acoustic analysis: (a) Frequency response function data and mode shapes images. (b) Result of acoustic radiation in a conventional 2D cross-sectional view in an acoustic field mesh using FEA. (c) The result of 3D acoustic radiation from an acoustic field mesh using FEA, 3D visualization of (b).

#### 4 RESULT AND DISCUSSION

As shown in Figure 3, the age composition of the interviewees is 30s for 17% of the luthiers (1 respondent), 40s for 67% of the luthiers (4 respondents), and 50s for 17% of the luthiers (1 respondent). One respondent had more than 5 years of experience, one respondent had more than 10 years of experience, and 67% of the luthiers (4 respondents) had more than 20 years. Figure 4 shows the results of the responses to the survey presented in this study, where Figure 4 (a) through (c) are for structural analysis, and Figure 4 (d) through (f) are for acoustic analysis.

#### 4.1 Understanding of each phenomenon

In response to Figure 4 (a) to the question about structural analysis, 67% of the luthiers (4 respondents out of 6) strongly agreed with the answer, and 33% (2 respondents) agreed with the answer, indicating that all respondents agreed with the answer and there were no negative comments. This may indicate that luthiers have a high level of understanding and high expectations for structural analysis. In fact, response Figure 4 (b) shows that 17% of the luthiers (1 respondent) strongly agree, 67% of the luthiers (4 respondents) agree, and 17% of luthiers (1 respondent) say that they do not know, but there is no negative response. This indicates that the visualization data in the structural analysis is intuitively easy for luthiers to understand, suggesting that it is relatively easy for luthiers to understand the data even if they do not have expertise.

On the other hand, in response to Figure 4 (c), 33% of the luthiers (2 respondents) strongly agreed, 50% of luthiers (3 respondents) agreed, and 17% of luthiers (1 respondent) answered that I don't know, but there was no negative response in this area either. Thus, answer Figure 4 (c) indicates that acoustic analysis is highly interesting to luthiers, but the percentage of respondents who agree tends to be lower than that for structural analysis. This trend is supported by the response Figure 4 (d), which shows that 17% of the luthiers (1 respondent) strongly agree and 17% of the luthiers (1 respondent) agree, while 67% of the luthiers (4 respondents) answered, I do not know. Thus, answer Figure 4 (d) indicates that it is difficult for the luthier to relate the acoustic analysis to their own experience intuitively and that the luthier's understanding tends to be lower than that of the structural analysis.

#### 4.2 Discussion from individual interview results

Table 1. Online survey questions.

- (a) I have a high interest and curiosity in structural analysis research.
- (b) I have a general understanding of stress mechanisms used in structural analysis research to the extent that I can connect it to my own senses.
- (c) I have a high interest and curiosity in acoustic analysis research.
- (a) have a general understanding of phenomena used in acoustic analysis research to the
- (d) extent that I can connect it to my own senses.



Figure 3. Survey respondent attributes. Left is the age composition of the attendees. Right is years of experience composition of the attendees.

All 6 respondents were interviewed individually for a detailed analysis of the reasons for their answers in Figure 4 (a) through (c). Some of the opinions obtained were, "Structural analysis allows me to check the answers with my own experience" and "It is useful for adjustment because I can see the connections between the parts of the musical instrument." Another commented, "It is useful for judging which areas can be scraped and which cannot be scraped while making a violin, and for reproducing the arch shape and thickness distribution. This may suggest that the experiments based on the visualization data of the structural analysis, as shown in Figure 1, can be intuitively connected to the luthier's own experience and knowledge, and the cause-and-effect relationship can be easily determined. In other words, the luthier's intuitive understanding is possible in understanding the structural analysis because it is close to the sensory phenomena that the luthier usually feels without requiring special expertise.

On the other hand, it seems that without a certain level of specialized knowledge, it is difficult to properly understand acoustic analysis, as shown in Figure 2, and establish a causal relationship between the analysis data and experiences. In fact, a luthier said, "I joined the acoustical society and read its journals to get an image or a clue of acoustic analysis, but I could not understand at all even though I saw charts and figures." This is probably because it is essential to understand specialized knowledge such as frequency response function (FRF) and mode resonance frequency, which form the basis for understanding acoustic analysis. This specialized knowledge is difficult for a certain number of luthiers to understand and require a certain level of specialized knowledge to understand even the visualized data of acoustic analysis, which may be the reason why the agreed rates for Figure 4 (c) and (d) are lower than those for Figure 4 (a) and (b).

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#### 4.3 The discrepancy between the luthier's expectations and understanding

In structural analysis, the luthier has been shown to have high expectations as well as a high level of comprehension that allows for an intuitive connection between experience and visualized data. Meanwhile, despite the luthier's certain expectations in acoustic analysis, it seems that he may have considerable challenges in comprehension. In particular, several luthier's comments indicate that it is difficult for luthiers to intuitively connect acoustic analysis visualization data such as mode shapes with data as shown in Figure 2(a) that requires understanding based on specialized knowledge such as FRF and mode resonance frequency and that even if they are interested in acoustic analysis, they are at a loss as to how to connect it to their own practice, given their lack of specialized knowledge. In other words, even if a luthier is interested in acoustic analysis, they may not clearly understand the theory behind the data. Figure 2(b) shows a cross-sectional view of acoustic radiation, and the luthier seemed to be very interested in this kind of visualization of sound directionality. Furthermore, there was a positive comment with a sense of anticipation that 3D visualization data such as the one shown in Figure 2(c) might be intuitively understandable. This was not denied in the responses to Figure 4 (c) and (d) regarding the acoustic analysis, and the large percentage of "I do not know" responses indicates both confusion and anticipation on the part of the luthier.

However, it can be said that in structural analysis, as shown in Figure 1, the luthier can confirm the phenomenon with visualized data and convert their empirical knowledge and sensation into confidence because the luthiers themselves feel and know the phenomenon sensitively. In other words, in acoustic analysis, as shown in Figure 2(a), there are many aspects that the luthier does not understand sensitively, and even if the luthier confirms the phenomena with visualization data such as charts and graphs, it may not match their own experience. Even if luthiers could see visualization data such as mode shapes, they would not know how to connect it to their own practice. Therefore, the situation may be such that the luthier uses the visualization data for sensory confirmation because many phenomena in the structural analysis are already known to the luthier empirically, but the acoustic analysis is increasingly difficult to understand intuitively because many phenomena in the acoustic analysis are not yet known even empirically by the luthier.

This is a very important point to focus on when considering scientific research methods in the visualization data the luthier seeks. It can be assumed that modern luthiers use scientific approaches, such as visualization data, to empirically confirm what they already feel and know and to confirm the traditional techniques they have inherited. Meanwhile, for what modern luthiers may be relying on a scientific approach such as visualization data, which is easy to understand, to open up a new path for themselves in inheriting the tradition.

#### 4.4 The scientific approach required by luthiers

In any case, it is strongly suggested that the luthier hopes to intuitively connect and integrate his own experience with scientific data in sensory craftsmanship and to connect it with their confidence. Thus, a luthier's potential expectations in acoustic analysis, as shown in Figure 2, can be assumed to be significant. As a comment on visualization data in general, respondents said, "It is great that I can turn visualization data into my own certainty. I can put my trust in it, and it eliminates my doubts." and "Visualized data is very reliable when I am alone and have nothing to believe in." In other words, it seems that modern luthiers are seeking a scientific approach that is more intuitively connected to their practice to utilize scientific data, such as visualization technology for both what they already know empirically and their unknown senses.

These considerations suggest that the high level of expectation and the high level of understanding coincide in structural analysis, as shown in Figure 1 since it is a subject in which the luthier is often convinced in conjunction with the senses already obtained by the luthier themselves. On the other hand, since a large proportion of acoustic analysis involves trying to learn about knowledge and sensations unknown to the luthier from scientific sources, there is a discrepancy between expectation and comprehension, and there may be a latent expectation for intuitive understanding.

This indicates that an approach that enables a certain level of understanding without specialized knowledge is needed in acoustic analysis as it is in structural analysis in order to provide intuitive understanding for areas where the luthier has had to rely on traditional information and empirical intuition. Specifically, it is strongly suggested that a visualization method that basically does not require the understanding of specialized knowledge, such as Frequency Response Function (FRF) and Mode Resonance frequency, which form the basis of understanding acoustic analysis, is required. Based on this specialized knowledge, the behavior of mode shapes could be understood, but from the luthier's standpoint, there could be a fundamental problem of not being able to visualize how the mode shapes produce the acoustics when the final music instrument is assembled. In this respect, it is considered that the understanding of structural analysis does not require specialized knowledge and shows the reality that it can be sensibly connected to the practice of luthier. Thus, the results of this survey suggest that luthiers expect to develop innovative approaches to acoustic analysis results that could be sensitively connected to luthier practice.

## 5 CONCLUSION

This study suggests that luthiers have high expectations and understanding of visualization in structural analysis and intuitively connect their own experience with visualization data. This suggests that visualization data in structural analysis has the potential to play a significant role in strongly supporting luthiers' sensuous creation, given that they have had to rely on traditionally inherited skills and information and their own empirical intuition.

On the other hand, finding an approach that leads to the understanding of luthier not only in structural analysis but also in visualization in acoustic analysis is an issue to be addressed in the future. Therefore, we should continue to pursue the possibility of effective affective support for sensible artisanship practices from the standpoint of luthier sustainably inheriting the tradition.

## ACKNOWLEDGMENTS

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# TACTILE TOY DESIGN AND EVALUATION FOR BLIND CHILDREN

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## ABSTRACT

This article describes the design and usability evaluation of a set of tactile toys suitable for blind children. This set of toys includes three categories which includes vehicles, buildings, and animals. They are common objects but are difficult for blind people to recognize overall appearance through touch. The toys include wooden blocks and their magnetic accessories. Before assembling, blind children can touch and explore each part of the objects. After assembling, they can explore the overall structure of the objects. Through playing the toys, blind children will learn spatial concepts such as front and back, left and right, up and down, direction, and distance. This toy set also includes a story picture book and sounds of the context, which are used to enhance interactivity and strengthen blind children's understanding of objects and the context they belong to. The System Usability Scale (SUS) and the scale of Usefulness, Satisfaction, and Ease of use (USE) were used to evaluate the toys. The SUS evaluation results showed that the acceptance of toys is "Acceptable", and the corresponding adjective evaluations are "Good" and "excellent". The USE evaluation results showed that although the blind subjects considered the toys did not save their time to learn three dimensional and spatial concepts, they gave positive scores with respect to the ease of use, satisfaction, and learnability.

Keywords: toy design, blind children, tactile exploration, spatial concept

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#### **1** INTRODUCTION

More than 80% of human cognitive information processing comes from vision (Sanders & McCormick, 1987). Losing vision seems to be equivalent to losing most opportunities to obtain information. However, sensory compensation mechanism will be developed by visually impaired people. Through practice, adaptation, and frequent use of other senses, they are more sensitive to senses other than vision than those with normal vision (Lowenfeld, 1960). Wong (2011) pointed out that blind people's fingertip tactile spatial threshold is smaller than that of sighted people of the same age. The more time spent reading Braille, the smaller the fingertip tactile spatial threshold. The results of a study verified by fMRI also show that the tactile exploration of blind people is like the vision of ordinary people, and will change after repeated exposure. The same object gradually becomes familiar (Cacciamani & Likova, 2016).

This article mainly describes the design and usability evaluation of a set of toys suitable for blind school children. This set of toys conforms to the principles of children's toy design and allows blind children to understand through the splicing, dismantling and playing of geometric blocks. We chose vehicle, buildings, and animals along with the corresponding scenarios to design the toys. This is because these three types of objects are common our in daily life, but their overall appearances are difficult recognized through touch. Blind children are able to use the toys to explore shape, distance, size, and surface texture.

#### 2 LITERATURE REVIEW

The fingertips of blind people who often use tactile reading are more sensitive than sighted individuals. However, a large number of studies have shown that it is difficult for blind people to recognize tactile pictures of common three-dimensional objects (Sinha & Kalia, 2012). The reason may be due to the difficulty of recognizing shapes through touching the raised outline, or due to the difficulty of understanding the three-dimensional objects that the shapes represent, although the shapes can be recognized through touching. This situation comes from the incoherence produced when three-dimensional objects are displayed on a flat surface. The factors that affect recognition come from size, complexity or prior visual experience (Sharma, Srinivasan, & Rao, 2022). Research by Hsu (2001) pointed out that the ability of blind people to shape three-dimensional objects is slightly better than drawing objects on paper. This is because three-dimensional objects retain a large amount of information that can be directly detected by blind people through touching, while two-dimensional information requires retinal experience or training to be successfully Interpreted. This phenomenon also occurs in children with normal vision. Research by Zhang (2000) found that second-grade primary school students cannot express visual reality for three-dimensional objects on a flat surface, while fifth-grade students and adults are able to do it.

Due to a lack of visual experience, born blind children are quite unfamiliar with three-dimensional and spatial concepts such as shape, size, distance and direction. If they do not receive sufficient learning opportunities to access spatial concepts, they may face problems in movement, cognition, and delayed social development (Piculo, Orsi & Botura, 2019). In terms

of teaching strategies to train geometric and spatial concepts, Yi and Lin (2016) recommended the use of simplified object models as teaching aids, and making good use of various geometric panels to construct and deconstruct objects.

In terms of developing three-dimensional teaching aids and toys, in order to make it easy for blind students to use, meet safety requirements and achieve learning purposes, a series of design principles need to be met. Before designing a set of building toys suitable for blind school children, Hatice and Nilüfer (2019) first observed 125 school children in the classroom for a total of 90 hours for 5 weeks from three aspects of how to learn, how to move, and how to play. The observation focused on the interactive behavior with teachers and classmates during breaks and lunch time. From the results of behavioral observations, the authors summarized following three principles for designing blind children's toys:

(1) Improving life skills: including improving orientation ability, spatial concept, reading ability, and computing ability. Toys should provide comprehensive perception of familiar objects in life, and creating real-world models to practice daily life skills.

(2) Improving sensory stimulation: including tactile perception, the ability to track boundary indents and bumps. Toys should provide stimulation of various materials, textures and shapes. Stimulation of sounds and smells are better included.

(3) Promoting physical and mental development: children can be encouraged to explore, use creativity and imagination while playing the toys. They also will be encouraged to use the sense of touch to build mental maps, and be encouraged to develop their memory.

In addition, Hatice and Nilüfer (2019) also summarized general toy design principles, which include considering simplicity and durability of parts, supporting single and multi-player mode, considering gender friendly, and joint playing with other toys, etc.

Sun and Dong (2021) investigated the current toy designs for visually impaired school children and found that they were generally only focused on tactile, resulting in insufficient perceptual compensation conversion and poor sensory interaction. Therefore, the synesthesia theory was introduced into the design strategy of toys for blind children, including bringing the perception ability into context of games and promoting multi-sensory linkage. In addition, the design principles include considerations of safety and ease of use. In terms of safety, because blind children cannot detect dangers without touching the toys, the material and shape should be comfortable, rounded, and reduce hard and sharp structures. In terms of ease of use, since most blind children have poor patience and are prone to impulsivity, the toy should be designed to reduce the complexity of operation as much as possible and to give appropriate prompts.

To summarize, when born blind children learn three-dimensional and spatial concepts, it is better for them to use geometric blocks and panels to simplify three-dimensional shapes. It will be easier for them to learn via repeat tactile exploring, assemble, and disassemble the blocks. This may not only increase their familiarity with three-dimensional objects, but also enhances the sensitivity of their fingertips.

## **3 TOY DESIGN FOR BLIND CHILDREN**

The framework of designing the entire set of toys follows the teaching strategy for blind children learning geometrics proposed by Yi and Lin (2016), which is using simplified object models and making good use of geometric panel to deconstruct objects. We chose several objects that are common yet not easy to recognize through touching, such as a house and a bus, as prototype to design toys. Shapes of these common objects were simplified into simple wooden blocks. For example, the basic shape of an apartment is a long and thin cuboid. Blind children can explore the shape of the wooden blocks through touch to understand general appearance of the original object. Secondly, each wooden block is equipped with a number of magnetic puzzle pieces or accessories that can be assembled on the wooden block, so that the assembled wooden block can carry more information about the original object, such as the doors and windows of the apartment and a red cross sign shown on an ambulance. Through repeated touch, exploration, assembly and disassembly, blind children can slowly develop spatial concepts of front and back, left and right, up and down, as well as the original appearance of objects.

This toy set is planned three main types: vehicle, buildings, and animals. Details about item plans and final works of each type are given below.



Figure 1. A wooden block and its accessories that represent an ambulance.

#### 3.1 Series of Vehicle

The vehicle series includes a car, an ambulance, a bus, and a double-decker bus. Apart from the double-decker bus, each vehicle is represented using a simplified wooden block. The wooden blocks of ambulance and bus are assembled to represent the double-decker bus, as shown in Figure 2. Each vehicle is equipped with accessories such as windows, lights, roofs, bottoms, wheels, etc., which are represented by raised simplified geometric shapes, as given in Figure 3(a). The wheels include two designs, one is normal wheels and the other has a raised point on the tires (Figure 3(b)). This produces vibration feedback when the vehicle toys are pushed forward and backward, making it easier for blind children to count and practice the sense of distance. Vehicle series toys can be used to train spatial concept, such as front and back, left and right, forward and backward, and to understand the general shapes of vehicles.



Figure 2. Wooden block design of the 4 types of vehicle: a car, an ambulance, a bus, and a double-decker bus (from left to right).



Figure 3. (a) the toys of car and ambulance; (b) the wheel design with a raised point on the tire; (c) the prototype toy of a bus.

#### 3.2 Series of Buildings

The building series consists of two isosceles right-angled triangular prisms and two cubic wooden blocks (Figure 4(a)). The wooden blocks are combined into four building forms: tent, single story house, apartment, and two-story house. The tent is composed of two triangular prisms. The single-story house is composed of a triangular prism and a cubic wooden block. The apartment is composed of two cube blocks. The two-story house is composed of a triangular prism and two cube blocks. Each building is equipped with simplified doors, windows, roof tiles and other accessories, as given in Figure 4(b). The building series can be used to learn to judge and compare the height of objects, and to understand the basic shapes of buildings.



Figure 4. (a)wooden blocks of building series; (b) the blocks of a house and their accessories; (c) the prototype toy of a house.

#### 3.3 Series of Animals

The animal series consists of two wooden blocks, representing the head and the body of animals (Figure 5(a)). Four types of noses, ears, tails, limbs, and furs were designed to represent four animals: crocodile, rabbit, elephant, and cow. Each part of the animal toys can be used to tactilely explore the physical characteristics of the animals. The basic structure of the four animals can be explored when the toys are assembled.



Figure 5. (a) wooden blocks of animal series; (b) the assembled blocks and accessories; (c) the prototype toy of a rabbit.

#### 3.4 Integration and Packaging

In addition to the design of the toys, we also wrote stories that fit the context of the vehicle, buildings and animals, and then drew the stories to cute picture books. The stories along with the toys allow blind children and parents, teachers and ordinary children to learn and play together, making the game more interesting and interactive (Figure 6(a)). Parents or teachers can also scan the QR code to play sounds regarding the three series, increasing auditory stimulation to blind children while playing toys, which would strengthen the blind children's cognition about the objects and the context they belong to (Figure 6(b)). The above designs satisfy Hatice and Nilüfer (2019) and Sun and Dong (2021) on the principles of toy design for blind children.

In terms of packaging design, each of the three series of toys are integrated into a hardboard box. The box is easy to open and close, and intuitive to take out the parts. All wooden blocks and sub-packages of the accessories are neatly arranged. The braille information of each sub-package is revealed on the upward surface. This makes the whole set of toys easily accessible for blind children through touch (Figure 7).



(b)

Figure 6. (a) picture books that tell stories about vehicle, buildings and animals; (b) Scanning the QR code to play sounds.



Figure 7. Packaging design of the toy set



Figure 8. the tactile toy set and accessories.

# **4 EVALUATION OF THE TOYS**

The System Usability Scale (SUS; Brooke, 1996) and the USE Scale (Lund, 2001) were used to test the usability, ease of use, satisfaction, and learnability of the toy design. A 5-point Likert scale was used to design the questionnaire with 1 being strongly disagree, 2 being disagree, 3 being no opinion, 4 being agree, and 5 being strongly agree. Six blind children, age from 9 to 12 were recruited to conduct a post-use questionnaire survey.

The consistency of the subjects is determined by the root mean squared (RMS) of the individual subject and the mean score of all subjects (eq.1). The results show that the maximum

and minimum RMSs of the 6 blind children are 0.57 and 0.42, respectively, showing that the difference between an individual subject and the average of all subjects is less than 1, indicting high consistency of the subjects' responses.

$$\mathbf{RMS} = \sqrt{\frac{\sum_{i=1}^{n} (a_i - a)^2}{n}}$$

eq.1

*n* represents the number of questions,  $a_i$  is an integer from 1 to 5, representing the score of the  $f^h$  question, a represents a mean score of the  $f^h$  question.

The results of SUS scale show that the usability score ranged from 75 to 92.5. According to the definition of SUS score by Bangor (2009), the acceptance of toys is "Acceptable", and the corresponding adjective evaluations are "Good" and "excellent". In terms of the USE evaluation, the results show that when blind children play the toys, the ease of use, satisfaction, and learnability of the toys are rated well, with the exception of "This set of toys saves me time in learning three dimensional and spatial concept". The average score of this evaluation indicator is 3.17. All other evaluation indicators received a response of 4 points or above. The indicators of "This set of toys help me understand the appearance of vehicle, buildings, and animals", "This set of toys is useful", and "This set of toys is easy to use" rated the highest score of 4.83.

## 5 CONCLUSION

When blind children learn three-dimensional and spatial concepts using physical learning aids, real objects are easier to be understood than flat representations. This article describes the design and usability evaluation of a set of building blocks suitable for blind children. This set of toys includes three categories of vehicles, buildings, and animals. They are common objects but are difficult for blind people to recognize overall appearance through touch. The toys include wooden blocks and their magnetic accessories. Before assembling, blind children can touch and explore each part of the objects. After assembling, they can explore the overall structure of the objects. Through playing the toys, blind children can learn spatial concepts such as front and back, left and right, up and down, direction, and distance. This toy set also includes a story picture book and sounds of the context, which can enhance interactivity and strengthen blind children's understanding of objects and the context they belong to. The SUS evaluation results found that the acceptance of toys is "Acceptable", and the corresponding adjective evaluations are "Good" and "excellent". The USE evaluation results showed that although the blind subjects considered the toys did not save their time to learn three dimensional and spatial concepts, they gave positive scores with respect to the ease of use, satisfaction, and learnability.

During the execution of this study, we found that visually impaired children have access to fewer types of knowledge-based teaching aids and toys than sighted children, making them a relatively disadvantaged group in acquiring knowledge. The possible reason is that the cost of conveying same amount of knowledge tactilely is much higher than that via vision. From the perspective of design, an object only needs to be drawn into a picture card for sighted children

to understand. For blind children to recognize the same object, they need embossing outlines or even a 3-dimension representative of this object. From the perspective of business, the small market of teaching aids for blind children increases the cost of development and sales. Therefore, future development and research in this field may be directed towards simplification and easy mass production, so as to provide more diverse and affordable learning aids and toys.

#### **ACKNOWLEDGMENTS**

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# **EMPATHY MAPS IN PERSONA CONSTRUCTION**

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# ABSTRACT

This study investigated the application of empathy maps in persona creation, focusing on their impact and role in the process. Empathy is a key skill in design thinking, involving the understanding of others' perspectives. Empathy maps enhance this skill through collaborative, visual thinking. The study employed the methods of Ferreira et al. (2015) and thinking aloud protocols to analyze participants' cognitive processes. The findings indicate that empathy maps altered problem-solving strategies, helping participants to focus on specific issues, although they did not significantly affect the number or duration of persona creation activities. This research provides empirical evidence of the role of empathy maps in the design process and reveals their influence on user-centered design strategies. These insights demonstrate that empathy maps can facilitate more systematic design work, even though they may not necessarily stimulate the generation of more ideas and might require additional time to ensure overall coherence. Future research should further validate the effectiveness of these tools in various design workflows to enhance empathy-driven design practices.

*Keywords:* design thinking, user-centered, think aloud

# **1** INSTRUCTION

Empathy is a multifaceted skill requiring the ability to perceive and understand others' perspectives and emotions, making it a critical capability applied across various fields. Since the term "empathy" emerged in the design domain in the late 1990s, it has been recognized as one of the most unique and essential steps in human-centered design thinking (Köppen & Meinel, 2015). The literature emphasizes user-centered concepts, asserting that achieving adequate user experience necessitates a thorough understanding of user needs and expectations (Ferreira, Conte, & Barbosa, 2015). When designers empathize with users, they are inspired and guided to create products that meet user needs (Kouprie & Visser, 2009). To make this process as effective as possible (Osterwalder & Pigneur, 2010), simple yet specific visual tools like empathy maps are commonly used (Bland, 2016).

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Empathy maps, designed to capture and visualize users' thoughts, serve as a framework to foster empathy (Gray, 2010). They convert user attitudes and behaviors into textual formats, aiding design teams in gaining deeper insights into end users. However, empathy maps provide static information that may not intuitively reveal interactions across different domains (Siegel & Dray, 2019). These insights are frequently transformed into detailed personas, which offer comprehensive descriptions of user characteristics, needs, and behaviors. Personas facilitate better design decisions by providing a more holistic and dynamic understanding of users, thereby aiding design teams in creating products or services that more effectively meet user needs (Ferreira, Conte, & Barbosa, 2015). Personas contain detailed descriptions of user characteristics, needs, and behaviors, aiding design teams in better designing products or services to meet user needs (Ferreira, Silva, Oliveir, &Conte, 2015). Previous studies have explored the subjective usefulness of constructing personas with empathy maps through surveys. However, Dunning, et al. (2004) pointed out several biases associated with survey methods, including unrealistic optimism about one's abilities, believing oneself to be above average, ignoring key information, and having information deficits. Therefore, this paper extends this research and modifies the experimental design to examine the impact of integrating empathy maps in persona creation by designers, aiming to delve into the process of creating personas through the think aloud method. Subsequent findings from this study may provide insights into the impact of empathy maps on other stages of the design process.



Figure 1. Design thinking model

The design thinking model defined by IDEO points out that empathy is the first stage in the entire process.

## 2 LITERATURE REVIEW

#### 2.1 Empathy Map

The empathy map, proposed by Scott Matthews of the business design firm XPLANE, is a collaborative visualization tool aimed at concretizing information about users to (1) create a shared understanding of user needs and (2) aid decision-making for designers. The goal is to foster a certain degree of empathy among designers (Sarah Gibbons, 2018), enabling teams to quickly focus on users when a deeper understanding is required. This user-centered approach emphasizes observing the world through a different perspective to understand users, often used to create personas, allowing design teams to delve deeper into understanding users and uncover their true needs (Ferreira, Silva, Oliveir, &Conte, 2015).

The initial version of the empathy map proposed by Scott Matthews (2012) includes sections such as See, Say & Do, Hear, Think & Feel, each describing various experiences of the target audience. Additionally, Bland (2012) identified "Pain Points and Needs" as important areas to explore (refer to Figure 2). However, each field is independent, and design teams may struggle to understand the relationships between them (Siegel & Dray, 2019).



Figure 2. Empathy Map Example Adapted from Bland, D. (June 25, 2012).

#### 2.2 Persona

Personas are commonly used tools during the empathy phase to enhance stakeholders' understanding of their audience, customers, or users. Widely applied in product design, service design, software design, and marketing (Cooper, 1999), they help understand users' needs, experiences, behaviors, and goals. Based on actual user data collected from multiple individuals, personas aim to provide realistic representations of target users while revealing their common characteristics (Nielsen et al., 2013). Cooper (1999) proposed several benefits of using Persona: (1) it helps development teams understand user characteristics; (2) it proposes solutions related to primary user needs; (3) it provides a personalized framework to bring potential users closer to the team.

#### 2.3 User experience

User-centered design has become increasingly emphasized in modern design practices, aiming to better understand user needs, thoughts, and experiences to improve overall user experience (UX). The ISO standard 9241-210 defines UX as a comprehensive concept encompassing all aspects of the user's interaction with a product, including usability and accessibility. Understanding, predicting, and reasoning about the UX process is crucial, making user experience modeling particularly important (Law & Abrahão, 2014).

From the literature mentioned above, it is evident that both empathy mapping and personas serve as design tools to help us approach target users and uncover their true needs. The key difference lies in the level of detail in personal data description: empathy mapping focuses more on the lifestyle and psychological perspectives of the target audience, aiding in understanding users through others' viewpoints and highlighting the importance of role and user experience modeling in the design process.

## 3 METHODS

This study explores the utilization of empathy mapping and its impact on persona creation through experiments with two individuals experienced in design thinking and empathy mapping.

Adopting Ferreira, Silva, Oliveira, & Conte, (2015) methodology, we designed questionnaires to evaluate participants' subjective perceptions and acceptance of empathy mapping. Additionally, we employed the think aloud method to analyze thought processes, thereby assessing the effectiveness of empathy maps in facilitating persona creation.

## 3.1 Research Method

The experiment lasted 40 minutes, starting with a 5-minute introduction and warm-up session. Participants first learned the structure of the experiment and participated in a warm-up exercise: reading a newspaper article about a future product while thinking aloud. The warm-up aimed to familiarize participants with the thinking aloud process. Video and audio recordings captured verbal expressions, facial expressions, and behaviors throughout the process. When participants stopped thinking aloud, researchers encouraged them to verbalize their thoughts to ensure comprehensive data collection.

During the formal think aloud experiment, the study compared the effects of empathy map integration on the creation of personas through two processes:

- First Process: Participants read the newspaper article and extracted information to create a persona.
- Second Process: Participants extracted information from the newspaper article to populate an empathy map and then used it to create a persona.

At the end of the experiment, participants completed a questionnaire to capture their subjective experiences. Templates for the empathy map (Gray, 2010) and persona were provided. The persona template included sections for: (1) Basic information (name, age, gender, occupation, income); (2) Personality traits and interests; (3) Behavioral habits and lifestyle patterns; (4)A photograph that matches the persona's image. Participants are not required to fill out all fields, but rather to engage in divergent thinking based on the provided stimuli.

# 3.2 Stimuli & Questionnaires

The stimuli for this study were newspapers, selected from reputable websites and refined for better comprehension by the participants. The articles discussed potential future products or services, detailing their functions, features, and possible applications. Different articles were used for the warm-up phase and the first and second processes to avoid repetitive content that might cause participants to carry over thoughts from a previous experiment, thereby affecting the accuracy of the results.

The questionnaire for this study primarily draws from the factors defined in the Technology Acceptance Model (TAM), as outlined by Ferreira et al. (2015), to investigate participants' personal perceptions of tool operation. Please refer to Table 1 for the questionnaire content.

Table 1. Subjective Questions in Questionnaire Survey

Number	Questions
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1	Would you choose to use empathy maps again if you had to use personas again? Why?
2	How do you perceive the assistance provided by empathy maps?
3	In your opinion, which aspects of empathy maps have a positive impact on creating personas?
4	In your opinion, which aspects of empathy maps have a negative impact on creating personas?
5	Would the difficulty level of the content in the two newspaper articles affect the responses?

## 3.3 Coding system and analysis

The coding system used in this study was based on the coding methodology employed by Chun-Heng Ho (2001). To ensure accuracy, the initial coding was followed by a second round of coding one month later. During the analysis phase, the team first employed a problem decomposition strategy to break down the participants' problem-solving processes and sequences. Subsequently, by reviewing the participants' thinking strategies, the protocols were segmented (refer to Table 2) and mapped to the information from the newspaper or the empathy map, as well as to the contents of the personas. This approach aimed to discern whether participants employed explicit or implicit strategies when searching for information in the newspaper or the empathy map while creating personas.

This study defined thought strategies into the following two categories:

- Implicit thinking strategies: Intuitive decision-making or forward search strategies.
- Explicit thinking strategies: Observable retrospective reflection or inference based on past information, evident referencing of empathy maps during persona creation influencing decision-making, or backward search strategies.

Timecode	Transcript
02:00	It seems that the people who need this product are basically women who have this strong need.
02:10	Because men usually don't care that much about maintenance.
02:17	It should be said that women are a relatively typical ethnic group.
02:20	If the person is female, they need to be a little older for the product to be effective.
02:28	About 40 years old.

#### Table 2. Subjective Questions in Questionnaire Survey

## 4 **RESULTS**

Throughout the entire experimental process, it is noteworthy that both participants subjectively acknowledged the assistance provided by empathy mapping in the subsequent creation of personas, enabling a clearer focus on the questions (refer to Table 3). However, the number of ideas generated in the personas created after utilizing empathy mapping did not show significant differences, and both participants spent a longer duration of time.

Number	Answers
A1	Yes, through empathy maps, we can clearly identify the pain points and needs of the characters, which can further enhance the persona.
B1	I would use it; I feel that it somewhat helps me to focus more when building persona.
A2	Empathy maps can help to think step by step.
B2	There are moments when I feel that empathy maps guide me in building characters and also help me to recall them in my mind.

**Table 3**. Answers Regarding the Utility of Empathy Map.

## 4.1 The Process of Problem Decomposition for Participants A & B

The problem decomposition strategies of participants A & B (refer to figure3) reveal striking similarities in their approaches to persona creation, with differences mainly observed in the sequence of addressing individual sub-problems. This study posits that the minor discrepancies may stem from the participants being constrained by the provided templates and their preconceived notions shaped by prior design education regarding persona construction.



Figure 3. Problem Decomposition Processes of Participants A & B

Participants generally divided the personas into two main sections: basic information and additional details such as interests, lifestyle patterns, and behavioral habits.

#### 4.2 The Strategy Process of Participant A in Creating Personas

Participant A, with over three years of experience in learning and applying design methodologies, demonstrated a preference for employing implicit thinking strategies when addressing subproblems during the first process. Following the initial reading of the newspaper, he proceeded to create personas. Subsequently, he tended to adopt an implicit thinking

strategies. Finally, when selecting images for the target personas, he transitioned to using explicit thinking strategies to evaluate the alignment between each sub-solution and the chosen images (refer to Figure 4).



**Figure 4**. The strategy employed by Participant A and B in the first process, after reading the articles and using empathy maps to address the issues.

In the second process, when Participant A incorporated the use of empathy maps after reading the articles and continued to create personas, it was observed that he initially employed implicit thinking strategies to address the sub-problems related to basic information. However, for other sub-problems, there was clear evidence of using explicit thinking strategies, such as searching for past information or referencing the empathy maps to confirm sub-solutions (refer to Figure 5). Particularly through the analysis of verbatim transcripts and actions captured by the camera recording, it was evident that Participant A extrapolated sub-solutions from the pain points and needs sections of the empathy maps.





## 4.3 The Strategy Process of Participant B in Creating Personas

Participant B, in the first process, after reading the articles and subsequently creating the persona to address the sub-issues, initially adopted a more single implicit strategies, generating more intuitive solutions (Figure 4). This is evident from the participant's statement in the transcript: "This is my first thought after reading the article.

In the second process, Participant B, after reading the articles, utilized the empathy map before addressing the sub-issues, and notably altered the original singularly forward working strategy (Figure 5). Transitioning from an implicit thinking strategies, they began to retrospectively refer to the descriptions on their empathy map when constructing the persona. For instance, when describing the character's personality in the persona, they mentioned, "Outgoing but attentive, which is related to the empathy map I just created.

## 5 CONCLUSION

Based on the experimental findings, it was observed that the incorporation of empathy maps significantly influenced participants' problem-solving approaches, shifting from implicit forward-thinking to explicit backward-thinking strategies. During the subsequent phase of persona creation, participants utilized insights from empathy maps to ensure coherence among sub-solutions. Questionnaire responses revealed that empathy maps facilitated participants' focus on specific issues, particularly pain points and needs. However, this did not lead to a substantial increase in the quantity of ideas generated within the personas. In the subsequent phase, participants introduced only a limited number of additional ideas and allocated more time to persona construction. This implies that while empathy maps promote systematic thinking and coherence, they may not inherently stimulate idea generation. Empathy maps may aid designers in structuring their work more systematically, interlinking each sub-solution within the personas. Nevertheless, they may not inherently stimulate participants to generate more ideas and may necessitate additional thinking time to ensure overall coherence.

Furthermore, the team identified that the sequence in which participants selected images influenced the entire persona creation process. Participant A selected images aligning with personas as the final sub-problem, reflecting on each sub-solution during the selection process. In contrast, Participant B relied on intuition to initially select images and maintained a single forward-thinking strategy. Thus, it is postulated that the sequence of addressing sub-problems may impact the strategies adopted during the work process. Each step in the problem-solving process could influence subsequent solutions, and simple alterations in sequence could prompt individuals to revisit past information to confirm solutions during persona creation.

Finally, to mitigate potential bias arising from differences in newspaper complexity, the experiment surveyed participants' perceptions of the complexity of the newspapers. However, significant differences were observed between the two participants regarding their perceived difficulty of the newspapers. This divergence may be attributed to individual backgrounds, preferences, or variations in typical knowledge acquisition. Given that qualitative research focuses on in-depth investigations of specific cases, this study sampled only two participants familiar with design tools. Future research will include a larger number of participants to enhance the credibility of the findings. Additionally, since the experimental results suggest that empathy maps can systematize the design process, the team plans to further investigate their integration into various design workflows to verify their effectiveness.

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# DESIGN OF A JAPANESE LANGUAGE EDUCATION COMMUNITY WORLD BIBLIOBATTLE CHAMPIONSHIP

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# ABSTRACT

In this paper, the design concepts of the World Bibliobattle Championship (WBC) are described. Bibliobattle is a book review game that is widely enjoyed in schools and public libraries across Japan. This game offers several benefits to players, such as improving communication skills and fostering friendships. Therefore, incorporating Bibliobattle into language education classes also presents advantages. To promote the use of Bibliobattle in Japanese language classes, the authors have organized an annual event, the WBC. The WBC is a Bibliobattle competition conducted in Japanese, designed to serve as a hub for communities involved in Japanese language education. In this paper, the design concepts of the WBC are explained, followed by an overview of its history. Then, the results of questionnaires conducted to evaluate the effectiveness of the event are presented.

*Keywords:* Japanese language education, public speaking, book review, gamification, learning community.

# **1** INTRODUCTION

As a learning material for foreign language education, the authors group focused on a communication game, called Bibliobattle, and have been trying to introduce the game into Japanese language classes (Yamaji et al, 2013). Through these practices, we identified several benefits of Bibliobattle for learning public speaking in Japanese (Fukazawa & Kobayashi, 2012), such as (1) flexibility in selecting speaking topics, (2) rapid and direct feedback, and (3) training in constructing content within a time limit.

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To promote the use of Bibliobattle in Japanese language classes, the authors' team has organized an annual international Bibliobattle competition conducted in Japanese since 2014 (The Committee of World Bibliobattle Championship, 2024). The event is designed to serve as a hub for communities involved in Japanese language education. We anticipate that incorporating elements of "competition" and "communication" from gamification theory (McGonigal, 2012) will enhance students' motivation to learn.

In this paper, the official rules of Bibliobattle are described, followed by an overview of its use in language education. Next, the conceptual design and history of the WBC are presented. Finally, the results of a questionnaire conducted to evaluate the effectiveness of the event are shown.

# 2 BACKGROUND

# 2.1 What is Bibliobattle?

Bibliobattle is a book review game widely played in schools and public libraries across Japan. The official rules for Bibliobattle can be found on the official site of the Committee of Bibliobattle (2024), along with the minor regulations listed below.

# The official rules

- 1 Presenters join with a favorite or interesting book.
- 2 Each presenter introduces the book for 5 minutes.
- 3 After each presentation, all participants discuss the book for 2--3 minutes.
- 4 After all presentations are finished, all participants vote for the book they want to read the most. The book with the most votes is selected as the "Champion Book."

# The minor regulations

- Presenters join with a favorite or interesting book.A) Make sure that each presenter chooses their own book for their presentation.B) An organizer can set a specific topic or theme for the Bibliobattle.
- Each presenter introduces the book for 5 minutes.
  A)After exactly 5 minutes, the presenter must finish their presentation immediately.
  B)Presenters should not use handouts or slides, etc.
  C)Presenters must use up all 5 minutes of their presentation time.
- 3 After each presentation, all participants discuss the book for 2--3 minutes.
  - A)Participants should not criticize presenters or their presentations. Participants are encouraged to ask questions for additional information which helps them decide which book to vote for.
  - B)All participants should contribute to creating a friendly and enjoyable atmosphere.
  - C)Discussion time can be extended by the organizer but should not significantly exceed the original time schedule.
- 4 After all presentations are finished, all participants vote for the book they want to read the most. The book with the most votes is selected as the "Champion Book."

- A)Presenters also have the right to vote. However, they cannot vote for the book they presented.
- B)The "Champion Book" must be determined by a democratic vote by all participants. Note that all participants have an equal right to vote; that is, the ``Champion Book" should not be determined by a small number of people in power, such as the chair, an organizer, or teachers.

Here, "participants" refers to everyone who joins the game, including both presenters and listeners. As we can see from the rules, Bibliobattle places great importance on the feeling of live interaction. This factor is crucial for learning public speaking.

# 2.2 Bibliobattle in language education classes

In language education classes, the four skills—speaking, listening, reading, and writing—are considered essential components. Among these, creating educational materials for speaking skills is particularly challenging because it is difficult to prepare engaging topics that can stimulate all students' motivation to speak. As an approach to solving this problem, Bibliobattle has gained attention. By introducing this book review game, students can participate in classes with greater interest, as "reading" is a commonly enjoyed hobby, and books hold universal value for everyone.

Suto (2013) pointed out three benefits of introducing Bibliobattle into language education classes:

- 1. Improve students' motivations for active participation in class.
- 2. Students can experience both making a speech based on preparation and speaking on topics ad-lib in a short time under a certain level of pressure.
- 3. It enhances students' ability to articulate their thoughts in speech..

Several instances of English language classes have been reported where Bibliobattle games were introduced. Kimura (2021) incorporated Bibliobattle into his English learning classes to supplement the lack of "speech based on experience." Freiermuth and Ito (2022) introduced Bibliobattle into EFL (English as a Foreign Language) classrooms to promote L2 reading enjoyment and motivate students to read English books. Oda (2018) introduced Mini-Bibliobattle⁶⁸ in a class and identified several benefits.

Bibliobattle has also been introduced into Japanese language education classes. Yamaji and Suto (Yamaji et al., 2013) implemented Bibliobattle as the main activity in an intermediate Japanese language class. They investigated the effects on students' public speaking abilities using protocol analysis methods. Ego (2021) also conducted an advanced-level Japanese language class with Bibliobattle.

⁶⁸ Another rule of Bibliobattle that is played with three minutes presentations. Originally, it is designed for early elementary grades.

In this way, many practices of language education class with Bibliobattle have been conducted.

## **3 WORLD BIBLIOBATTLE CHAMPIONSHIP (WBC)**

#### 3.1 Outline

WBC is a Japanese language education program event grounded in the theories of gamification (McGonigal, 2012), particularly emphasizing "competition" and "communication." The primary goal is to offer Japanese language learners an opportunity to practice public speaking. Additionally, it aims to serve as a central hub for Japanese language education communities worldwide.

WBC is designed as a tournament-style competition held once a year. Currently, Japanese language classes in Japan, Taiwan, and Thailand participate in the program. In these classes, students enjoy playing Bibliobattle games. Qualifying rounds of the tournament are held in these classes, and students compete to win. The winners of each qualifying round advance to the final stage, where the winner of the final round is awarded the title of "World Bibliobattle Champion of the Year."



Figure 1. Image of the World Bibliobattle Championship (WBC) Tournament.

A WBC competition event consists of several qualifying rounds and a final round. Qualifying rounds are divided into two types, Type A and Type B.

A qualifying round of Type A is a game for non-native speakers of Japanese. Lecturers of Japanese language classes can propose this type of qualifying round. A lecturer who wishes to propose a qualifying round must submit a plan that includes the date, location, and estimated

numbers of presenters and audience members to the WBC office in advance. Each qualifying round must have at least four presenters and at least ten audience members, including the presenters.

Meanwhile, a qualifying round of Type B is a game for native speakers of Japanese. This type of qualifying round is hosted by the WBC executive committee and is held once a year. That is to say, only one Japanese native speaker joins the final round as the "Japanese representative" presenter of the year.

The final round of the year is hosted by the WBC executive committee. The presenters who won the qualifying rounds compete in the final round. As mentioned above, the winner of the final round is awarded the title of "World Bibliobattle Champion of the Year." The picture in Fig. 2 shows a scene from the awarding ceremony at WBC 2023, held in Higashiosaka City, Japan.



Figure 2. A Scene from the Awarding Ceremony at WBC 2023.

## 3.2 Regulations

The regulations of WBC are based on the rules of the National University Bibliobattle Competition in Japan (National University Bibliobattle Competition Preliminary Office, 2023). The regulations of WBC are as follows:

- 1. Presenters must use Japanese in their presentations. However, they may choose a book written in any language.
- 2. In discussion sessions, presenters may speak with the aid of interpreters as necessary.
- 3. Presenters may use props to explain the book and related episodes.
- 4. Distributing resumes is prohibited.
- 5. Using memos with texts read is prohibited except memos wrote on the book and sticky notes.
- 6. The use of presentation tools, such as PowerPoint or Keynote, is prohibited.
- 7. Presenters must use the full five minutes allocated to them.
- 8. Participants should not criticize presenters or their presentations, nor should they ask captious questions. Participants are encouraged to ask questions that help them decide which book to vote for.
- 9. The voting criterion is "the book you most want to read." Participants should not vote simply to support a friend.
- 10. Only participants who have watched all the presentations have the right to vote.
- 11. The host does not vote, except in the case described in the 12.
- 12. If two or more books are selected as "Champion Books," a decisive vote is conducted. In this case, the host also votes, with their vote counting as half.

In the above regulations, items 1) and 2) are additions to the original rules of the National University Bibliobattle Competition in Japan. The first item is included to encourage presenters' motivation, as they can better understand the book's content before making their speech. The second item is included to facilitate meaningful discussion by eliminating language barriers, allowing all participants to feel satisfied with their involvement.

# 3.3 History of WBC

Date	Qualifying round	Final round
October 25, 2014	Muroran, Japan Taichung, Taiwan Wuhan, China Melbourne, Australia	Hokkaido, Japan (Muroran city) 6 presenters
October 24, 2015	Muroran, Japan Taichung, Taiwan Jiaozuo, China	Hokkaido, Japan (Muroran city) 5 presenters
October 22, 2016	Muroran, Japan Taichung, Taiwan Wuhan, China Melbourne, Australia	Hokkaido, Japan (Muroran city) 5 presenters
November 3, 2017	Muroran, Japan Taichung, Taiwan Changhua, Taiwan Melbourne, Australia	Hokkaido, Japan (Muroran city) 5 presenters
November 11, 2018	Muroran, Japan Taichung, Taiwan Wuhan, China Melbourne, Australia	Hokkaido, Japan (Muroran city) 6 presenters
November 11, 2019	Muroran, Japan Fukagawa, Japan Taichung, Taiwan Bangkok, Thailand	Hokkaido, Japan (Shiraoi town) 6 presenters
October 21, 2023	Higashiosaka, Japan Yao, Japan	Osaka, Japan (Higashiosaka city)

#### Table 1. History of WBC

Taichung, Taiwan	5 presenters
Bangkok, Thailand	

Table 1 shows the dates and locations of the qualifying rounds and final rounds of previous WBC events. Table 2 shows the number of participants in the final rounds from the first event to the seventh event. As we can see from the table, most participants came from Asian countries, with more than a quarter from Taiwan. Additionally, in four out of the seven events, presenters from Taiwan won the final rounds and received the Champion Book awards.

Nationality	number of presenters
Taiwanese	10
Chinese	9
Japanese	7
Thai	4
Australian	4
Malaysian	2
Zimbabwe	1
Nepal	1
Total	38

# 3.4 Evaluation

To evaluate the effectiveness of the event, questionnaires were conducted from August 9 to September 13, 2023, during a qualifying round and exercise classes in Bangkok, Thailand.

The questionnaire items are:

- Q1 Did you enjoy the Bibliobattle game?
- Q2 Do you want to play Bibliobattle game again?
- Q3 Do you think Bibliobattle is beneficial for learning Japanese?

T Participants responded to the questionnaire using a four-point scale. The participants were students from the Thai-Nichi Institute of Technology who are studying Japanese in their courses. A total of 40 responses were collected. Figure 3 shows the average results.

As we can see from the results, the participants enjoyed the Bibliobattle games and found them beneficial for learning Japanese. Thus, the program can effectively encourage active learning among students.





# 4 CONCLUSION

In this paper, the conceptual design and history of the WBC were described. From 2014 to 2023, the final rounds featured 38 presenters from eight countries. Qualifying rounds were held in seven educational communities worldwide. The following is a list of the universities where qualifying rounds were held:

- Da-Yeh University, Taiwan
- Huazhong University of Science and Technology, China
- Kindai University, Japan
- Muroran Institute of Technology, Japan
- National Taichung University of Science and Technology, Taiwan
- Royal Melbourne Institute of Technology, Australia
- Takushoku University Hokkaido College, Japan
- Thai-Nichi Institute of Technology, Thailand

In this way, WBC serves as an international hub for Japanese language education communities.

Since 2023, the WBC executive committee has decided to hold the final rounds as hybrid events, combining on-site and online participation. This decision allows communities from more countries to easily join the WBC. As WBC continues to grow, we invite more Japanese language education communities and learners from around the world to join us. If you are interested in the event, do not hesitate to contact us.

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# ENHANCING RELAXATION THROUGH PORTABLE FOOTBATHS WITH VIRTUAL VISUALS AND A SULFUR SCENT: A COMPARATIVE ANALYSIS OF CHINESE AND JAPANESE PARTICIPANTS

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# ABSTRACT

This study combines footbaths with Virtual Reality (VR) to enhance relaxation. Portable footbaths are convenient but lack the openness of outdoor ones. Virtual visuals and olfactory stimuli address these limitations. The study examines sensory preferences of Chinese and Japanese participants. The results of a psychological evaluation based on the semantic differential method suggest that Chinese and Japanese participants differ in their preference for and familiarity with visual stimuli, but are not affected by the presence or absence of a sulfur scent. Cerebral blood flow changes were measured with and without a sulfur scent, and the results showed visual and olfactory stimuli influenced brain activity differently. Under a nighttime foot-bathing scene, a sulfur scent activates both left and right brain activities in Chinese participants, while Japanese participants showed higher left-brain activity under a daytime outdoor-bathing scene, both with and without a sulfur scent. These findings suggest the need to consider sensory preferences in VR footbath design, taking into account cultural and individual differences.

*Keywords:* Virtual Reality (VR), Sensory Preferences, Cerebral Blood Flow.

# **1** INTRODUCTION

Despite advances in information technology, the number of people who find it difficult to relax, even during holidays, due to busy work schedules has increased. Another notable

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problem in modern society is significant aging. As people age, their legs and lower backs weaken, causing difficulty in walking and making it challenging for the elderly to use public transportation and move around. This study aims to address one of these issues through research and development using portable footbaths and Virtual Reality (VR) technology.

Portable footbaths offer numerous benefits, such as providing an easy way to experience onsen, facilitating rehabilitation, and offering relaxation for the elderly and others who find it difficult to visit actual onsen locations. Additionally, VR technology is being used for virtual immersion, social interaction, education, and cognitive training. By focusing on the benefits of portable footbaths and VR technology and combining the two, it is possible to create new services that improve quality of life and promote physical and mental health.

This study examines the effects of combining portable footbaths and VR on psychological relaxation and explores more convenient and easy-to-use forms of leisure entertainment. The study uses cerebral blood flow (total hemoglobin) data from a wearable near-infrared spectroscopy device called the HOT-2000 as statistical indicators and employs a semantic differential method for subjective evaluation analysis. In addition, an aroma diffuser will be used to diffuse the smell of sulfur, and onsen VR videos will be used to explore scenarios that enhance comfort during footbaths. The relaxation effect will be evaluated using subjective assessments through questionnaires based on the semantic differential scales and objective physiological indicators, specifically cerebral blood flow. This study examines whether the relaxation effect is enhanced when VR footbaths are combined with olfactory stimulation, using a sulfur scent as the olfactory stimulus. In addition, this study compares the relaxation effects between Japanese and Chinese individuals.

### 2 RELATED STUDIES

#### 2.1 Stress Relief and Relaxation Using VR

Kazuyuki Matsumoto et al. (2019) investigated the stress-relieving potential of VR for bedridden patients, finding significant physical and psychological benefits. They discovered that tailored VR simulations, particularly those simulating outdoor walks in a quiet environment, reduced tension and promoted relaxation. They emphasized the adaptability of VR to individual preferences and its practicality for the elderly, noting advances in affordable VR technology.

Further supporting the potential of VR in stress relief, Hoffman et al. (2003) explored the use of VR to alleviate pain in burn patients, finding that VR distraction significantly reduced pain perception. This highlights VR's broad applicability in mitigating various forms of discomfort and stress. Similarly, Li et al. (2017) examined the impact of multisensory stimulation on relaxation, discovering that VR experiences incorporating visual, auditory, and olfactory stimuli significantly enhanced users' relaxation and well-being. This study underscores the potential of multisensory VR experiences in stress reduction and mood enhancement. Additionally, Chirico et al. (2016) investigated the effects of VR meditation on cancer patients, demonstrating that VR meditation significantly reduced anxiety and depression while improving quality of life, further confirming VR's value in psychological health interventions. Despite these promising findings, several limitations persist in existing research. Individual differences in VR experiences, such as cultural background, are often overlooked, which could significantly impact the effectiveness of VR interventions. Furthermore, while multisensory experiences have been proven effective, optimal integration of different sensory stimuli remains underexplored.

# 2.1 Emotion Research Using Near Infrared Spectroscopy (NIRS)

Near-infrared spectroscopy (NIRS) is a non-invasive technique widely used in sensory and emotional research to measure cerebral hemodynamic responses. Hoshi and Tamura (1993) demonstrated NIRS's capability to detect changes in brain activity due to various sensory stimuli. In multisensory research, Hoshi (2003) used NIRS to investigate the effects of combined sensory stimuli on brain function, highlighting its relevance for studying the interplay between olfactory and visual inputs. Regarding olfactory stimuli, Tanida et al. (2007) utilized NIRS to examine the impact of different scents on brain activity, supporting its use in exploring how scents like sulfur influence cerebral blood flow and emotions.

Although specific NIRS studies on footbaths are limited, its established utility in sensory research justifies its inclusion in our methodology. Using NIRS is considered more suitable for impression evaluation studies involving a VR device than other measurement methods. Our study utilizes NIRS as a suitable measurement method to capture brain activities during the multisensory footbath experience.

#### 3 METHODS

#### 3.1 Participants

Twenty participants, including 10 Chinese and 10 Japanese individuals, were selected for the experiment. The group was evenly divided by gender, with 10 males and 10 females. The ages of the participants ranged from teenagers to people in their 40s, with an average age of 27.8 years for males and 26.7 years for females. On average, the Chinese participants had spent 5 years in Japan, and all participants were right-handed. The purpose of this diverse selection was to increase the reliability and generalizability of the experiment and to enrich the interpretation of the results with deeper insights.

### 3.1 Equipment

Participants wore a near-infrared spectroscopy (NIRS) device over the prefrontal cortex to monitor changes in cerebral blood flow associated with brain activity. This device (HOT-2000, NeU Corp.) consists of 2-channel detectors and is adjustable to fit different head sizes. It can also be used simultaneously with a VR head-mounted display (HMD). In our experiment, we used a VR headset device with an eye-tracking system (FOVE 0, FOVE Inc.). Additionally, an aroma diffuser (MUJI MJ-PAD1, Ryohin Keikaku Co., Ltd.) emitted a sulfur scent during the VR video sessions. In this study, a portable footbath (EH2862P-W, Panasonic) maintained a temperature of approximately 40 degrees Celsius from the toes to the calves, which is considered comfortable and conducive to relaxation.



Figure 1. (Left) Portable footbath, (Right) VR headset device with 2-channel NIRS sensors.

#### 3.2 Experimental Procedure

The experimental procedure is as follows:

- At the beginning of the experiment, participants were fitted with a near-infrared spectroscopy (NIRS) device placed over the prefrontal cortex to monitor changes in cerebral blood flow associated with brain activity. Participants then engaged in a 1-minute relaxation period with their eyes closed to ensure a relaxed state. Following this, they watched a scentless VR video for approximately 30 seconds while concurrently receiving a footbath.
- After experiencing the VR video and footbath, participants immediately completed a 3-minute questionnaire to record their subjective ratings and impressions of the experience. The questionnaire aimed to capture their immediate reactions to the combined VR and footbath session.
- 3. Subsequently, participants took a 1-minute relaxation break to return to a baseline state of relaxation. They then viewed the same VR video again, this time infused with a sulfur scent emitted from an aroma diffuser.
- 4. Following this session, participants filled out another 3-minute questionnaire detailing their overall impressions and evaluating the impact of the sulfur scent on their combined VR and footbath experience.
- 5. A week after the completion of the first experiment, participants underwent a second session under the same experimental procedures. However, the VR video content in the second session differed from that used in the first session. This design allowed for exploration of potential differences in relaxation responses based on different environmental settings.



Figure 2. VR videos: (Left) A nighttime foot-bathing scene, (Right) A daytime outdoor-bathing scene.

#### 3.3 Psychological Evaluation and Analyses

The study employed the Semantic Differential Method (SD method), comprising 10 pairs of adjectives, to elicit subjective evaluations of relaxation levels from participants on a 8-point scale. The adjective pairs related to consciousness and emotions included "good—bad," "attractive—unattractive," "refreshing—discomforting," "relaxed—stressed," "awake—asleep," "peaceful—uneasy," "calm—excited," "happy—unhappy," "bright—dark," and "warm—cool." This method allowed for the comparison of how participants from different cultural backgrounds responded to the same VR experience.

#### 4 RESULTS & DISCUSSION

#### Subjective Ratings

The results of the statistical tests revealed significant differences in the subjective evaluations of Chinese and Japanese participants depending on the bathing scene. Specifically, in the nighttime footbath scene, Chinese participants' subjective evaluations were relatively positive regardless of the presence or absence of a sulfur scent. In the condition without a sulfur scent, Chinese participants rated "attractive," "refreshing," "relaxed," "peaceful," and "happy" significantly higher than Japanese participants. In the condition with a sulfur scent, Chinese participants rated "good," "relaxed," "awake," "peaceful," and "bright" significantly higher than the Japanese.

On the other hand, there was no significant difference in subjective evaluations between Chinese and Japanese participants in the daytime outdoor bath scene. Although we were not able to test for significant differences, we found that the presence of the sulfur scent caused both Chinese and Japanese participants to change their evaluation of "relaxed" to "stressed," while the presence of the sulfur scent led both groups to increase their evaluation of "peaceful." Note that the good-bad subjective evaluation data for the daytime outdoor bath scene was faulty and was not included in the graphs or statistical tests.



**Figure 3.** Subjective evaluations of Chinese and Japanese participants for a nighttime foot-bathing scene: (Left) Odorless: without a sulfur scent condition, (Right) Odorous: with a sulfur scent condition.



**Figure 4.** Subjective evaluations of Chinese and Japanese participants for a daytime outdoor-bathing scene: (Left) Odorless: without a sulfur scent condition, (Right) Odorous: with a sulfur scent condition.

These results suggest that the combination of the footbath and VR videos, with or without the sulfur scent, enhances Chinese participants' evaluations of the footbath as "relaxing," "peaceful," and so on. On the other hand, the combination of footbaths and VR images of daytime outdoor bathing scenes with greenery and trees suggests that there is little cultural difference in impression evaluations. It was also suggested that, depending on the type of images, a certain level of relaxation and sense of well-being can be achieved from VR images without olfactory stimulation.

#### 4.1 Brain Activity Measurement

Using the Hot-2000 device, changes in cerebral blood flow were measured in both left and right foreheads (corresponding Prefrontal area in the brain) under different conditions, revealing that the sulfur scent significantly affects brain activity.

**Left forehead:** In the nighttime footbath scene, Chinese participants showed higher activity with the sulfur scent. While Japanese participants showed higher activity both under odorless and odorous conditions in the daytime outdoor bath scene.

**Right forehead:** In the nighttime footbath scene, Chinese participants showed higher activity with the sulfur scent. While there is no significant difference between Chinese and Japanese participants for the daytime outdoor bath scene.



**Figure 5.** Total-hemoglobin changes (corresponding Cerebral Blood Flow) measured in both left and right foreheads: (Left) A nighttime foot-bathing scene, (Right) A daytime outdoor-bathing scene.

The findings suggest that olfactory stimuli affect brain activity differently depending on cultural background. Chinese participants showed greater changes in cerebral blood flow compared to Japanese participants, indicating potential differences in brain activity patterns. Further research is necessary to fully understand these cultural differences. These results highlight the impact of scent on brain activity, suggesting that scent stimuli affect cerebral blood flow and contributing to understanding how scents influence cognitive function and emotions.

Figure 5 statistically shows that the cerebral blood flow in Chinese Japanese is reversed in the footbath condition at night and in the open-air bath condition during the day. This result suggests that the psychological evaluation using the SD method is not related to the measurement results using NIRS. We reviewed related studies but found no similar reports. These results suggest that further research should be conducted under a variety of cultural differences, VR conditions, and olfactory conditions.

#### 4.3 Cultural Differences

Individuals from different cultural backgrounds may perceive and interpret scents differently. Cultural background influences familiarity and emotional associations with certain scents. For example, Chinese participants might associate the sulfur scent with positive experiences like hot springs, leading to higher left brain activity under the sulfur scent condition. In contrast, Japanese participants might perceive this scent differently, resulting in a weaker response.

Cultural habits and the types and frequencies of scents encountered in daily life also affect responses to specific scents. The types and frequencies of scents in daily life differ between China and Japan, leading to different brain responses. Chinese participants might be more familiar with the sulfur scent, showing a more pronounced response, whereas Japanese participants might be less familiar with it, showing a weaker response.

Furthermore, people from different cultural backgrounds might have different emotional reactions to scents. Scents can trigger emotions and memories, which may vary across cultures, resulting in different brain activity patterns.

# 5 CONCLUSION

The study examines sensory preferences of Chinese and Japanese participants. The results of a psychological evaluation based on the semantic differential method suggest that Chinese and Japanese participants differ in their preference for and familiarity with visual stimuli, but are not affected by the presence or absence of a sulfur scent.

Cerebral blood flow changes were measured with and without a sulfur scent, and the results showed visual and olfactory stimuli influenced brain activity differently. Under a nighttime foot-bathing scene, a sulfur scent activates both left and right brain activities in Chinese participants, while Japanese participants showed higher left-brain activity under a daytime outdoor-bathing scene, both with and without a sulfur scent.

In conclusion, the presence of scent in a footbath affects both emotion and brain activity between Chinese and Japanese participants. This suggests that olfactory stimuli elicit different responses, providing valuable insights for designing footbath experiences in different cultural contexts.

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INTERNATIONAL CONFERENCE ON KANSEI ENGINEERING AND EMOTION RESEARCH 2024

# INTERRELATIONSHIP BETWEEN SENSORY PERCEPTION AND EMOTION WITH VISUAL INFORMATION, FOCUSED ON FEELING OF PAIN

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# ABSTRACT

Pain is a complex and multimodal experience that extends beyond mere physical sensations. This study delves into the intricate relationship between pain perception, related sensory experiences, and emotional evaluation induced by visual information. Through a series of experiments and analyses, we explore how different types of visual stimuli influence the pain perception, how to facilitate easier perception of pain, and the interaction between emotional response (feeling of pleasure) and other sensory experiences (e.g., feeling of pain, tactile, and temperature), including their effects in between. These insights provide valuable guidance for incorporating sensory changes in product design to enhance user experience and comfort.

Keywords: Pain and Emotion, Color and Visual Expression, User Experience Design

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#### **1** INTRODUCTION

Neuroscientific advancements have revealed a shared affective network in the brain, particularly involving the anterior insula and cingulate cortex, which becomes active during both direct pain experiences and when observing others in pain (Bastiaansen et al., 2009; Goldman & de Vignemont, 2009; Caruana et al., 2011). This underscores the neural basis for empathy and suggests that visual stimuli can influence emotional responses through mechanisms like visual empathy. However, it remains unclear whether similar emotional fluctuations occur when interacting with neutral objects lacking perceptual salience, potentially impacting user experience. Research in kansei science (Yamanaka, 2017) has been exploring the connections between sensory perception and emotional states.

Previous studies have shown that visual elements, such as images on drink packaging, can affect human perceptual responses (Mizutani et al., 2010). These studies suggest that visual perception may influence other senses through higher-level mental systems, including memory. Additionally, research has demonstrated that the color red can influence human behavior by altering perceptions, such as increasing the intensity of pain (Elliot & Aarts, 2001). Red often evokes feelings of fear due to its associations with danger, such as fire, blood, and dangerous animals (Moller, Elliot, & Maier, 2009). Kuniecki, Pilarczyk, and Wichary (2015) found that red visual cues can enhance pain perception when they precede painful stimuli.

This study aims to explore these phenomena and their implications for enhancing user experience through sensory-focused design. By conducting a series of experiments, we seek to elucidate how pain interacts with other sensory modalities and emotional states. Understanding these interactions can provide valuable insights into product design, particularly in creating sensory environments that reduce pain and enhance user comfort. This introduction sets the stage for a detailed examination of the interrelationship between sensory perception and emotion, focusing on the influence of visual information on the feeling of pain, with an eye towards practical applications in design.

#### 1.1 Type of Expression and Pain Perception

Appraisal theory suggests that emotions arise from evaluating events and stimuli, meaning the same expression can evoke different emotional responses depending on individual interpretation. Pain perception is shaped by how an individual interprets a stimulus, not by the expression itself. Objects, environments, and visual stimuli are emotionally evaluated, influencing behaviors and reactions. Understanding how visual characteristics trigger pain perception is key to emotional design.

### 1.2 The Influence of Color

Pain perception in neutral objects is significantly affected by expression types, particularly color. For example, red is linked to danger and pain, while neutral or cool colors like white, yellow, blue, and green elicit less intense reactions. Altering color and adding harmful elements (e.g., red spots on fruit) can heighten pain perception, aligning with Scherer's (1984) concepts of intrinsic pleasantness and goal compliance.

This study explores how visual modifications in neutral objects can elicit targeted emotional responses, aiming to: (1) verify how visual features (e.g., color, shape) influence pain perception; (2) analyze how these stimuli affect user perceptions and psychological states; and (3) offer design recommendations to enhance emotional appeal and user experience. These insights contribute to advancing emotional design through visual stimuli.

# 2 EXPERIMENTAL STUDY

# 2.1 Objective

The purpose of this experiment was to visually determine the connectedness of pain to other perceptions.

# 2.2 Hypotheses

- 1. Subject attributes influence visual perception.
- 2. Visual property of stimuli, such as color and shape, influence the perception of pain in neutral objects, with red having a particularly strong impact on pain perception.
- 3. Pain Perception Triggers Other Sensory and Emotional Evaluations.

# 2.3 Experiment

2.3.1 Expected process of perception

- 1. The Influence of visual property on Pain Perception.
- 2. Pain Perception will arise mainly through visual stimuli itself.
- 3. Emotional impact arose by visual-Induced Pain Perception.



Figure 1. Framework of the study

# 2.3.2 Participants

A total of 30 volunteers participated in the University of Nihon University College of Art, including 18 females and 12 males (18-20s). Participants were undergraduate and graduate students in various disciplines.

# 2.3.3 Stimuli

Based on the hypothesis, the experiment included two factors: stimulus type and expression type (visual variations). Four neutral fruits were chosen, regarding variation in color, shape and other attribute used to examine the affection of visual effects toward sensory and emotion.

For type of expression, each presented in three different visual expression, were used in the experiment to assess the perceived salience of neutral objects through visual stimuli. The selected fruits were presented in nature(N) and visual modification of painful (P) and pure white (W). Participants were exposed to a total of 12 images corresponding to these variations.

For the natural fruit cases (nature(N)) AI-generated images are used to show the common and realistic fruit forms, including some natural surface damage (e.g., bananas and apples) to closely resemble real fruits. The natural objects were created using the Midjourney system with inputs such as:

- "/imagine/Generate a neutral cucumber, real, on a white background"
- "/imagine/Generate a neutral apple, on a white background, real"
- "/imagine/Generate an open pomegranate with neutrality, on a white background, real"
- "/imagine/Generate a neutral banana, real, on a white background"

Using AI-generated images for the natural objects helped retain the commonality of the objects and minimized individual variations caused by personal interpretations. This method ensured that the images displayed the most typical fruit forms, reducing human selection bias.

The white and painful cases were both designed by the authors. Each fruit in the painful cases was red enhanced modification was applied. Various methods of red application of damage (spotting, peeling, wound and peel-out, and bruising) were used according to keep the naturality of modification to base fruits.



Figure 2. Visual stimuli (four kinds of fruits / three type of expression)

# 2.3.4 Measurements

Participants answered questionnaires to evaluate their reactions to each image presented. These questions aimed to measure participants' sensory and emotional evaluations as detailed below:

- Sense of Pain: Participants were asked, "Do you feel pain?" with response options ranging from "nothing (0) " to "some (1) " and "a lot (2) ."
- Sense of Tactile: The question, "Do you feel touch?" allowed participants to select among "nothing (0) ," "some (1) ," and "a lot (2) " to describe their level of tactile sensation.
- 3. Sense of Temperature: For warmth, participants responded to "Do you feel warmth?" with choices including "very cold (-2)," "some cold (-1)," "numb

(0) ," "some warm (1) ," and "very warm (2) ."

 Feeling of Pleasure: Lastly, participants described their current emotional state by answering "How do you feel right now?" Options provided were "unpleasant (-2) ," "some unpleasant (-1) ," "neutral (0) ," "some pleasant

(1) ," and "pleasant (2) ."

These measures were employed to quantitatively capture the participants' sensory and emotional evaluations to each image, thus facilitating a thorough analysis of their experiences throughout the study.

# 2.3.5 Evaluation process

Each image was printed at true size on plain white paper to accurately perceive the appearance of an object. Participants viewed and examined each image individually at a comfortable distance, avoiding cross-influence. Afterward, they completed a questionnaire to assess the feelings and perceptions elicited by the fruit presentations, ensuring the effects of each visual condition on perceived intensity were isolated and measured.

To enhance randomization and reduce data bias from visual residuals, each type of fruit had nuanced shapes. These differences allowed for a more comprehensive evaluation of the effect of visual stimuli on pain perception.

# 2.4 Results

2.4.1 Differences between subjects and evaluations

To confirm differences in sensory perception by age group (10s to 20s), nationality and gender analyzed using one-way ANOVA. The result showed that there were no significant differences in evaluations based on age or gender. However, there were significant differences in sensory evaluations by nationality, although emotional evaluations (happy and unhappy) did not show significant differences. (Table 1).

Participants by sensory and feeling:	pain	tactile	temperature	pleasure
Age (10s /20s)	0.8111	0.4011	0.5905	0.8934
Nationality (JPN / non-JPN)	0.0064**	0.0092**	0.0436*	0.6537
Sex (male / female/NA)	0.1653	0.5035	0.6623	0.429

Table 1. Influence of age, nationality, and gender on sensory perception (p-value in one way ANOVA)

To explore differences of nationality in sensory evaluation by fruits (apple, banana, pomegranate, cucumber), one way ANOVA was applied. The result summarized with p-value are shown in table 2. This revealed that the difference of nationality in sensory evaluation only found in cucumber.

Stimulus by sensory and feeling	pain	tactile	temperature	pleasure
Apple	0.4717	0.6758	0.0835	0.2154
Banana	0.6383	0.5135	0.1622	0.7794
Cucumber	<.0001**	0.0002**	0.8736	0.231
Pomegranate	0.6494	0.2415	0.3052	0.6051

Table 2. Difference of sensory perception of nationality by fruits (p-value in one way ANOVA)

So, we decided to analyze the interaction of sensual perception and emotional feeling by type of expression excluding cucumber. Even excluding cucumber, still enough variation of property of fruits are kept.

2.4.2 Multiple regression analysis of Emotion (Pleasure) and Sensory Evaluation (pain, tactile and temperature)

With the result of analysis, the evaluation result confirmed without significant bias caused by characteristic of panel and type of stimulus. Then to confirm general relationship throughout the type of stimuli, regression analysis was applied and confirmed the relationship of emotional evaluation (pleasure) and sensory evaluation (pain, tactile and temperature). The result of section and slope with p-value shown in table 3.

Y= pleasure	section		slope		
X=	value	p-value	value	p-value	
pain	0.2556	0.0006*	-0.7734	<.0001*	pleasure = 0.2556 - 0.7734*pain
tactile	-0.401 3	<.0001*	0.3130	0.0004*	pleasure = -0.4013 + 0.3130*tactile
temperature	-0.161 4	0.0173*	0.1488	0.0227*	pleasure = -0.1614 + 0.1488*temperature

Table 3. Multiple Regression analysis: pleasure and sensory evaluation

2.4.2.1 Negative correlation between pain and pleasure sensation

The regression slope estimates (Table 3) revealed a significant negative correlation between pain and pleasure, indicating that pain more strongly triggers negative emotions compared to the effects of touch and temperature on pleasure. Greater pain decreases pleasure, thereby affecting emotional perception.

# 2.4.2.2 Positive correlation in tactile and temperature perception toward pleasure

The study also found significant positive correlation of tactile and temperature perception toward pleasure. That is, the higher the level of tactile, the stronger the individual's perception of pleasure. This suggests that pleasure perception not only affected by pain, but also significantly affected by perception of tactile and temperature. Although the effect of temperature is weaker, but these somatosensory perceptions affect emotional evaluation.

2.4.3 Differences in sensory and emotional evaluation by type of expression (ANOVA)

To confirm the relationship between type of expression and sensory evaluation, Significant differences in sensory and emotional evaluation by type of expression were found. (Table 4).

Table 4. Difference of sensational and emotional evaluation by type of expression (ANOVA)

sensory / feeling	pain	tactile	tactile temperature	
type of expression	<.0001*	<.0001*	0.0078*	<.0001*

# 2.4.4 Effect of presentation modality on differences in sensory perception (HSD test)

To confirm the relationship between type of expression and sensational perception, two-way ANOVA was applied. Also, the effect by type of expression was confirmed with Tukey-Kramer's HSD test. (Table 5)

 Table 5. Relationship and affection between type of expression by sensory perception (two-way ANOVA)

Sensory perception	Significancy	Average of affection	Matrix of type of expression By Tukey-Kramer HSD test (the difference of effect is not significant with the same charactered pair)			n erence of haractered	
				painf ul	nature	white	
pain	p-value	1.189	painful	А	<.0001 *	<.0001*	
	<.0001*	0.433	nature		В	<.0001*	
		0.044	white			С	
				natur e	painful	white	
tactile	p-value	1.056	nature	А	<.0001 *	<.0001*	
	<.0001*	0.589	painful		В	0.8633	
		0.533	white		В	-	
			1				
				natur e	painful	white	
temperat	p-value	0.100	nature	А	0.7888	0.0085*	
ure	0.0078*	0.000	painful	А	В	0.0529	
		-0.356	white		В		
			-	-			
pleasure				white	nature	painful	

p-value	0.389	white	А	0.0175 *	<.0001*
<.0001*	-0.011	nature		В	<.0001*
	-0.900	painful			C

Overall, a significant relationship was confirmed (p-value), but the order of expression toward each sensation (represented by the average of affection) differed by sensation. The effect of expression type was also uneven.

Table 5 shows that painful expressions significantly heightened pain perception compared to natural and white expressions. Expressions resembling real objects evoked stronger tactile responses than both painful and white expressions, suggesting that natural objects provide minimal sensory stimulation but offer a richer sense of dimensionality.

White expressions induced a sense of coldness (negative on temperature) but had no impact on pain perception, touch, or pleasure, indicating that white objects are more neutral compared to natural colors and pain-related objects. Additionally, visual color enhances tactile perception more than shape.

In terms of perception and emotion, painful images notably evoked emotional reactions, even influencing neutral objects, indicating that visual stimuli associated with pain can affect both sensory perception and emotional evaluation.

# 2.4.5 Analysis of perceptual and emotional differences based on type of expression (t-test)

Table 5 shows that different expression types evoke significantly different sensory and emotional perceptions. To assess the impact on pain perception, we compared mean values of images depicting fruits in different states: natural (N), painful (P), and white (W) for pomegranate (P), apple (A), and banana (B) (Table 6).

The results indicate that the perception of pain increased significantly with pain-related images, with an average pain score of 1.19—Pomegranate (P(P)) = 1.40, Banana (B(P)) = 1.37, and Apple (A(P)) = 0.80. In contrast, the intensity of perception for inherent red stimuli was lower, with Apple (A(N)) > Pomegranate (P(N)) > Banana (B(N)). This suggests that inherent red has a certain level of stimulation; however, it is less intense compared to the red associated with pain.

Different visual expressions of pain varied in their effect based on the type and severity of the damage. For example, wound and peel-out (pomegranate, 1.40) had a greater impact than peeling (banana, 1.37), both surpassing bruising (apple, 0.80). This difference, possibly due to color intensity or the nature of the damage, requires further investigation (Table 6).

Table 6. Comparison of average of pain level associated with type of visual expression for painful

Fruits	natural (N)	painful (P)	white (W)	Visual expression in painful (P)
pomegranate (p)	0.50	1.40	0.03	wound and peel-out

apple (A)	0.67	0.80	0.03	bruising
banana (B)	0.13	1.37	0.07	peeling

#### **3** DISCUSSIONS

Experiments showed that gender, age, and personal attributes had minimal impact on visual stimuli, except for cucumber. A significant negative correlation was found between pain perception and pleasure, while other sensory perceptions were positively correlated, with temperature perception having a weaker effect.

Further analysis revealed that tactile evaluations were stronger when objects displayed their intrinsic color, suggesting that an object's texture, whether real or simulated, significantly influences haptic experience, with color impacting haptics more than shape. Color also influenced the perceived neutrality of objects, with specific color modifications evoking pain perceptions, like "painful," through visual cues alone.

Red was found to stimulate visual perception, but inherently red objects tend to reduce this effect, mitigating emotional responses. However, specific shapes and emphases can cause neutral objects to evoke strong pain perceptions and influence emotions, indicating that objects can be designed to elicit stronger pain perceptions, affecting both sensory and emotional evaluations.

### 4 CONCLUSIONS

This study systematically explored how visual stimuli, particularly color, influence sensory perceptions and emotional evaluations related to pain, providing insights into human pain processing, and guiding the design of tactile sensations and colors in products. The findings confirm a complex interplay between visual presentation and the resulting sensory and emotional experiences. Key insights are summarized as follows:

#### 4.1 Cultural Variations in Visual Perception.

Cucumber perceptions varied significantly by nationality, introducing a confounding variable. To preserve result integrity, cucumbers were excluded from the final analysis. Future research should investigate how cultural differences influence visual perception, especially of everyday objects like cucumbers.

#### 4.2 Impact of Visual Stimuli on Pain Perception and Emotional Evaluations

Visual modification with color significantly influences pain perception. Specifically, red does indeed induce a certain degree of pain perception, accompanied by noticeable emotional evaluations, including feelings of discomfort and slight effects on tactile and warmth sensations. However, the inherent red color of objects tends to reduce the stimulation of pain perception. This finding is valuable for developing strategies to mitigate the pain-inducing effects of red.

#### 4.3 Tactile and Thermal Perception

Tactile perception is more influenced by the visual color realism of actual objects than by shape alone. However, thermal perception is minimally affected by visual stimuli, suggesting that thermal sensation patterns are less susceptible to visual influence.

#### 4.4 Influence of Inherent Color on Pain Perception

It remains to be discussed whether the change in emotional intensity is due to the shape of the wound or the degree of color intensity. However, due to the limited sample size and potential influence of shape variations, the evaluation of pain stimuli caused by neutral objects in red and other colors was somewhat constrained. Future research should include a larger sample size to enhance the reliability of the findings. This will be explored in greater depth in future studies.

#### 4.5 Future Research Directions

This study revealed significant insights into the interrelationship between sensory perception and emotion, particularly focusing on pain induced by visual information.

While acknowledging inconsistencies in visual features and the need to control these variables in future research, the findings offer valuable insights into how alterations in color and shape influence emotional projection and empathy through visual communication with various objects.

Future studies should investigate the effects of other visual attributes, such as texture and grain, and their interaction with other sensory modalities. Examining these factors can deepen our understanding of multisensory integration and its impact on emotional well-being.

#### 4.6 Summary

In summary, this study emphasizes the critical role of visual information in shaping our sensory and emotional experiences of pain. By elucidating the specific impacts of color and shape, it provides valuable insights for sensory research, pain management, and emotional evaluation. Future research is anticipated to make further breakthroughs in understanding the relationship between visual stimuli and pain perception.

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# FINE-TUNING IMAGE GENERATIVE AI FOR EMBEDDING IMPRESSION SPACE: A CASE STUDY ON MILK CARTON DESIGN

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# ABSTRACT

This study aimed extending conventional Kansei engineering design approaches that utilize the Semantic Differential (SD) method and principal component analysis, by employing an image generation model capable of producing high-quality images. Our research focused on the design of milk cartons. We additionally trained the image generation model, Stable Diffusion, using the LoRA technique, which was guided by the correspondence between the impression space derived from survey data and the images of existing products. Moreover, we employed this fine-tuned network to generate product design images that correspond to each principal component, as well as images associated with specific Kansei words, and conducted an assessment to examine whether the generated images appropriately reflected the Kansei words. The results indicated that while the generated images partially reflected the impression space, there was also factor that could not be reflected. The findings highlight the complexities involved in fine-tuning an image generative AI to replicate a defined impression space, providing challenges for improving AI-driven design tools in Kansei engineering.

Keywords: Stable Diffusion, Fine-Tuning, Milk Carton Design

# **1** INTRODUCTION

In creating competitive products, it is crucial to incorporate consumer preferences into product design. Kansei engineering, a method for translating consumer impressions into specific product designs, has proven effective in product development. Among various Kansei engineering techniques, the quantitative approach known as "Kansei Engineering Type II," which utilizes multivariate analysis, has been widely adopted since the 1980s due to its versatility and

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procedural simplicity (Nagamachi, 1995). This approach involves first measuring impressions of samples within a given product category using the Semantic Differential (SD) method. These impressions are then used to construct an impression space with relatively few dimensions, revealing the positions of the samples within this space. Furthermore, by using methods such as Quantification Theory Type I, the relationship between this impression space and design elements is examined, translating impressions into design elements. The Kansei Engineering Type II method, grounded in linear multivariate analysis techniques, has several advantages. The impression space constructed through principal component analysis or factor analysis typically requires only a few dimensions, ensuring interpretability of the evaluation space and explainability of the results. Additionally, while collecting samples can be challenging depending on the evaluation domain, this conventional method requires a relatively small number of product samples, which is advantageous.

However, conventional Kansei engineering methods for translating impressions into design elements have their limitations. Decomposing a design into elements can be difficult depending on the analysis subject. Furthermore, even if design elements that evoke a particular impression are identified, there remains a significant gap between combining these elements and creating a final product design. Thus, while traditional Kansei engineering methods are convenient, they often fall short in generating a fully realized design.

In recent years, the emergence of high-quality image generation models such as GANs and Latent Diffusion Models has generated expectations for dramatic changes in the field of product design. Several studies have already attempted to apply GANs to product design (Li et al., 2019; Liu et al., 2019; Wu et al., 2021). Moreover, services offering web design and logo design using models like Stable Diffusion and DALL-E, which generate high-quality images from text prompts, are already available on the market.

However, constructing such image generation models typically requires pre-training on thousands to tens of thousands of images, posing challenges for application to specific domains. A promising approach to this problem is additional training for the generation model. Ishihara et al. (2023) proposed a method for additional training on Stable Diffusion using HyperNetworks, enabling the generation of designs on milk cartons based on textual prompts while maintaining the general shape of milk cartons. This research demonstrated the possibility of generating product designs for specific domains by combining Stable Diffusion with fine-tuning on domain-specific images.

Nevertheless, it is currently challenging for image generation models to replace traditional Kansei engineering. One reason is that, even if images are generated using pre-trained models with various objects and prompts, these pre-trained models are essentially black boxes. This means the model may not necessarily possess an impression space relevant to a given domain. Thus, interpreting whether the generated images appropriately reflect design intentions and verifying the reliability of the generated results is difficult.

Therefore, this study proposes a scheme to utilize the high expressiveness of image generation models while preserving the domain specificity and interpretability of conventional Kansei engineering methods. This is achieved by additional training of pre-trained image generation models on product evaluation spaces constructed using traditional Kansei engineering techniques, specifically the combination of the SD method and principal component analysis. Following prior research (Ishihara et al., 2023), the text-to-image model Stable Diffusion is employed as the image generation model. Instead of Hyper Networks (Heathen, 2022; Kurumuz, 2022) used in the previous research, this study adopts LoRA (Low Rank Adaptation) (Edward, 2021), a type of adapter with lower computational burden, for additional training on Stable Diffusion.

As a test case for this method, this study focuses on the design of the side of milk cartons. Gable-top milk cartons have standardized sizes, but generally available pre-trained generative models do not output shapes that conform to these standards. Therefore, it is useful for verifying the effects of additional training. In this study, we performed principal component analysis on impression evaluation data of milk carton package designs based on SD method. We then used LoRA to conduct additional training on Stable Diffusion with pairs of principal component scores and images for each package. To examine whether this method can output designs that match specific impressions, we generated milk carton images and verified if the generated images evoked the intended impressions.

# 2 METHODS

#### 2.1 Proposed Method

The proposed method generates high-quality product images that evoke a given impression using the Stable Diffusion image generation model based on a diffusion model. Stable Diffusion (Latent Diffusion Model) combines a CLIP text encoder, an inverse diffusion process, and image generation using a VAE to produce high-quality images from input text (Rombach et al., 2022). Stable Diffusion controls the image generation process with cross-attention layers that handle the relationship between the input prompt transformed into a feature vector by the CLIP text encoder and the corresponding prompt, outputting images that correspond to the prompt.

To generate images suitable for the product domain, it is necessary to fine-tune the pre-trained Stable Diffusion. One method to accomplish this is LoRA (Low-Rank Adaptation; Hu et al., 2021). LoRA is a proposed method for additional training large language models. It suggests fixing the weights of the pre-trained model and injecting trainable layers (rank factorization matrices) into each transformer block, significantly reducing the number of trainable parameters. Compared to typical fine-tuning, LoRA can greatly reduce the number of trainable parameters. This method can also be applied to additional training for Stable Diffusion and is one of the most used methods for fine-tuning Stable Diffusion today. LoRA can be applied to the cross-attention layers that associate image representations with the prompts describing them. The additional training with LoRA is said to produce images of comparable quality to other computationally intensive learning methods, such as HyperNetworks. In this study, LoRA was adopted as the fine-tuning method.

The procedure of the proposed method is divided into three major parts:

(1) Construction of the Product Evaluation Space: Similar to conventional Kansei engineering, the SD method is used first to evaluate the impressions of samples, and a relatively low-dimensional impression space is constructed through principal component analysis. Dimension reduction by principal component analysis is used because Stable Diffusion cannot include a large number of tokens in its prompts and to enhance the explainability of the final generated images.

(2) Fine-tuning of Stable Diffusion with LoRA in the Evaluation Space: The pre-trained Stable Diffusion is further trained by adding the principal component scores corresponding to each sample as weights to the sample image prompts. Although the prompts are transformed into feature vectors by CLIP, the weights of the prompts alter the norm of these feature vectors.

(3) Image Generation with Kansei Words: From the principal component loadings of the Kansei words used during impression evaluation, principal component score vectors that strengthen/weaken the impression corresponding to specific Kansei words are obtained. Further, by providing these principal component score vectors as weights to the prompts in Stable Diffusion, product images that evoke a specific impression are generated.

#### 2.2 Image Generation

#### 2.2.1 Sample

From commercially available milk cartons in Japan, 63 types were selected. These were all the same 1-liter milk cartons with a gable-top design. Each milk carton was unfolded and then digitized using a scanner to capture images of all sides and the gable part. Using the preset 1-liter milk carton 3D model in Adobe Dimension ver. 3.4.9, the scanned images of the sides and gable part were applied as textures, and images were taken. The images were taken from eight different angles (0°, 15°, 30°, 45°, 60°, 75°, 90°, 105°) for each milk carton (Figure 1). In addition to these, images of the model with a white texture applied were also taken. As a result, a total of 512 milk carton images were created. These images were used for additional training.

#### 2.2.2 Impression Survey of Milk Cartons

This analysis is based on the results of a prior study (Ishihara et al.,1999) that examined the relationship between the design differences of milk cartons and their impressions. In the prior study, female students from Onomichi Junior College participated as evaluators, with 28 participants. The stimuli used included images that combined one side of the 63 types of milk cartons used as samples with the sloped part of the gable. Each image was printed on each page of the evaluation sheet at a height of about 10 cm. The evaluation sheet listed 69 unipolar Japanese evaluative terms (i.e. Kansei words) for each image to inquire about the impression of each image. The evaluation was conducted using a 5-point Likert scale. These evaluative terms were determined based on a preliminary survey (Nagamachi, 2010).





Figure 1. Example of 3D Images of a milk carton used in the additional training set

Figure 2. Biplots of principal component scores and loadings (PC1 vs. PC2 / PC1 vs. PC3)

#### 2.2.3 Principal Component Analysis

The average scores for each evaluation criterion of each milk carton were calculated, and a principal component analysis based on the correlation matrix was conducted. The results showed that the first three principal components had a high cumulative contribution rate (cumulative contribution rate: 72.6%), so these components were considered for further examination. The principal component scores for each milk carton and the principal component loadings for each evaluative word are shown in Figure 2. This three-dimensional space is referred to as the impression space.

The first principal component showed a positive correlation with Kansei words such as 'warm', 'gorgeous', and 'pretty', and a negative correlation with 'dark', 'modest', and 'steady', and can be interpreted as reflecting Activity. The second principal component exhibited a positive correlation with words like 'refined', 'intelligent', and 'elegant', and a negative correlation with 'unsophisticated' and 'coarse' and can be interpreted as reflecting Evaluation. The third principal component showed a positive correlation with 'heavy', 'hard', and 'over-decorated', and a negative correlation with 'light', 'refreshing', and 'plain', and can be interpreted as related to Potency. The results of the principal component analysis suggest that the evaluation space of the milk cartons possesses what is known as the evaluation-potency-activity (EPA) structure.

#### 2.2.4 Additional Training

When performing additional training with LoRA, the word 'milkcarton' was added to all captions used for training along with the images. Additionally, the position of each sample within the evaluation space (i.e., the principal component scores) was added to the captions as a token weight. Since LoRA cannot assign negative weights to captions, different captions were used for positive and negative principal component scores. To avoid overlap with words already learned by CLIP, each principal component was represented by three letters (for example, a

positive score for the first principal component was denoted as 'c1p', and a negative score as 'c1n'). The absolute value of the principal component scores was reflected in the captions as a weighting coefficient. For example, if a sample had a first principal component score of 1.00, a second principal component score of -1.50, and a third principal component score of 0.33, the additional training prompt would be as follows:

# milkcarton,(c1p:1.00)milkcarton,(c2n:1.50)milkcarton,(c3p:0.33)milkcarton

This prompt was created for each sample, and additional training was performed on Stable Diffusion using LoRA to learn the relationship between the impression space and the sample images. The number of training iterations was 200.

# 2.2.5 Variations in Generated Images Along Each Principal Component

The relationship between each principal component (Positive/Negative) and the images generated by the Stable Diffusion model, which was enhanced through further training using LoRA, was examined by providing prompts with specified weights of principal components. Images generated using six types of prompts (3 PCs x Positive/Negative) for four different seed values are shown in Figure 3. PC1, which is related to Activity, appears to be positively associated with the brightness of colors. While it is difficult to identify a systematic relationship between PC2, which reflected Evaluation, and the images generated, this principal component may be associated with decorative designs. PC3, associated with Potency, appears to be related to the use of yellow colors and complex illustrations.

# **3** ASSESSMENT OF IMPRESSION ACCURACY IN GENERATED IMAGES

# 3.1 Method

We conducted an experiment to determine if images of milk cartons, generated according to the method outlined in Section 2.2 and incorporating the principal component loadings of Kansei words, could successfully evoke the intended impressions associated with those specific Kansei words. These generated images are referred to as the 'correct images'. Additionally, for comparative purposes, images were generated with the positive and negative loadings of each Kansei word's principal components inverted.

Twelve university students (mean age = 20.5 years) participated in the experiment. Participants were tasked with selecting the more suitable milk carton image that corresponded to a given Kansei word from two choices, for all 69 Kansei words. The seed values of image generation and the positions of the images in each pair were randomized.

# 3.2 Result

The accuracy for each Kansei word was determined by the proportion of participants who selected the 'correct image,' with the chance level being 50% (Figure 4). The average accuracy was 65.3%, and the results of the binomial test indicated that the accuracy was significantly higher than the chance level (p<.01). However, the accuracy was not very high, indicating that the Kansei words were not sufficiently reflected in the generated images. Accuracy varied

considerably depending on the Kansei word. High accuracy was observed for Kansei words associated with high loadings of the 3rd principal component related to Potency (Figure 4). In contrast, low accuracy was found for Kansei words associated with relatively high loadings of the 2nd principal component related to Evaluation (Figure 5).





Figure 3. Variations in generated images along each principal component



Figure 4. Results of the assessment for each Kansei word. The red dashed line indicates the chance level.



Figure 5. Images generated from loadings of Kansei words with high accuracy in the Assessment ( + ), and images generated from the loadings with reversed signs ( - ).



Figure 6. Images generated from loadings of Kansei words with low accuracy in the Assessment (+), and images generated from the loadings with reversed signs (-).

### 4 DISCUSSION

The principal component analysis of the impression data suggested that the evaluation space was composed of factors related to Activity, Evaluation, and Potency. Among these, the Potency factor was reflected in the images generated by our proposed method, as indicated by the assessment results. However, the Evaluation factor was not clearly reflected in the output images. These results suggest the presence of Kansei factors that are challenging to represent in generated images using this method, which may partly be due to the complex relationship between the Evaluation factor and the latent space of Stable Diffusion model. Furthermore, the simplicity of the LoRA network used for additional training might have been insufficient to capture this complexity. Dreambooth (Ruiz et al., 2023) or Dora (Liu et al., 2024), additional training methods other than LoRA, might be effective in embedding the impression space into the Stable Diffusion model.

# 5 CONCLUSION

In this study, we aimed to construct a design methodology with high expressiveness by combining traditional Kansei engineering techniques with image generation models. We conducted principal component- analysis on impression evaluation data for milk carton package designs based on the Semantic Differential (SD) method. From the results, we built a product evaluation space, which was then used to further train an image generation model. Our goal was to develop a method that could generate package design images corresponding to specific Kansei words by applying additional training to the image generation model.

Our results suggest that the factor representing Potency can be reflected in the generated product images. On the other hand, the relationship between the factors of impressions related to Evaluation and the characteristics of the product images could not be learned using this method. This suggests that Evaluation is related to complex image features and that these features are not simply represented within the latent space of Stable Diffusion. In the future, it will be necessary to explore methods for embedding such complex impression factors into the generative model.

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# COMPARISON OF PSYCHOLOGICAL EVALUATIONS WHEN OPPONENTS IN FACIAL ROCK-PAPER-SCISSORS ARE FACE ILLUSTRATION IMAGES OR REAL PERSONS: DEVELOPMENT OF A FACIAL ROCK-PAPER-SCISSORS PROGRAM THAT INCORPORATES SMILING FACIAL EXPRESSION SETTINGS

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#### ABSTRACT

We developed a facial rock-paper-scissors program that incorporates facial expressions and vocalizations of swallowing training into facial rock-paper-scissors using oral-facial exercises. The program that can be used in the rehabilitation of cognitive and swallowing functions has the psychological effect of improving mood by designating a smiling facial expression for 'scissors,' formed by horizontally stretching the mouth and raising the corners of the mouth. The program can be performed easily using a tablet or a personal computer at medical institutions and facilities with limited numbers of staff, or by the elderly alone at home. In this study, the author compared psychological evaluations between when playing a facial rock-paper-scissors game using face illustration images displayed on a PC and when playing it in person-to-person mode. The results showed that both confirmed psychological effects of improved mood. This indicates the usefulness of the facial rock-paper-scissors program in which patients can easily undertake rehabilitation by engaging in the program using face illustration images displayed on the screen.

*Keywords:* Swallowing function, Cognitive function, Facial rock-paper-scissors, Rehabilitation, Psychological effect

# **1** INTRODUCTION

In today's rapidly-aging society in Japan, urgent action is needed to combat aspiration pneumonia. Research and other efforts in the medical field have shown that mouth, tongue,
and cheek exercises used as swallowing training, and rehabilitation to maintain and significantly improve swallowing function (Takehara, I. et al., 2014; Omori, T. et al., 2016; Seirei Hamamatsu City Rehabilitation Hospital, 2023). As a practical example of efforts aimed at maintaining and improving cognitive function, performing the task of responding orally and facially to rock-paper-scissors may also lead to the maintenance and improvement of cognitive function (Anai, M. et al., 2001). Based on these previous studies, we considered that it would be possible to perform rehabilitation to maintain and improve swallowing and cognitive functions by developing a new program that would simultaneously provide swallowing training and a response-type facial rock-paper-scissors exercise with oral-facial movements. Therefore, the author devised a new program that incorporates swallowing training and a response-type rock-paper-scissors game that involves oral-facial movements. Prior to development of the program, we confirmed the effectiveness of the program design using a smiling facial expression for 'scissors,' formed by horizontally stretching the mouth and raising the corners of the mouth [Yoshioka, K. 2023, Fig. 1].]



Figure 1. Images presented in the Facial rock-paper-scissors program (patent pending)

The facial rock-paper-scissors program randomly displays an illustrated image of a face on a tablet terminal. The user performs a response-type rock-paper-scissors game using oral-facial movements to win against the displayed face image. When performing a facial rock-paper-scissors game in a person-to-person mode, people may feel embarrassed that their partner sees their face, and the effectiveness of mouth and cheek movements may decrease. Therefore, a program for rehabilitation that can be followed by a single person using a tablet terminal is likely to prove very useful. The program can also be performed at medical institutions and facilities with limited numbers of staff, or by the elderly alone at home.

In this study, aiming to test the effectiveness of our facial rock-paper-scissors program using face illustration images, the psychological evaluations were examined when performing the facial rock-paper-scissors program using face illustration images displayed on the screen of a PC and when performing it in person-to-person mode.

# 2 OVERVIEW OF THE FACIAL ROCK-PAPER-SCISSORS PROGRAM (PATENT PENDING)

In Japan, 'rock-scissors-paper' is respectively represented vocally as *guu, choki* and *paa*. When facially expressing 'paper' in the rock-paper-scissors program, the vowel at the end of the

syllable *paa* is stretched to pronounce *aaah* by opening the mouth widely in all directions, creating a mouth and cheek exercise. In facially expressing 'scissors,' the vowel at the end of the word *choki* is stretched to pronounce *ii* by stretching the mouth widely and horizontally to perform another mouth and cheek exercise. The expression of 'scissors' has the psychological effects of smiling to improve mood. In facially expressing 'rock,' the vowel at the end of the syllable *guu* is stretched to pronounce *uuu* by pursing the mouth to perform a mouth and cheek exercise (Fig. 1).

## **3** COMPARISON OF PSYCHOLOGICAL EVALUATIONS WHEN OPPONENTS IN FACIAL ROCK-PAPER-SCISSORS ARE FACE ILLUSTRATION IMAGES OR REAL PERSONS

#### 3.1 Experimental method

In the experiment employing the facial rock-paper-scissors program using face illustration images, 72 face illustration images with expressions depicting 'rock,' 'scissors,' and 'paper' were randomly displayed for three seconds each on a MacBook Pro with a 15-inch screen. The participants performed a response-type facial rock-paper-scissors program to beat the displayed images, using oral-facial movements and voicing. In the experiment of performing the program in the person-to-person mode, as in the experiment using the face illustration images, the opponents randomly varied their facial expressions of 'rock,' 'scissors,' and 'paper' 72 times and held them for three seconds each, and the participants played the response-type facial rock-paper-scissors game with their opponent, using oral-facial movements and voicing.

In our previous research, the psychological evaluation of university students was equivalent to the evaluation in a preliminary experiment with elderly people at home. Therefore, for this study, eleven university students (four males and seven females, aged 18 - 23) participated in the experiment using the illustrated face images, and eleven university students (four males and seven females, aged 18 - 22) participated in the experiment of playing the response-type rock-paper-scissors game in person-to-person mode. The participants were psychologically evaluated before and after the program using the POMS-BF (Profile of Mood States-Brief Form Japanese Version).

#### 3.2 Results

In the psychological evaluation using POMS-BF, T-scores were examined by two-factor two-level analysis of variance over the following six scales: tension–anxiety (T–A), depression–dejection (D), anger–hostility (A–H), vigor (V), fatigue (F), and confusion (C), according to the type of opponent (i.e., face illustration images or real persons) and before and after playing the facial rock-paper-scissors game. Significant differences were confirmed in the T-scores on the scale for the levels of tension–anxiety, vigor, and fatigue after playing facial rock-paper-scissors. There were no significant differences or interaction effects between the two versions: using face illustration images or real persons.

## 3.3 Discussion

Psychological evaluations were made between using face illustration images or real persons as opponents. The results showed no significant differences or interaction effects between the

two versions in evaluations using POMS-BF. The facial rock-paper-scissors program has the psychological effect of significantly improving mood by lowering the levels of tension-anxiety and fatigue and improving vigor.

The results mean that when playing the facial rock-paper-scissors game, when the opponents are face illustration images displayed on a PC, the mood improves in the same way as when playing against a real person. The efficacy of the game using face illustration images was thus validated.

## 4 CONCLUSION

The author developed a facial rock-paper-scissors program that requires oral-facial movements that incorporates swallowing exercises, lip training, and mouth opening training, for rehabilitation of swallowing and cognitive functions. In this study, aiming to test the effectiveness of the facial rock-paper-scissors program using face illustration images, the psychological effects of the program were examined when performing it both while using face illustration images displayed on a PC and when performing it in person-to-person mode. The results showed that the levels of tension–anxiety and fatigue, and the level of vigor increased, indicating improved mood. The study confirmed that when performing the facial rock-paper-scissors game using face illustration images, similar psychological effects can be obtained to when performing it in person-to-person mode. These results indicate the usefulness of the facial rock-paper-scissors program in which patients can easily undertake rehabilitation by engaging in the program using face illustration images displayed on the screen. This program thus has potential as a new form of rehabilitation support for patients, the elderly and medical staff. We are conducting a practical evaluation using a facial rock-paper-scissors program app that can be used on a tablet terminal with elderly people in a medical institution.

This research was conducted with the approval of the Research Ethics Committee of Meisei University.

Rehabilitation Support Device/Method/Program Patent Inventor/Owner: Kiyomi Yoshioka

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# THE PROPOSAL OF PICTOGRAM WITH FACIAL EXPRESSION AS BACKGROUND

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## ABSTRACT

There are a lot of pictograms include the "Prohibition," "Mandatory" or "Warning" symbol in our daily life. These symbols indicate strong claim such as "DO SOMETHING" or "DO NOT SOMETHING." However, human tend to defy the instruction includes strong claim. Therefore, we propose a new style pictogram: pictogram with facial expression as background. Its feature is that there is a facial expression behind the pictogram makes the viewers feel other's gaze. It is revealed that human behave more altruistically when others' gaze exists, so we expect that pictogram with facial expression as background can inform necessary actions or restrictions without the "Prohibition," "Mandatory" or "Warning" symbol. This paper explains our proposal and show the example pictograms we created.

Keywords: pictogram, Public information symbols, facial expression, gaze

## **1** INTRODUCTION

A pictogram is a graphical symbol that is used to represent a semantic concept based on meaning of its shape. It is important that the meaning of pictogram conveys correctly, so ISO (International Organization for Standardization), JISC (Japanese Industrial Standards Committee) and so on deliberate and design the standards for pictograms. Pictograms are divided two types: Public information symbols defined by ISO 7001 and ISO 7010, and Communication support board using pictorial symbols (referred to as Communication support board within the context of this paper) defined by JIS T0103 and ISO 19027. ISO 7001 defined facilities, guidance and so on. ISO 7010 defined how to draw symbols; for instance, "Prohibition" is represented as a red circle and a red diagonal line, "Mandatory" is represented as a blue circle, "Warning" is represented as a yellow equilateral triangle with black rounded corners. The examples of pictograms are shown in Figure 13. There are many pictograms which mean about human's action or status in Public information symbols. That's why ISO 3864-3 defines the guideline for

how to depict human-shaped pictogram (referred to as human pictogram within the context of this paper). Communication support board helps the human who are not good at communication by speaking and writing to convey their will or demand (Hiranchiracheep, 2018).



and Communication support board (three on the right)

This paper proposes a new style pictogram which combines the "Prohibition," "Mandatory" or "Warning" symbol and Communication support board which has facial expression. Our focus is that conveying the meanings of prohibition, mandatory and warning by facial expression of background. This new style pictogram is referred to as pictogram with facial expression as background within the context of this paper.

## 2 PICTOGRAM WITH FACIAL EXPRESSION AS BACKGROUND

The pictograms which mean "Prohibition," "Mandatory" or "Warning" are displayed many places in our daily life, so almost human will understand the meaning appropriately. However, there is also possibility human watch these pictograms out of habit because they are displayed a lot. As a result, human would lose the responsibility and the morality which follow rules (Douskos, 2021; Matthews, 2013). In addition to it, human may not follow the rules due to "Forbidden fruits effect" and "Boomerang effect." Firstly, Forbidden fruits effect is the word from Genesis' chapter 2 in the Old Testament. Human can become interested unknown stimulation easily (Hsee & Ruan, 2016; Oosterwijk, 2017) and the desire to see what is forbidden and unavailable can be happened easily (FitzGibbon, 2020). That's why human sometimes behave against instruction. Secondly, Boomerang effect is the phenomenon which persuaded-person behaves the exact opposite action of persuading-person's telling (Cohen, 1962; Byrne & Hart, 2009). Therefore, we considered alternative pictograms replaces the "Prohibition," "Mandatory" and "Warning" symbols which have the meaning of "DO NOT SOMETHING" or "DO SOMETHING."

We focused on the effect by other's gaze. Previous studies reveal the result that human can behave more altruistically when others' eyesight exists. For instance, Izuma (2010) shows when observer exists, more people donated. The effect is happened by not actual eye, too. For instance, Haley and Fressler (2004) show that the amount of money the examinees distribute increases significantly by using a monitor displays illustration makes examinees remind human's face. Bateson etal (2006) also show unmanned coin box collected more money in the period the box has illustration decorated picture of eye. Therefore, this paper proposes a new type pictogram: pictogram with facial expression as background. The feature of it is that there is picture can make human feel others' eye behind pictogram. We expect it can inform actions human must do or must not do without the "Prohibition," "Mandatory" or "Warning" symbol.

## **3 DESIGN EXAMPLES**

We designed three facial expressions based on Communication support board, and combined them with 16 pictograms as example. Table 9 shows the detail of background's facial expression, and Figure 14 shows 16 example pictograms.

Facial expression	The detail
۲ (	We designed it based on "angry" shown in Figure 1 to replace the "Prohibition" symbol. If human do actions which is prohibited, that action will be reprehended. The meaning of "angry" is "feeling strong emotions which make you want to shout at someone (omission) because they have behaved in an unfair, cruel, offensive etc way, or because you think that a situation is unfair, unacceptable etc" according to Longman Dictionary. We want to make the viewers have feeling, others look to you accusingly if you do actions which is prohibited, by this facial expression.
$\langle ; \rangle$	We designed it based on "happiness" shown in Figure 1 to replace the "Mandatory" symbol. When human meet desirable situation, smiling is happened. The meaning of "happy" is "having feelings of pleasure, for example because something good has happened to you" according to Longman Dictionary. We want to make the viewers have feeling, others look to you favorably if you follow the instructions, by this facial expression.
	We created it based on "be scared" shown in Figure 1 to replace the "Warning" symbol. When human face to dangerous situations, they are worried or anxious. The meaning of "scared" is "frightened of something" according to Longman Dictionary. We want to make the viewers have feeling, others look to you worriedly because danger is imminent, by this facial expression.

Table 1. The detail of background's facial expression



#### SLIPPY SURFACE Figure 2. 16 example pictograms

In Figure 2, the left side of each example is normal pictogram which has a "Prohibition" or "Mandatory" or "Warning" symbol, and the right side is pictogram with facial expression as background we designed. The phrase under each example is the meaning of example. These 16 examples of normal pictogram in Figure 2 meet the following three conditions: (1) The "Prohibition," "Mandatory" or "Warning" symbol is drawn. (2) Over half body of human pictogram is depicted. (3) Being displayed many places in our daily life.

## **4 SUMMARY AND FUTURE WORKS**

This paper proposed a new style pictogram: pictogram with facial expression as background. We will have experiment to verify whether this pictogram can inform the action human must do or must not do without the "Prohibition," "Mandatory" or "Warning" symbol in the near future.

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# **CROSSMODAL CORRESPONDENCES BETWEEN** TASTE AND VISION REGARDING COMPLEXITY OF SHAPE

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## ABSTRACT

Crossmodal correspondences between taste and vision have recently drawn attention to improving diet. Crossmodal correspondence refers to a compatibility effect between attributes or dimensions of a stimulus in different sensory modalities. In this study, we aim to verify crossmodal correspondences by using complexity. First, we generated cupholders having complexity as visual stimuli and used orange juice as taste stimuli. Next, we conducted an experiment in which subjects evaluated their taste. As a result, a negative correlation between complexity and sweetness, and a positive correlation between complexity and sourness were confirmed.

Keywords: crossmodal correspondences, complexity, taste, vision

## **1 INTRODUCTION**

The result of multimodal information processing is known to be larger than the linear sum of the results of unimodal information processing (Bushara et al.,2003). The integration of various senses in the perceptual information processing process can be divided into three types: synaesthesia, multisensory integration, and crossmodal correspondences (Spence, 2011). Among these, the present study focuses on the crossmodal correspondences between vision and taste, which has been attracting attention in recent years to improve dietary habits. Crossmodal correspondences refer to an effect in which compatibility is found between the attributes and dimensions of stimuli given to different sensory modalities (Spence, 2011). Yanagisawa (2018) proposed the crossmodal expectation effect and modeled it mathematically before and after switching sensory modalities, the prior sensation is used to predict the

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posterior sensation. The crossmodal expectation effect is a phenomenon that occurs when the prediction or expectation based on the prior sensation affects the perception of the posterior sensation. Crossmodal correspondences with such characteristics are classified into four types: structural correspondence, statistical correspondence, semantic correspondence, and hedonic correspondence (Deroy, Crisinel, & Spence, 2013). The hedonic correspondence is the dominant cooperativity between vision and taste. In this study, we aim to verify the cooperative response between the senses by using the complexity of the shape in visual information. First, we selected a quantification index that expresses the complexity of the shape, and generated a cupholder that serves as a visual stimulus using the index. Next, the cup holder is filled with a beverage, which serves as a taste stimulus, and the taste is evaluated. The results are used to analyze the influence of the complexity of the cup holder on the sense of taste.

#### 2 QUANTIFYING COMPLEXITY AND USING IT TO GENERATE CLOSED CURVE SHAPE

#### 2.1 Curvature entropy

The method for calculating curvature entropy H (Ujiie et al., 2012; Okano, Matsumoto and Kato, 2020; Matsumoto, Sato, Matsuoka, Kato and 2019; Kato and Matsumoto, 2020), an index for quantifying the complexity of a closed curve shape, is described below. First, the total length of the curve is divided into equal segments, and the range of curvature E in each segment is discretized by dividing it by the number of states V. The occurrence probability  $q_i$  of each state and the transition probability  $q_{i,j}$  between states are then calculated. Using these, H is calculated as follows.

$$H = -\frac{1}{\log_2 V} \sum_{i=1}^{V} \sum_{j=1}^{V} q_i q_{i,j} \log_2 q_{i,j}$$

#### 2.2 Closed curve shape generation method

In this study, the basic shape, which is the basis for shape generation, is represented by a cubic Bézier curve, and the coordinates of each control point on the curve are searched using the particle swarm optimization method (Yamaguchi, 1988). Cubic Bézier curves can represent various shapes, and the computational load can be reduced by setting a low curve order (Hosaka, 1992). The cubic Bézier curves can reduce the computational load by setting points that can represent various shapes and a low curve order.

#### **3** VERIFICATION OF CROSSMODAL

#### 3.1 Experimental procedure

This section describes the conditions and procedures of a functional evaluation experiment to verify intersensory cooperation using a closed curve form created using the method described in the previous section. The experiment was conducted with the approval of the Bioethics Committee of the Graduate School of Keio University.

1. Subjects: 30 males and females

2. Taste stimulus: Orange juice diluted with water to a mass percent concentration of 20%

3. Visual stimulus: A cup holder with a closed curve shape on its side, which was created by a 3D printer by shaking H at five different levels

4. Experimental environment: A quiet room with a temperature kept at about 20°C

5. Experimental procedure: First, the subjects rinsed their mouth before the experiment. Next, the subject was told that the orange juice in the cup holder was diluted to various concentrations. The subjects then tasted the juice through a straw in the order of left to right, avoiding touching the cups with their hands or mouths. Finally, the subjects had to choose between two samples that had the greatest sweetness and sourness.

The procedure for creating cupholders using the closed curve shape generation method based on shape complexity described in the previous section is outlined. First, sensory evaluation experiments were conducted to set the parameters of H. The parameters were selected for V = 14, E = 0.4, and  $R^2 = 0.63$ . These parameters were adopted because they

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Curvature entropy	0.044	0.104	0.162	0.222	0.280
Figure					

gave the highest coefficient of determination. The selected shapes are shown in Fig. 1.

#### Figure 1. Sample shapes and their curvature entropy

#### 3.2 Experimental Results and Discussion

Based on Thurston's pairwise comparison method, the selection rate was obtained by dividing each frequency by the total number of 20 trials. The standard normal distribution score obtained by the inverse function of the cumulative distribution function in the standard normal distribution for the selection rate was averaged for each row to obtain an estimate of the interval scale, Thurston's scale. Using these results, the relationship between the curvature entropy and Thurston's measures of sweetness and sourness for each group is shown in Fig 7.



Sweet was

#### Figure 2. Relationship between curvature entropy and Thurstone's scale

shown to be negatively correlated with curvature entropy (r = -0.869), while sourness was positively correlated with curvature entropy (r = 0.959).

#### 4 CONCLUSION

In this study, we quantitatively analyzed the influence of the complexity of the closed curve shape of the cup holder side on the perception of sweetness and sourness using curvature entropy, a quantification index of complexity. As a result, a negative correlation between curvature entropy and sweetness, and a positive correlation between curvature entropy and acidity and density were confirmed in the taste evaluation of orange juice, indicating that curvature entropy affects the evaluation of sweetness and sourness.

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# **EMOTION INTENSITY IN ACOUSTIC FEATURES** AND CLASSIFICATION ACCURACY USING SUPPORT VECTOR MACHINE

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## ABSTRACT

In this study, the aim was to elucidate the correlation between emotion intensity and accuracy in emotion classification. Individual emotion classification was conducted using acoustic features extracted from audio data based on varying emotion intensities. Support Vector Machine was employed as the classification method, utilizing carefully selected acoustic features to classify individual emotions across different intensity levels. The findings revealed higher classification accuracy for individual emotions when the intensity was strong compared to weak intensity. Additionally, it was demonstrated that enhancing the classification accuracy of the "joy" emotion requires the utilization of acoustic features distinct from those of other emotions.

*Keywords:* Emotion intensity, Mel frequency cepstral coefficient, Formant, Harmonics-to-noise-ratio, Support vector machine (SVM)

## 1 INTRRODUCTION

While numerous studies have explored emotion estimation (Jonathan, 2021), few have addressed the intensity aspect of emotions. Accurate emotion classification holds potential for various applications (Aranha, Corrêa, & Nunes, 2019), including customer satisfaction assessment and enhancing robot interaction.

This research aims to elucidate the accuracy of emotion classification based on emotion intensity. We employ Support Vector Machine (SVM), a machine learning method, utilizing three types of acoustic parameters extracted from speech data.

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## **2** PARAMETER EXTRACTION

## 2.1 Audio data

The study utilized the "Online Game Voice Chat Corpus with Emotion Rating Values (OGVC)". Speakers included 13 male and female university students experienced in online gaming. Data was collected from conversations during gameplay, segmented into short sentences, with each utterance labeled to indicate the type and intensity of emotion. Specifically, the study focused on data representing low and high intensity emotions of "anger", "joy", and "sadness".

## 2.2 Method of parameter extraction

For parameter extraction, Python libraries surfboard and librosa were employed to extract seven types and ten features. Among these features, three parameters were utilized: Mel frequency cepstrum (MFCC), formant, and Harmonics-to-Noise Ratio (HNR).

## **3 PARAMETER SELECTION USING SUPPORT VECTOR MACHINE**

#### 3.1 Emotion estimation with support vector machine

Support vector machines, known for their easily adjustable parameters, were employed as the machine learning method in this study. The three acoustic parameters outlined in Section 2 were utilized as explanatory variables. Meanwhile, the target variables comprised three emotions: "anger," "joy," and "sadness." Learning and evaluation were conducted for both low-intensity emotions (245 datasets: "Anger: 78, Joy: 88, Sadness: 78") and high-intensity emotions (233 datasets: "Anger: 81, Joy: 79, Sadness: 81"). Tests were performed, and results were compared on the street. The kernel employed for learning was linear, and the cost functions C and  $\gamma$  were determined via the grid search method, following the procedure below:

• Perform a grid search across all combinations of cost functions C (0.001, 0.01, 0.1, 1, 10, 100) and  $\gamma$  (0.001, 0.01, 0.1, 1, 10, 100) to determine the optimal parameters. During this process, the training and test data were evaluated at a ratio of 3:1.

• Determine the classification accuracy using the best parameters of the cost function determined in (1). Again, the training and test data were evaluated at a ratio of 3:1.

#### 3.2 Classification results

Table 1 presents the classification results for low emotional intensity in terms of the confusion matrix, classification accuracy rate, recall rate, and precision. The table indicates that "joy" is frequently misclassified as "anger." The overall accuracy rate was approximately 45%, which cannot be considered high.

Table 2 depicts the classification outcomes for high emotional intensity. A comparison with Table 1 reveals a higher overall classification accuracy. This suggests that stronger emotions lead to clearer feature distinctions, resulting in improved classification accuracy.

Evaluation indices	Results
Confusion matrix	Anger Joy Sadness Anger [16 1 3 Joy 8 3 4 Sadness 5 0 7]
Correct answer rate	0.448
Recall rate	0.494
Accuracy	0.459
F-value	0.458

Table 1. Classification results for low emotional intensity

Evaluation indices	Results
Confusion matrix	Anger Joy Sadness Anger [ 9 5 2 Joy 11 6 2 Sadness 6 1 7]
Correct answer rate	0.553
Recall rate	0.600
Accuracy	0.527
F-value	0.502

The aim of this study was to elucidate the correlation between emotional intensity and classification accuracy, which was achieved. However, the classification accuracy was lower compared to previous research on emotion classification. The following section will discuss the reasons for this discrepancy.

## 4 CONSIDERATION

Figure 1 illustrates a comparison of HNR features. The horizontal axis represents each emotion, while the legend indicates the intensity. It can be observed from the figure that the emotion "joy" falls within a range between the values of other emotions. Furthermore, while other emotions exhibit varying feature quantities based on intensity differences, there are no discernible differences in feature quantities for the emotion "joy" across different intensity levels. This pattern was similarly observed for MFCC and formant. Consequently, it is inferred that the low classification accuracy of the emotion "joy" can be attributed to these factors.



Figure 1. Comparison of Harmonics-to-Noise Ratio features

## 5 CONCLUSION

In summary, the study concludes with the following key findings:

1. Classification accuracy improves with higher emotional intensity.

2. Effective classification of joy emotions using acoustic features requires the utilization of features that exhibit significant differences from those of other emotions.

#### **ACKNOWLEDGMENTS**

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# DEVELOPMENT OF AN ANALYTICAL PROTOCOL FOR SIX HORMONES IN FINGERNAILS: A MID-TO-LONG-TERM PSYCHOPHYSIOLOGICAL ASSESSMENT

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## ABSTRACT

Hormones in the human body respond to stress and can be used as biomarkers to evaluate stress levels. Recently, there has been a growing focus on fingernail hormones for their accessibility as a human specimen. Nail cortisol has been the primary focus of attention in this area of research, but other hormones also change in response to physical and mental conditions. Therefore, this study developed a protocol for analyzing six hormones (Cortisol, DHEA, Testosterone, Progesterone, Estradiol, and Melatonin) from a single nail specimen. To evaluate the effectiveness of the proposed quantitative protocol, these six hormones in nail and saliva samples of healthy adults were quantified. The analysis results of the nail samples were biologically plausible: Male and female hormones were significantly higher in their respective genders. Nail samples are much easier to collect and store than saliva, urine, blood, or hair samples. Longitudinal analysis of multiple nail hormones with this protocol may make it possible to visualize changes in the body's internal environment over the medium to long term.

Keywords: Fingernail hormones, Stress hormones, Sex hormones, Salivary hormones

## **1** INTRODUCTION

Hormone secretion in the human body is modulated by mental stress, with cortisol levels notably increasing in response to mental workload, psychosocial stressors such as job interviews, and undesirable or adverse social events (Dickerson & Kemeny, 2004). Since cortisol can be quantitatively analyzed from human hair and nails, it has garnered attention as a noninvasive stress evaluation index.

On the other hand, in addition to cortisol, several different hormones are influenced by physical and mental changes, particularly sex-related hormones that are susceptible to stressors. However, no method has been established to analyze hormones other than cortisol from hair (Sugaya et al., 2020) and nail samples (Izawa et al., 2021). This study investigated a method for

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the simultaneous quantitative analysis of six hormones from a single nail sample. Furthermore, to confirm the feasibility of the proposed protocol, hormone levels extracted from nail samples were compared with those from saliva samples.

## 2 METHOD

This comprehensive study analyzed six hormones (cortisol, DHEA, testosterone, estradiol, progesterone, and melatonin) referencing the existing nail and hair cortisol analysis protocols (Nagai et al., 2023; Ohira et al., 2017; Yoshida & Nomura, 2017). Since the concentration ranges of these hormones in nail samples, aside from cortisol, were previously unknown, we conducted rigorous preliminary exploratory studies to develop an effective protocol. Consequently, we propose the following protocol for the simultaneous quantitative analysis of these six hormones in nail samples.

## 2.1 Proposed protocol

- 1. Washing: Using methanol, remove oil, fat, and other contaminants from the nail sample.
- 2. Crushing: Nail specimens are crushed into 1-2 mm square pieces (Figure 1a).
- 3. Extraction: Add 1.0 mL of methanol to 40 mg of crushed nail sample to extract hormones from the sample for 72 hours (Figure 1b).
- 4. Aliquot: After 72 hours of extraction, the methanol supernatant is aliquoted.
- 5. Concentration: Evaporate the aliquoted methanol and dilute it with buffer solution.
- 6. Analysis: Each hormone is analyzed quantitatively, employing enzyme-linked immunosorbent assay (ELISA) on the extracted solution prepared above.



Figure 1. a) Crushed nail sample, b) Extraction of hormones

## 2.2 Saliva samples

The concentration of each hormone was determined using ELISA from the saliva of the same participants who provided the nail samples, allowing for a comparative analysis between the two types of samples. Twenty-two healthy young adults (11 males and 11 females, mean age: 21.3) provided both nail and saliva samples.

#### 3 RESULTS AND DISCUSSION

For all participants, almost all of the six hormones quantitatively analyzed from the nail samples were within the quantitative range of biochemical analysis (ELISA), indicating that the proposed protocol meets the required specifications for reliable quantitative analysis.

Furthermore, the results of the sex hormone analyses were biologically plausible. For example, testosterone, the male hormone, had significantly higher concentrations in both nails and saliva in males than in females (p < 0.001). Conversely, the female hormones, estradiol and progesterone, had significantly higher concentrations in females than in males (p < 0.001 and p < 0.01, respectively).

In terms of saliva-nail correlation, a significant positive correlation (p < 0.01) was observed for testosterone and estradiol, whereas no significant correlation was found for the other hormones. This discrepancy may be attributed to the fact that saliva reflects the instantaneous values of hormones in the body, while nails reflect the integral values over the medium to long-term period.

In conclusion, this study proposed a protocol for the simultaneous quantitative analysis of six hormones from a single nail sample. Nails are the most accessible human specimens as they are routinely discarded in daily life. Therefore, this method holds promise for application in a variety of fields, including preventive medicine, mental stress evaluation, and working environment assessment.

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# RELATIONSHIP BETWEEN THE ADVANCING/RETREATING PROPERTIES OF COLORS AND OBJECT SHAPE DISTORTION

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## ABSTRACT

The relationship between the advancing/retreating properties of colors and object shape distortion is investigated through online and darkroom experiments. Pairs of non-distorted/distorted disk objects in yellow and blue on backgrounds of various brightness were presented, and the respondents selected which looked larger. The results indicate that the blue disk looks larger than the yellow disk on the bright background, independent of the disk's distortion. For the dark background, the ratio of the respondents who answered that the blue distorted disk was larger than the yellow one increased in the case of the darkroom experiment. It suggests that the effect of the distortion may override that of the advancing property of the yellow in the dark background.

Keywords: advancing and retreating properties of colors, shape distortion, emotion in color

## **1** INTRODUCTION

When two objects of different shapes whose sizes look similar are presented simultaneously, it is often difficult to find which object is more extensive in the area (Whitaker, McGraw, & Pearson, 1999). If a different color is assigned to each object, it is more difficult to (Nakaya, Negishi, & Shinomori, 2015). Some colors are advancing, which has the effect that the object looks as if the object looked closer, and some colors are retreating, which has the opposite effect. It still needs to be made clear which shape and color differences have more influence on size recognition.

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This research investigates the effects of shape and color differences on the appearance of size. We presented blue and yellow disks of the same size and the blue and yellow disks whose shapes were distorted on the several background brightness. The respondents selected which looked larger. The experiments were performed online and in the darkroom. The results indicate that the properties of advancing and retreating are interchanged according to background brightness, and the effect of shape distortion appears on the background, which is pure or nearly pure black.

## 2 EXPERIMENTS

## 2.1 Presented images

The presented images are two disks in yellow and blue, as shown in Fig. 1(a), and disks whose shapes are distorted randomly in shape, as shown in Fig. 1(b), on the background of various gray levels—the areas of colored regions in yellow and blue. The arrangement of yellow and blue disks is fixed because interchanging yellow and blue does not influence the response in a preliminary experiment. The difference in respondents' color sense was not considered in the experiments because the difference is negligible for the case of yellow and blue.



(b)

Figure 1. Presented images. (a) Two disks. (b) Distorted disks.

## 2.2 Online experiment

The non-distorted and distorted disk pairs shown in Fig. 1 on six different background gray levels were presented to respondents by Google Forms. Figure 2 shows non-distorted disk pairs on the six background gray levels. The gray levels are indicated as 100 (white), 75, 62, 49,31, and 0 (black), according to the brightness indicator of the app "ibisPaint X" (ibisPaint, 2024).



Figure 2. Non-distorted disk pairs on six different background gray levels for the online experiment.

The six non-distorted disk pairs were presented randomly, and the respondents were asked to select one disk that looked larger for each pair. The respondents were not allowed to answer that the sizes were the same. Then, the six distorted disk pairs were presented randomly, and the respondents were asked similarly.

#### 2.3 Darkroom experiment

The online experiment cannot present the images in the same size and color appearance because they depend on each respondent's terminal screen. To overcome this weakness, we performed a darkroom experiment. Figure 3 shows the experimental setup in the darkroom. A Windows 11 computer and the EIZO CG279 display in Adobe RGB mode were employed. Each disk-pair image appeared as a 135 mm x 90 mm rectangle on the screen, and the distance between the screen and the respondent's eyes was 50 cm.



**Figure 3**. Device arrangement in the darkroom experiment. The curtain behind the respondent was closed when the actual experiment was performed.

The blue was set to (0, 0, 255), and the yellow was set to (255, 255, 0) by the RGB scale in the Adobe Photoshop color picker. These color parameters were converted to the Lab scale in the color picker, and we got L = 33 and 93 for blue and yellow, between 0 and 100, respectively. The background was set to 7 gray levels, L = 100 (white), 93 (same as L of yellow), 73, 53, 33 (same as L of blue), 16, 0 (black). The respondents' answers were collected using Google Forms, similar to the online experiment.

## **3** EXPERIMENTAL RESULTS AND DISCUSSION

The number of respondents was 34 for the online experiment and 11 for the darkroom experiment. Figure 4 shows the results of the online and darkroom experiments. The horizontal axis indicates the background gray level, and the vertical axis indicates the ratio of the respondents who answered that the blue disk was larger. The blue line is for the non-distorted disk, and the orange line is for the distorted one.

The results indicate that the blue disk looks larger than the yellow disk on the bright background, independent of the disk's distortion. The brighter the background, the higher the ratio of respondents who answer that the blue one is larger, for the gray level higher than 50%.



Figure 4. Experimental results. (a) Online experiment. (b) Darkroom experiment.

The results of the online and darkroom experiments are different for the dark background. There is no significant difference between the non-distorted and distorted disks, and the yellow disk looks larger in the case of the online experiment.

In the darkroom experiment, the response was the same as the online experiment for the non-distorted disk, while for the distorted disk, some respondents answered that the blue disk was larger. The ratio of the respondents who answered that the blue disk was larger increased for the background darker than L = 33, the L value of the blue disk. It suggests that the effect of the distortion may override that of the advancing property of the yellow in this background condition.

#### 4 CONCLUSIONS

This research investigates the relationship between the advancing/retreating properties of colors and object shape distortion. The online and darkroom experiments were performed, and it was observed that the advancing property of color can be overridden by shape distortion. The results are preliminary, and more precise experiments by many respondents, employing different colors and considering the difference of color senses, are expected.

#### **ACKNOWLEDGMENTS**

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## **PREDICTING METHOD FOR APPEARANCE OF MOVING OBJECTS IN INSTANTANEOUS PRESENTATION**

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## ABSTRACT

When they see a moving object, they may follow it with their eyes or they may cross it without following it. The appearance of an object that is not followed by the eyes is different than when it is followed. If we can develop a method to manipulate the appearance of objects that pass in front of us, we can extend the scope of design. Based on a model that explains the phenomenon in which object boundaries are perceived clearly due to motion, our research group has developed a method for predicting the appearance of objects rotating at a constant speed in a certain direction using digital image filtering. However, this method was limited to rotating figures. In this study, we verified the effectiveness of this predicting method under conditions that reproduce the visual situation when the eye does not follow a moving stimulus by presenting the stimulus instantaneously. The results show that the proposed method provides a promising clue for constructing a method for predicting the appearance of moving objects.

Keywords: Designing, Digital image filter, Motion sharpening, Human vision

## **1** INTRODUCTION

In our daily lives, we have many opportunities to see moving objects. In some cases, they follow the object with their eyes, and in other cases, they pass by without following the object. In visual design and product design, it is important to control the appearance of the object and to evoke appropriate sensitivity information in the consumer. If we can develop a method to

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design the appearance of the object when it is not followed by the eye, or an object that moves unexpectedly in front of the eye, the method will broaden the scope of the designer's work. It can be used as a new means of information transmission.

The phenomenon in which the object appears sharper as it moves is called motion sharpening. Several explanatory models have been proposed (Ramachandran, Rao, & Vidyasagar, 1974; Hammett, Georgeson, Bedingham, & Barbieri-Hesse, 2003; Pääkkönen & Morgan, 2001). Takeuchi showed its potential application as a video compression technology (Takeuchi, 2005). Our research group has developed a method for predicting the appearance of objects moving at a constant speed in a certain direction based on visual impulse response model (Otaka, Kaneko, & Osa, 2024). However, the effectiveness of this method was confirmed only when the object was rotating. The purpose of this study is to verify that the prediction method is effective by reproducing a situation in which the target is passed by without following it with the eyes by presenting the presentation stimulus instantaneously.

## 2 METHOD

The impulse response model of vision explains motion sharpening by superposition of inhibitory and excitatory responses of vision system (Pääkkönen & Morgan, 2001). Our research group has developed a method for predicting the appearance of moving objects based on this visual impulse response model using digital filtering (Otaka et al., 2024). This method can predict the appearance of the object moving at a constant speed and in a constant direction (call it "Forward transformation"). It is also possible to predict the appearance of the object when it was stationary before it moved by performing the inverse operation (call it "Inverse transformation"). The procedure is shown below:

1. Design a function h(x) that represents the impulse response of vision by superposition of positive and negative Gaussians. The two Gaussian parameters are determined from the object's moving speed and visual characteristics.

2. Fourier transform the original image f(x, y) and the function h(x) to obtain F(u, v) and H(u, v). H(u, v) is a 2-dimensional filter in Fourier domain.

3. Calculate the filtered image G(u, v) in Equation 1.

$$G(u,v) = F(u,v)H(u,v)$$
(1)

4. Inverse Fourier transform G(u, v) to obtain an image g(x, y) that represents the appearance of the moving object.

To obtain the appearance of the object at stationary before it moves, use Equation 2 in procedure 3 and follow the same procedure. Here, d is a very small value.

$$G(u,v) = F(u,v)/\{H(u,v) + d\}$$
(2)



Figure 1. Presenting and comparison stimuli. Image 4 was created by the "Inverse transformation" of the proposed method based on Image 1. The appearance of Image 4 when it is moved from left to right at a set speed is as shown in Image 2. Image 2 is the image predicted by the "Forward transformation" of the proposed method when Image 4 is moved at the set speed. Image 3 is the image predicted by the "Forward transformation" of the proposed method when there is an error of the set speed equal to the result of the previous study. Image 4 is the presenting image moved in the experiment. Figures 1 to 4 were used as comparison stimuli to answer what the images looked like.

#### **3** EXPERIMENT AND RESULT

The validation of the predicting method (Otaka et al., 2024) was limited to the case where the object rotates. In this study, we reproduce the case in which the experimental participant does not follow a moving object with his/her eyes by presenting the stimulus instantaneously.

Figure 1 shows the presented stimuli (Fig.1(d)) and the comparison stimuli (Fig.1(a)-(d)) used in the experiment. Fig. 1 (a) shows the original image and Fig.1(d) shows the predicted "Inverse transformation" at an assumed speed of 567 mm/s. Fig.1(d) is moved at the assumed speed, the appearance is close to that of Fig.1(a). Fig.1(b) shows the predicted image when Fig.1(d) is moved at an assumed speed of 567 mm/s. In other words, it predicts the appearance of Fig. 1(d) when it is moved at the assumed speed. Fig.1(c) shows the predicted image when Fig.1(d) is moved at an assumed speed of 340 mm/s.

Experimental participants answered which of Fig.1(a) to (d) was closest to the appearance when image 4 of Fig.1(d) physically moved at the assumed speed. 30 trials were conducted. The presentation time in Fig.1(d) was 100 ms. Observations were made in a dark room, and the background luminance during instantaneous presentation was 24 cd/m². Three male participants aged 21-23 years participated in the experiment.

The results are shown in Figure 2. Participants 1 and 2 often responded that the image was similar to Fig.1(c) image3 or (d) image4. Participant 3 often responded that the image was similar to that of Fig.1(b) image2 or (c) image3. In the validation results for the case of a rotating figure, it is reported that when the speed of movement is high, the appearance of the object tends to be closer to the assumed appearance by moving the figure faster than the assumed speed (Otaka et al., 2024). Participants 1 and 2 would need to move even faster to get close to the assumed appearance, and participant 3 may be relatively well suited to the set speed of the predicting method. Therefore, the results represent the characteristics of the visual impulse response in individuals.

The experimental results indicate that the proposed method provides an effective clue to the

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Figure 2. Experimental results

construction of a method for predicting the appearance of moving objects, although some participants in the experiment are close to the assumed characteristics of the impulse response and others have errors.

#### 4 CONCLUSIONS

In this study, we verified the effectiveness of the prediction method in a situation in which a moving object was not followed by the eyes and the presented stimulus was presented instantaneously. The results show that it is possible to predict the appearance of moving objects that are presented instantaneously. The potential for application as a design method for objects not followed by the eye was suggested. In the future, it is necessary to consider how to tune the impulse response characteristics of vision for each individual.

#### **ACKNOWLEDGMENTS**

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# TEXTURE STATISTICS AS DETERMINANTS OF EMOTIONAL VALENCE OF NATURAL IMAGES AND SOUNDS: ANALYSIS IN THE TWO-STAGE SPECTRAL SPACE

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## ABSTRACT

We do not recognize objects and evens from images and sounds, but also have affective responses to them such as pleasantness and unpleasantness. These emotional responses are often directly caused by the statistical features of images and sounds themselves rather than by the recognized objects or events. In the present study, we report the results showing that emotional valence of various natural texture images and sounds, particularly unpleasantness and discomfort, can be well predicted from low-level image/sound statistics; i.e., the two-stage spectral characteristics of images and sounds.

Keywords: Image statistics, Sound statistics, Emotion

## 1 EMOTIONAL RESPONSES TO VISUAL AND AUDITORY STIMULI

We do not only recognize objects, scenes, and materials from images, but also have emotional responses to particular visual stimuli. For example, colorful jewelry may seem pleasant, whereas a collection of tiny insects or a drain with wet filth on it may appear vey disgusting. Similarly, we do not only perceive events and spatial environment from sounds, but also have emotional responses to particular auditory stimuli. For example, the sound of a musical instrument or a bell is pleasant, whereas the sound of blackboard scratches is highly uncomfortable.

These affective responses may be triggered by specific features in the images or sounds themselves, rather than by categories of recognized objects or events. Increasing evidence suggests that affective evaluations and preferences for visual stimuli such as gratings, noise, and natural surfaces are tightly associated with specific image statistics (Wilkins, 1995; Motoyoshi &

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Mori, 2016; Ogawa & Motoyoshi, 2020). It has also been suggested that auditory discomfort by scratching sounds are associated with specific frequency bands in the sound (Halpern et al., 1986).

## 2 EMOTIONAL VALENCE AS PREDICTED BY TEXTURE STATISTICS

According to the above daily examples, affective responses to visual and auditory stimuli strongly depend on the textural (including color) information in images and sounds. In both vision and audition, texture perception is known to be based on image and sound statistics (e.g., Motoyoshi et al., 2007). Prevailing computational models can synthesize textural impressions of natural images and sounds solely from statistical data (Portilla & Simoncelli, 2000; McDermott et al., 2013). Recent studies further indicate that these visual and auditory texture statistics are equivalently represented only by two spectral spaces (Okada et al., 2021; Maruyama et al., 2023).

Taking advantage of the versatility of two-stage spectra to describe impressions of arbitrary texture images and sounds, we investigated the two-stage spectral properties that determine affective responses, especially negative one, to a variety of natural texture images and texture sounds.

## **3 TWO-STAGE IMAGE SPECTRA FOR VISUAL DISCOMFORT (UNPLEASANTNESS)**

For vision, we found that ratings (14 observers) of pleasantness or unpleasantness for 194 diverse natural texture images were highly correlated with a particular frequency bands in the two-stage spectra of the image. Specifically, images with high power at middle spatial frequencies in the 1st-order spectrum (8-16 c/image) and a low-pass orientation-frequency characteristics (i.e., isotropic structure in the image) in the 2nd-order spectrum, were judged very unpleasant. Moreover, the unpleasantness rating was not different for images synthesized based on low-level image statistics from that for the original natural images (correlation coeffecient was 0.8 for all images, and 0.9 for unpleasant surfaces), suggesting that unpleasantness depends almost entirely on the low-level image statistics (Motoyoshi & Mori, 2016; Ogawa & Motoyoshi, 2020).

## 4 TWO-STAGE SOUND SPECTRA FOR AUDITORY DISCOMFORT

For audition, we found that ratings (7 observers) of unpleasantness for 185 natural sounds (1.0 s duration), including sounds such as scratching and metal scraping, were highly correlated with specific frequency bands in the two-stage spectra of the sound. Specifically, sounds with high power at relatively high frequencies in the 1st-order spectrum and high power peaking at intermediate frequencies in both the temporal (1-2 Hz) and spectro-frequency (0.1-0.2 c/kHz) dimensions of the 2nd-order spectrum were judged to be very uncomfortable. In addition, our previous study have also shown that for 325 diverse natural sounds, synthesized sounds that preserved only the two-stage spectra characteristics were perceived as sounding very similar to the original sound (Maruyama et al., 2023).

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# SUBJECTIVE EVALUATION OF SEMI-TRANSPARENCY METHODS AS MEASURES AGAINST OCCLUSION IN VIDEO GAMES: COMPARISON OF ALPHA BLENDING AND DITHERING UNDER VIEWING CONDITIONS WITH DIFFERENT RESOLUTIONS

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## ABSTRACT

In third-person video games, occlusion, where obstructive objects occlude a user-controlled avatar, is detrimental to the game user's experience. Major occlusion countermeasures include alpha blending and dithering which make the occluding obstacle semi-transparent. However, it is unclear whether these two techniques are effective at all screen resolutions. Therefore, in this study, we conducted a subjective evaluation of the two methods under the following viewing conditions: 2K-FHD (1920 x 1080 pixels) and 4K-UHD (3840 x 2160 pixels). Our results showed that alpha blending is not significantly affected by resolution, while dithering tends to give a similar impression to alpha blending under 4K-UHD viewing conditions but a lower impression at lower resolution.

Keywords: video game, occlusion, dithering, alpha blending, Kansei/effective evaluation

## **1** INTRODUCTION

In third-person video games based on three-dimensional computer graphics (3DCG), occlusion frequently occurs when the avatar controlled by the user becomes invisible because obstructive objects between the avatar and the camera block the user's view. Occlusion degrades the visibility and playability of video games and, if it occurs frequently or when unintended by the developers, undermines the users' basic enjoyment of the game. Occlusion is therefore a serious issue requiring countermeasures from the game system side, and

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improvement attempts have been made since the earliest days of 3DCG video games (Haigh-Hutchinson, 2009; Pinelle et al., 2008).

A major occlusion countermeasure is making occluders (foreground obstructive objects) transparent or semi-transparent using alpha blending (Wallace, 1981), a technique that uses coefficients known as  $\alpha$  values to combine the overlapping areas of superimposed images at a ratio of  $\alpha$ : $(1 - \alpha)$ . The authors confirmed that occlusion countermeasures using alpha blending to make occluders semi-transparent are useful for improving avatar visibility and reducing subjective fatigue (Jikihara et al., 2024). However, this method is sensitive to the order in which the images are rendered, and a processing load can easily arise during the rendering of the scene behind the overlapping section where occlusion has occurred; for example, when deferred shading is used, the G-buffer can be overwritten.

Using dithering to make occluders semi-transparent is another countermeasure. For example, in "ordered dithering" (Bayer, 1973), in the section where two images overlap, one image is rendered using pixels above a certain Bayer matrix threshold value, and the other image is rendered using other pixels. Dithering is a pseudo semi-transparency method in which each image is drawn individually pixel by pixel; therefore, it is less prone to problems caused by the order in which images are rendered compared to alpha blending. On the other hand, the degree of transparency expressed by dithering depends on the number of pixels per unit area, so if the screen resolution is insufficient, the Bayer matrix's structure will be visible, and the smoothness and beauty of the gradation may be compromised. However, the screen resolution needed to alleviate this problem has not yet been fully quantified.

We conducted an experiment in which video games were subjectively evaluated under 2K-FHD and 4K-UHD viewing conditions to clarify the impact of screen resolution on the effectiveness of the two aforementioned countermeasure against occlusion.

### 2 SUBJECTIVE EVALUATION EXPERIMENT OF VIDEO GAME

We implemented the two occlusion countermeasures mentioned earlier in a video game in which a player-controlled avatar must collect as many items on the game field as possible within 45 seconds. We then sought subjective evaluation of the impression produced by each measure.

The game under evaluation was created in Unity (version 2022.3.0f1). As shown in Figure 1, the following rendering processes were applied to occluding objects in the game:  $M_a$ ) the Unity Standard Shader with no occlusion countermeasures;  $M_b$ ) rendering with 50% transparency using alpha blending; and  $M_c$ ) rendering with pseudo semi-transparency using ordered dithering. Screen resolution was set at  $R_{2k}$  (1920 x 1080 pixels) and  $R_{4k}$  (3840 x 2160 pixels). The game was displayed full screen on an LCD monitor (CG2700-X, EIZO) at a viewing distance of approximately 0.8 m or three times the screen's height. The maximum luminance of the screen was calibrated at 200 cd/m². The playing environment was illuminated by a D₆₅ light source (Z-209PRO-6500K, Yamada Shomei Lighting Co., Ltd.).

Fourteen players, comprising nine males and five females in their 20s, subjectively evaluated the game using Sheffe's paired comparison method (Nakaya's variant) in analysis of variance (ANOVA). The participants played two versions of the game successively and responded to the following three questions on a 5-point scale: Q1) In which version did you find the image quality to be grainier? Q2) In which version did you find the image quality to be more aesthetically pleasing? Q3) Which version did you consider to be better overall? To counteract order effects, the sequence in which the game versions were played and the sequence in which the questions were asked were randomized for each participant.



a. No Countermeasures b. Alpha Blending (Semitransparent) c. Dithering (Pseudo Semitransparent) **Figure 1**. Difference in the occlusion scene under each condition

## **3** RESULTS AND DISCUSSION

Figure 2 shows the paired comparison scores. The error bars represent the yardstick  $Y_{0.05}$ . As shown in Figure 2, significant main effects were found for "Q1. No Grainy," "Q2. Beauty," and "Q3. Overall impression" (p < 0.001), indicating that relevant impressions vary depending on the presence of an occlusion countermeasure, the type of countermeasure, and the screen resolution. The following important properties were also statistically demonstrated: Result 1) A significant difference between the conditions  $M_cR_{2K}$  and  $M_cR_{4K}$  (Q1-3), Result 2) No significant difference between the conditions  $M_bR_{2K}$  and  $M_bR_{4K}$  (Q1-3), Result 3) No significant difference between the conditions  $M_bR_{2K}$  and  $M_bR_{4K}$  and  $M_cR_{4K}$  (Q1-3), and Result 4) Significant differences between the conditions  $M_a$  and  $M_b$ , also  $M_a$  and  $M_c$  (Q3).

Result 1 shows that, with dithering, the impression is low when viewed under 2K-FHD conditions, and it rises when viewed under 4K-UHD conditions, whereas Result 2 shows that alpha blending is not significantly affected by resolution. Furthermore, Result 3 shows that dithering viewed under 4K-UHD conditions gives an impression comparable to that produced by alpha blending viewed at resolutions of 2K-FHD and above, and Result 4 shows that the impression produced by dithering viewed under 2K-FHD conditions is better than that given by the game with no occlusion countermeasures.

Based on the experimental results, it is evident that in 3DCG video games, selecting the appropriate occlusion countermeasure according to the resolution is crucial. Specifically, for

resolutions of 4K-UHD or higher, dithering may provide a superior solution to occlusion problems. This is due to dithering's capability to maintain consistent visual impressions without being affected by the rendering order of 3D objects, thereby offering the performance advantages comparable to those of alpha blending. Conversely, for resolutions at 2K-FHD or lower, alpha blending should be prioritized for addressing occlusion problems.



### 4 CONCLUSION

In this paper, we compared the impressions given by alpha blending and dithering, which were both occlusion countermeasures used in 3DCG video games, under 2K-FHD and 4K-UHD viewing conditions. The results showed that alpha blending is less sensitive to resolution, whereas dithering tends to give an impression similar to that of alpha blending under 4K-UHD viewing conditions but a lower impression at lower resolution. Therefore, in 3DCG video games, it is essential to select the appropriate occlusion countermeasure according to the resolution. Future research will verify the effectiveness of dithering algorithms that do not involve a Bayer matrix and the effectiveness of methods that combine dithering and alpha blending.

#### ACKNOWLEDGMENTS

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# A CASE STUDY OF THE DEVELOPMENT OF A CARD-BASED ROLE-PLAYING GAME FOR LEARNING ABOUT COMMUNICATION

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# ABSTRACT

In this study, we explore whether an interactive card game developed to translate communication, the foundation of human relationships, into concrete actions has contributed to this goal, and based on the feedback, we look at the outlook for future model changes. The method used was to conduct a questionnaire survey after the game, and the results showed that the player commented, "I have played role-playing games before, but this was the first time I learned about the other player's background after playing the game, and it gave me new perspectives." We hope to use this to further develop the game in the future.

*Keywords:* Communication skill, Game development, Interpersonal relationships, Interactive card game

# **1** INTRODUCTION

## 1.1 Research background

We often find it difficult to communicate with others. And forming mutual agreements with multiple people in a group is one of the primary functions of conversational communication. (Katagiri et al., 2015). Katagiri also states the following.

Although conversation analysis research typically uses audio and video recordings of real. conversational situations as foundational data, it mainly focuses on the surface regularities

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of conversation. It does not delve into cognitive science concepts such as the beliefs, goals, and emotions of the interlocutors that underlie the conversation (Sidnell & Stivers, 2012 apud Katagiri et al., 2015).

However, in recent years, there have been many attempts to specifically address conversational communication through interpersonal games and business games, in which settings (Sugiura, 2003), roles, and time limits are prepared, and players interact with each other to experience communication and consensus building through conversation (Takahashi & Nakano, 2019). While simulated experiences under specific conditions in particular games can yield insights and outcomes, further research is needed to identify the factors that lead to behavioral expression in irregular situations encountered in everyday life.

### 1.2 Study purpose

This study aimed to incorporate two additional elements into the game experience, verify them through gameplay, and obtain feedback.

## 2 METHODS

## 2.1 Development of the "Oh! So!" card game

This is a card game with a scenario and a set of characters. Players are given specific lines at the beginning and, as they assume their roles, aim to recognize each other's objectives and ultimately reach an agreement. It has been reported that communication skills that involve consensus building, can be improved through vocal expression and the accumulation of conversation training experience (Yamaguchi & Nagamine, 2007). The "Study Group for Strengthening Human Resources in Japan's Industries" by the Ministry of Economy, Trade, and Industry of Japan (2018) highlighted that to improve teamwork skills, which are significantly influenced by interpersonal relationships, "the power to communicate," "listening skills," "flexibility," "situational awareness," and "discipline" are essential components of basic social skills. In this game, players engage in ad-libbed conversations using five of these six elements to achieve their objectives, aiming to build consensus and improve communication skills while playing.

Two new elements were added to this game. The first one is the card design. The cards that players hold during the game were designed with a texture and shape intended to feel as familiar as possible to the user. The cards are 88 mm x 55 mm in size, approximately the same as a business card, making them comfortable to hold since players are accustomed to this size. The edges were left wavy to prevent the paper from slipping out of the hand. For the hues, we selected pre-made paper with p-tone and It-tone patterns, ranging from reddish purple to reddish yellow, as well as yellow-green, green-based, and blue-green. The image conveyed by the color scheme—such as cuteness, freshness, and freshness—is intended to lift players' mood, potentially leading to smoother consensus building. The cards were also laminated to prevent deterioration and treated to protect them from moisture and wrinkles.

The second element was the post-game script exchange, whereby, players exchange scripts to learn about the circumstances of the other person, which would be impossible to know in real life. In recent years, popular role-playing games allow multiple players to assume the roles of fictional characters, which plays a central role in the enjoyment of the game. Research and practice have focused on the significance of communication education and learning through such games (Ishida et al., 2018). However, this is the first attempt to have players exchange scenarios after the game and "learn about the other person's background," making it a novel challenge for this game. This is because "dialogue clarifies differences in positions and perspectives" (Parsons & Lavery, 2012), and "opportunities to understand not only one's own perspective but also the perspectives of others and to bridge the gap between oneself and others are important" (Parsons & Lavery, 2012). By exchanging scenarios, players can overcome problems that arise from seeing things only from their own perspective. When players learn about the other's circumstances, they often experience a moment of realization, exclaiming, "Oh, so that is how it is!" This reaction inspired the title of the "Oh! So!" card game.

## 2.2 Rules for the "Oh! So!" card game

- 1. Three people in a group. A and B play against each other. C acts as the moderator and judge.
- 2. Players A and B each choose one type of envelope and read the "setting + dialogue" for each one.
- 3. Players A and B each have lines at the beginning, and then they improvise.
- 4. When the conversation reaches a stalemate, A and B draw "advice cards" to get hints.
- 5. The game ends after 5-minutes timer. A and B exchange scenarios and read them. Learn about the other person's situation (Figure 1).
- 6. C calculates the score from the "evaluation card" and gives a brief review and the outcome.



Figure 1. A view of the "Oh! So!" card game

## **3 PARTICIPANT REFLECTIONS AND FEEDBACK**

Game 1: Five participants, aged 30–50, were divided into two pairs, while the fifth was a facilitator. Game 2: The participants, all in their 50s, included one person as the moderator and two persons as the players. Feedback: One participant noted, "The scenario is interesting, and specific episodes like this that are common in everyday life really resonate with me" (40s woman/managerial position). Another participant commented, "It was good to have multiple

scenarios depicting different aspects of daily life. If the seminar only included typical scenes, it would be easy to act out these situations since we are accustomed to avoiding conflict as working adults" (50s man/consultancy).

### 4 CONSIDERATIONS AND FUTURE DIRECTIONS

After the game, one player remarked, "It is not easy to know the background of the other party in real life. However, I felt that if we could understand each other's situation, even through a game like this, the words that come out in real life would change." This observation suggests that interpersonal relationship simulation games can facilitate the acquisition of another's perspective. As a result, this game has since been commercialized under the name "Sympathize." We will continue to make revisions based on user feedback and refine the game so that players are motivated to play with more people.

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# THE DESIRABILITY OF WEARABLE DEVICES FOR ENERGETIC ELDERLY SINGLE-PERSON HOUSEHOLD MEMBERS

TOWARD THE PROMOTION OF USAGE

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## Abstract

As an offshoot of a study to promote the use of wearable devices among energetic elderly single-person household members, this study examined the desirability of wearable devices with reference to the concept of the Technology Acceptance Model. We conducted a web-based survey of energetic elderly single-person household members by creating questionnaires related to "perceived usefulness," "perceived ease of use," and "attitude toward using" of the Technology Acceptance Model and conducted multiple regression analysis on the relationship between them. The results showed that "more convenient than other convenient devices and means" in "perceived usefulness" and "easy to use with less hassle" and "wide range of use and convenience in daily life" in "perceived ease of use" positively influenced "attitude toward use" of wearable devices. The "perceived convenience" of wearable devices was positively influenced by the "attitude toward use" of wearable devices.

*Keywords:* Wearable Devices, Technology Acceptance Model, Elderly Single-person Household Members

# **1** INTRODUCTION

In Japan, the aging rate continues to rise, and is projected to increase to 31.6% in 2030 and 39.9% in 2060. In addition, the number of single-person households is increasing, and there is a possible risk of falling ill or requiring nursing care. On the other hand, the use of wearable devices for self-management of daily life has been considered, but the ownership rate of wearable devices is currently the lowest among those in their 70s. Therefore, the purpose of this study is to examine the desirability of wearable devices, referring to the concept of the

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technology acceptance model (F. D. Davis, 1989), as a beginning of research to promote the use of wearable devices targeting energetic elderly single-person households.

## 2 WEARABLE DEVICES TARGETED IN THIS STUDY

Wearable devices can be classified into six types: "wristband/wristwatch," "glasses/goggles," "ring," "neck," "headset/hat," and "others". In this study, we decided to focus on "wristband/wristwatch" wearable devices in light of the aforementioned objectives.

### **3 WEB-BASED QUESTIONNAIRE SURVEY**

### 3.1 Survey Questionnaire

The questionnaire consists of 25 items: Q1. 2 items regarding the respondents' attributes, Q2. 2 items regarding their health status, Q3. 1 item regarding their experience using wearable devices, Q4. 10 items regarding "perceived usefulness", Q5. 9 items regarding "perceived ease of use", and Q6. 1 item regarding their "attitude toward using". For Q4 and Q5, the questions were re-created to reflect the characteristics of wearable devices, while referring to the questions used in previous studies related to the technology acceptance model. Q1, Q2, and Q3 were single-response questions, while Q4, Q5, and Q6 were five-point rating scales: "Not applicable = 1, not applicable = 2, neither applicable = 3, somewhat applicable = 4, and applicable = 5.

A web-based survey was conducted from September to October 2023 targeting healthy elderly single-person household members aged 65 or older living in 12 ordinance-designated cities in Japan.

### 3.2 Survey Results

As a result of the web-based survey, responses were obtained from 917 respondents. Among these respondents, 171 were excluded from the subsequent analysis, as they were determined not to fall into the "healthy elderly" category targeted in this study, based on the results of their responses to the Q2 health status question items.

# 4 RELATIONSHIP BETWEEN PERCEIVED USEFULNESS, PERCEIVED EASE OF USE, AND ATTITUDE TOWARD USING

#### 4.1 Selection of Analysis Subjects

For the 746 respondents who were included in the analysis, Table 1 shows the results for each gender regarding their experience with Q3 Wearable devices. Among those analyzed, more than 80% of both men and women alike had "No" experience in using the device. In addition, this research is aimed at promoting the use of wearable devices in the future. Therefore, the 601 respondents (314 men and 287 women) who answered "No" to the question about their experience of using the device were selected as the subjects for the subsequent analysis.

	Yes	No	Unknown	Total
Men	54 (14%)	314 (81%)	20 (5%)	388 (100%)
Women	45 (13%)	287 (80%)	26 (7%)	358 (100%)
Total	99 (13%)	601 (81%)	46 (6%)	746 (100%)

Table 1. Details of Respondents of Experience with Wearable Devices

### 4.2 Method of Analysis

Multiple regression analysis (stepwise method) was conducted on the relationship between "perceived usefulness" and "perceived ease of use" and "attitude toward using" using Q4-1 to Q4-10 on perceived usefulness, Q5-1 to Q5-9 on perceived ease of use as explanatory variables, and Q6 on attitude toward using as an objective variable, separately for men and women using SPSS.

### 4.3 Results of the Analysis

### 4.3.1 Perceived usefulness

For men, five models were obtained. Model 5 with  $R^2 = 0.663$  and the largest explanatory ratio, was adopted here. This model is statistically significant with F (3, 310) =202.990, p<0.001. As shown in the left side of Table 2, Q4-1, Q4-7, and Q4-10 were selected as explanatory variables, while the other variables were excluded. Partial regression coefficients showed significant positive coefficients at the 0.1% level for any of them. For women, three models were obtained. Model 3 with  $R^2 = 0.581$  and the largest explanatory ratio, was adopted here. This model is statistically significant with F (3,283) =130.635, p<0.001. As shown in the right side of Table 2, Q4-2, Q4-7, and Q4-8 were selected as explanatory variables, while the other variables were excluded. Partial regression coefficients while the other variables are more convenient than alternative means," was found to influence the attitude toward using wearable devices. This suggests that when considering wearable devices being more convenient than other means.

Multiple correlation coefficient R	0.814		0.762	
Determination coefficient R2		0.663		0.581
Partial regression coefficient	(Constant)	0.184	(Constant)	0.249
	Q4-1	0.396 ***	Q4-2	0.272 ***
	Q4-7	0.245 ***	Q4-7	0.254 **
	Q4-10	0.224 ***	Q4-8	0.287 **

Table 2. Multiple regression analysis of "perceived usefulness" (left: Men right: Women)

p < 0.05 *p < 0.01 **p < 0.001

### 4.3.2 Perceived ease of use

For men, five models were obtained. Model 5, with  $R^2 = 0.508$  and the largest explanatory ratio, was adopted here. This model is statistically significant with F (5,308) =63.536, p<0.001. As shown in the left side of Table 3, Q5-1, Q5-4, Q5-5, Q5-8, and Q5-9 were selected as

explanatory variables, while other variables were excluded. Partial regression coefficients showed that Q5-4 and Q5-9 had significant positive coefficients at the 0.1% level, Q5-8 had a significant negative coefficient at the 0.1% level, and Q5-1 and Q5-5 had significant positive coefficients at the 5% level. For women, five models were obtained. Model 5, with  $R^2 = 0.519$ and the largest explanatory ratio, was adopted here. This model is statistically significant with F (5,281) =60.671, p<0.001. As shown in the right side of Table 3, Q5-1, Q5-3, Q5-4, Q5-8, and Q5-9 were selected as explanatory variables, while other variables were excluded. Partial regression coefficients showed that Q5-1 and Q5-9 had significant positive coefficients at the 0.1% level, Q5-8 had a significant negative coefficient at the 0.1% level, and Q5-3 and Q5-4 had significant positive coefficients at the 5% level. The variables common to both are Q5-1, Q5-4, Q5-8, and Q5-9, but the magnitude of the edited correlation coefficients indicate that Q5-8 "I think using wearable devices is a hassle" and Q5-9 "I think wearable devices are useful for a wide range of uses besides making calls and using the Internet. Q5-9 "I think wearable devices have a wide range of uses besides making phone calls and using the Internet, and they are convenient," influenced the attitude toward their use. This suggests that when considering wearable devices in the future, it will be important to devise ways to ensure that wearable terminals can be used easily and without hassle, and that they are evaluated as convenient with a wide range of use in daily life.

		-				
Multiple correlation coefficient R	0.713			0.721		
Determination coefficient R2	0.508			0.519		
Partial regression coefficient	(Constant)	0.376		(Constant)	0.378	
	Q5-1	0.122	*	Q5-1	0.240	***
	Q5-4	0.224	***	Q5-3	0.133	*
	Q5-5	0.147	*	Q5-4	0.155	*
	Q5-8	-0.317	***	Q5-8	-0.289	***
	Q5-9	0.556	***	Q5-9	0.520	***

Table 3. Multiple regression analysis of "perceived ease of use" (left: Men right: Women)

*p<0.05 **p<0.01 ***p<0.001

### 5 CONCLUSION

As a result, in considering wearable devices, it was considered important to devise ways to obtain evaluations that wearable devices are more convenient than other means, that wearable devices are easy to use without much effort, and that wearable devices have a wide range of uses and are convenient in their daily lives. We believe that further analysis of the complex causal relationships among the question items will help to derive clearer guidelines.

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# INNOVATIVE DESIGN FOR PRESCHOOL TEACHER'S DESK AND CHAIR

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## ABSTRACT

Modern preschool design often focuses on children's needs, neglecting the working conditions of preschool teachers. Teachers frequently squat or use child-sized furniture, leading to occupational injuries. Interviews reveal teachers have only a brief noon break and limited office space. To address these issues, our team proposes an innovative ergonomic desk and chair set. This design alleviates physical strain and doubles as a teaching aids cabinet when not in use, seamlessly integrating into the preschool environment. This solution enhances teachers' physical comfort and mental well-being, while improving the aesthetic quality of the learning space.

"*Keywords:* innovative design, preschool, occupational injury, desk and chair set

# **1** INTRODUCTION

With modern education evolving, there's increased focus on preschool design for children, often neglecting preschool teachers' challenges. This study addresses occupational health problems from prolonged squatting and using ergonomically unsuitable chairs. Bureau of Labor Insurance, Ministry of Labor 2022 reveals that improper occupational movements cause about 1,622 injuries annually (28% of total), particularly in educational settings. Preschool teachers, adjusting to children's height, frequently squat or use low chairs, leading to issues musculoskeletal disorders. These injuries impact their health and work efficiency. This study aims to investigate these issues and propose an ergonomic desk and chair set to alleviate physical burdens and improve the teaching environment.

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### 2 LITERATURE REVIEW

This section will focus on planning campus space for preschools, sources of teacher stress. Additionally, it will analyze and discuss relevant product characteristics from patent reviews.

### 2.1 Emerging Trends in Campus Environmental Planning and Teacher Work Stress

The Ministry of Education supports the "Campus Aesthetic Environment Reconstruction Project" to create visually appealing and balanced campuses. This emphasizes the importance of "environmental education" for students' attachment to the learning environment. Recent changes, like flipped classrooms, may impact teaching and learning methods (Huang, 2018). However, preschool teachers regularly face stress due to long working hours and irregular schedules, leading to both physical and mental exhaustion (Lin and Ensel, 1989). The demanding nature of constantly guiding young children deprives teachers of adequate rest time, contributing significantly to their stress levels.

### 2.2 Related Patent Research

Two related patents were found during the search. Patent M570652 (Wang, 2018) describes a mobile tea table with convenient storage. It features a rectangular main body with wheels and a handle, along with an expandable board on one side for increased space (**Figure 1**). Patent M589141 (Tang, 2019) details an improved drawer-side table car structure with support frames, assembly rods, and multiple storage layers (**Figure 2**). The transformable tables could provide inspirations for the desk design of preschool teachers.



Figure 1. M570652 Patent illustrations



## **3** RESEARCH METHODS AND PROCEDURES

The study uses interviews, empathy mapping, and competitor analysis for preliminary research. It will then apply industrial design processes to propose an ergonomic office and relaxation facility for preschool educators. This facility also transforms into a cabinet for children's teaching aids. Research steps are shown in **Figure 3**.

### 3.1 Interview Method

The interviewees included three preschool teachers from Montessori Kindergarten and Tsui Ping Kindergarten, as well as the principals of both preschools, totaling five professionals. The summarized findings from the interviews are as follows: 1. Classrooms lack ergonomic office spaces for teachers to avoid occupying learning space; 2. Adjustable desks are avoided due to the risk of injury to children; 3. Allowing kids to touch teachers' belongings maintains curiosity

but risks damage or loss; 4. Innovative facility or desks should provide office and storage space for teachers and additional functions for children when not in use.

### 3.2 Empathy Mapping

Observations and inquiries were conducted to understand preschool teachers' needs and thoughts regarding children's environments. Empathy mapping (Gibbons, 2018) was used for in-depth analysis (see **Figure 4**). This design aims to help preschool teachers reduce stress in the teaching environment while accommodating their surroundings.

Interviews revealed that existing principals prioritize children's safety and needs, neglecting furniture for teachers. Empathy mapping showed the importance of brief rest for teachers. Thus, we identified the development of multi-functional office desks and chairs as essential.

## 4 MAIN RESULTS

This stage introduces the product design and development process with develop conceptual sketches and renderings, prototyping, and design features.

### 4.1 Conceptual Sketching, Renderings, and Prototyping

20 concepts were sketched based on design briefs, using associative thinking. The focus is on ergonomic office and resting facilities for preschool teachers to meet their physical and mental needs. Following concept screening and computer-aided 3D model renderings were optimized. Relevant key dimensions were set and checked. Rough models were crafted using cardboard, cut and pasted to scale 1:1, for ergonomic testing purposes (see Figure 5).

### 4.2 Design Features and Scenarios

The desk measures 70 cm in height, 45 cm in width, and 70 cm in length. It includes compartments for storage, lifts for laptops or documents, and a frosted window for reminders (Figure 6). It can transform into a tool cabinet with perforated boards for storage when not in use. The design with wood integrates seamlessly into modern learning spaces, highlighting teaching materials and books to focus students' attention. Handles above the table allow easy movement and placement (see Figure 7). During office or resting use, preschool teachers can pull the chair backward, disengaging it from the fixed position with wheels, allowing for separate use of the seat and table (Figure 8). After use, the chair can be seamlessly integrated back into the table to serve as a teaching tool storage cabinet.

## 5 CONCLUSIONS

Modern preschool design often prioritizes children's needs over teachers', potentially impacting teaching quality. This study emphasizes the importance of considering both teacher work requirements and children's needs in environmental design. The proposed facility offers a comfortable workspace for teachers and accommodates children's tool storage, seamlessly integrating into preschool environments to enhance teaching quality and create a comfortable learning atmosphere.

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Figure 5. Renderings and rough models



Figure 7. Usage scenario illustration

Figure 6. Storage space in the desk



Figure 8. Operational testing

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# COMPARING PERCEPTIONS OF PLANT-BASED MEAT ALTERNATIVES (PBMAs) BETWEEN PBMA AND NON-PBMA EATERS USING A CO-OCCURRENCE NETWORK ON GENERATED TEXTURAL DATA

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## ABSTRACT

The global demand for meat is increasing despite limited production capacity. Therefore, meat alternatives have been being developed to meet the demand. Among them, plant-based meat alternatives (PBMAs) are widely accepted in Western countries. Conversely, such a move toward PBMAs is less common in Japan, and many consumers have never eaten them. In this study, textual data from a questionnaire designed based on the Kansei engineering method was used to explore the common and unique aspects of the perceptions of PBMAs held by consumers who have eaten them (eating group) and those who have never eaten them (non-eating group). The results showed that both groups were environment-, health- and taste-conscious. The eating group perceived PBMAs as a protein source, while the non-eating group perceived them as a product that is similar to but different from meat products. The fact that the non-eating group also had ideas about the taste of PBMAs suggests that the experience of eating PBMAs may add some value and change non-eaters' images of them as mere alternatives for meat. This may help promote the use of PBMAs in Japan.

*Keywords:* Plant-based meat alternatives, Consumer attitude, Co-occurrence network

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### **1** INTRODUCTION

The global demand for meat products is expected to rise (Ministry of Agriculture, Forestry and Fisheries, 2016). However, because livestock farming can cause environmental damage and may lead to poverty (Ministry of Agriculture, Forestry and Fisheries, n.d.), it is difficult to increase production in order to meet the demand. Therefore, meat alternatives are being developed and Plant-Based Meat Alternatives (PBMAs) are widely available on the market. PBMAs are gaining attention because they have a low environmental impact during production and they help to combat poverty thanks to their low production costs. In Europe and the U.S., the number of companies whose main business is PBMAs is increasing, and funds being invested in this industry are also growing (The Good Food Institute, n.d.). However, this is not the case in Japan, where 76.1% of the population has never eaten PBMAs, and more than half of those have no intention of eating them (Cross Marketing Inc., 2021). To help propagate meat alternatives, the present study provides a subjective evaluation of consumer perspectives of PBMAs using the Kansei engineering method. For this purpose, the common and unique aspects of the perceptions of both experienced and inexperienced eaters of PBMAs are explored.

### 2 METHODS

### 2.1 Data collection

The survey was conducted in June 2023 utilizing an online survey company (ASMARQ Co., Ltd., Tokyo. Japan). For screening purposes, the respondents were asked their gender, age, knowledge of PBMAs and experience with the consumption of PBMAs. Of the respondents who were aware of PBMAs, 200 respondents who had eaten PBMAs (eating group) and 200 respondents who had never eaten PBMAs (non-eating group) were asked to describe their perceptions of PBMAs through the online survey as in Taki et al (2023). Respondents were equally allocated by gender (male and female) and age (20s-60s). To ensure that the understanding of the definition of PBMAs was consistent across respondents, it was clearly indicated at the beginning of the survey.

### 2.2 Analysis

During the pre-processing of the survey responses, obvious typing errors were corrected. Two words that were extracted as multiple words but meant to be a single word were forcibly extracted as a single word. A co-occurrence network was then created with the experience of eating PBMAs as an external variable. The minimum number of occurrences of a word was set to 6. These parameters provided the top 50 occurrences of the extracted words. Reproducibility was ensured because the co-occurrence networks that could be created with a minimum frequency of 3-5 were the same. KH Coder was used for these (Higuchi, 2016).

### 3 RESULTS

It was found that both groups shared perceptions related to the environment and health, and that they focused on taste and texture (Figure. 1). In addition, the eating group expressed

perceptions of nutrition and protein source in responses specific to them. In contrast, the non-eating group expressed perceptions of veganism and real meat comparison.



Figure 1. Co-occurrence network diagram. The two central squares represent external variables. Common and unique items are separated by color.

### 4 DISCUSSION

The fact that those who have never eaten PBMAs have the same perceptions related to the environment and health as those who have eaten them may be attributed to the focus on sustainability that has been increasing in recent years. In previous findings, young people were more willing to buy meat products with a lower environmental impact (Boston Consulting Group, 2024), suggesting the possibility of age-related differences. It has also been shown in previous studies that consumers tend to prefer products with a good taste and texture (Taki et al., 2023). While it has been assumed that many people feel distrust or dislike towards the novelty of meat alternatives (Faccio et al., 2019), neither group in this study expressed such feelings, possibly because Japanese culture had long used soy products as protein alternatives.

The protein-based, nutritious perception, which only the eating group expressed, was considered to be derived from taste. As most PBMAs have less fat and more protein than meat (Food Composition Database, n.d.), their flavor may have contributed to the perception. In contrast, the non-eating group was aware of the difference between real meat and PBMAs. They seemed to consider PBMAs to be food for people with motivations such as veganism, as the non-eating group expressed the perception that PBMAs taste is inferior to that of meat. It can be inferred that this perception is a factor that prevents people from trying PBMAs. The eating group did not have a negative image of taste; therefore, once people who have never eaten PBMAs eat them, their perceptions may change dramatically.

## 5 CONCLUSION

In this study, the common and the unique aspects of the perceptions of PBMAs held by those who have and those who have not eaten PBMAs were explored using the Kansei engineering method. Changing the negative perceptions of PBMAs held by those who have never eaten them is the first step in increasing the popularity of meat alternatives.

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# EXPLORING SUSTAINABLE URBAN-NATURE CONNECTIONS THROUGH CITIZEN-PARTICIPATORY DESIGN WORKSHOPS: A STUDY ON GLOBAL GOALS JAM IN KYOTO/KEIHOKU

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## ABSTRACT

This study explores the potential of citizen-participatory workshops in promoting sustainable craftsmanship practices in Satoyama landscapes. The Global Goals Jam Kyoto/Keihoku 2023 workshop, held in the Keihoku area of Kyoto, Japan, demonstrated the effectiveness of such workshops in fostering creativity, environmental awareness, and a deeper understanding of Satoyama's values. The workshop, following a design sprint format, engaged participants from diverse backgrounds in collaborative efforts to address themes like urban-forest connections, biodiversity, and community engagement. Seven innovative proposals emerged, including a VR bridge connecting people to forests, a community woodworking space, and a cyclical Christmas tree program. This study highlights the potential of citizen-participatory workshops for advancing sustainable craftsmanship and fostering a deeper appreciation for Satoyama's values. Future research should focus on prioritizing participant autonomy and deep learning, while establishing mechanisms to translate creative ideas into tangible actions for a more sustainable future.

*Keywords:* citizen-participatory workshop, sustainable development goals, design sprint, global goals jam

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### **1** INTRODUCTION

This study documents and analyzes the process and outcomes of the Global Goals Jam Kyoto/Keihoku 2023, a citizen-participatory workshop aimed at exploring sustainable approaches to craftsmanship that align with the natural environment of forests and Satoyama (traditional rural landscapes in Japan, integrating forests, farmlands, and human settlements). Held in Keihoku, an area historically significant for supporting Kyoto's urban culture, the workshop emphasized understanding the historical flow of materials and craftsmanship. Participants engaged in fieldwork to enhance their sensory awareness of biodiversity and conceptualize urban-forest relationships. The goal was to prototype future actions and present these globally, contributing to the Sustainable Development Goals (SDGs).

### 2 WORKSHOP DESIGN

The workshop followed the Global Goals Jam's design sprint format, a two-day citizen-participatory workshop designed to generate local solutions for global sustainability challenges. The workshop was organized by Perspective Inc., FabCafe Kyoto, and Kyoto Sangyo University's Faculty of Information Science and Engineering. The primary goal was to explore sustainable approaches to craftsmanship that coexist harmoniously with forests and Satoyama.

### **3 ORGANIZERS AND PARTICIPANTS**

The workshop was a collaborative effort between Perspective Inc., which promotes healthy human-nature relationships through cyclical actions of making, FabCafe Kyoto, a café equipped with digital fabrication tools, and Kyoto Sangyo University, which provided academic support. Participants included four professionals from various industries, eighteen university students majoring in design, sustainability, and information science, and one university faculty member specializing in entrepreneurship. Project partners included hosts and children from a free school and various universities.

### 4 WORKSHOP PROGRAM

The workshop was structured into four design sprints: (1) Explore it, (2) Respond to it, (3) Make it, and (4) Share it. During the first sprint, participants engaged in field research along Nishitakase River in Kyoto and Kamigamo River in Keihoku area. The aim was to understand the historical connections and enhance sensory awareness of the environment. Participants were divided into groups to focus on three thematic design questions: urban-forest relationships, biodiversity, and engagement with Keihoku area.

The second sprint involved participants responding to the identified challenges by generating ideas and sharing their insights. Groups were formed based on three design questions: considering the relationship between urban and forest environments, coexisting with biodiversity, and engaging with the open fabrication facility, Fab Village Keihoku (FVK).

In the third sprint, participants created prototypes to communicate the challenges and insights they had discovered. Finally, in the fourth sprint, participants shared their prototypes and ideas through presentations, allowing for a broader dissemination of their work.

# 5 RESULTS

Table 1 below lists the outcomes of the desired scenarios proposed during the workshop.

Group	Title	Description			
Forest-A	Jikkan (Realization)	We propose a bridge that brings awareness to trees and forests that are close to us and provides a sense of connection through VR technology. Walking along the bridge, the view changes from urban area to forest, making participants feel that we are not disconnected, but connected. By sending photos of the forest taken to the bridge, participants can create new connections.			
Forest-B	Oh! Bento OBENTO as Media	Focusing on the connection between our daily lives and nature, and particularly on "food," this approach aims to reaffirm the relationship between people and nature by understanding the background of the ingredients and viewing the bento (lunch box), a collection of various ingredients, as a medium.			
Forest-C	Neighborhood Workshop URUSU	The "URUSU" is located in the city and functions as a woodworking room where Japanese Urushi lacquer can be handled easily. It also works as an entrance to the "FVK" in Keihoku, and proposes a way to connect the "forest" and the "city". Through the use of the workshop and the act of making in the workshop, the dichotomy between "forest" and "city" will be relaxed.			
River-A	Christmas Trees for Circulation of Trees	We propose a cycle in which local residents select trees in the forest during the Christmas period, use them as Christmas trees, and then recycle them as wood for reuse in furniture, tableware, and other products. This will create a consistent attachment and cycle, and will aim to create a rich forest where a variety of trees can grow. As this cycle continues for 10 or 100 years, it will lead to a livable future for us all.			
River-B-1	Wildlife Supermarket	The "Wildlife Supermarket" is a proposal for rediscovering our connection to nature in our urban lives, which are so fragmented from the natural environment. The supermarket is designed to help visitors better understand their relationship with nature through the purchase experience by recreating on the sales floor the natural form and environment from which processed products are made.			
River-B-2	New Keihoku Old Tales	"New Keihoku Old Tales" is a proposal for children to deepen their relationship with rivers, using the folklore of Keihoku as inspiration. The story focuses on fostering a relationship with the river through conservation efforts so that people will eventually find a personality in the river and treat it as a familiar friend. It also aims to build a culture of feeling connected to the river by creating a new play culture			

## Table 1. Outcomes of the workshop

		for the river.
River-C	Craftsmanship Nurtured by Water and Land - Resonance between Craftsmen and Nature in Keihoku	Craftsmen in Keihoku have a deep connection with the local community and nature through their crafts, which are rooted in daily life. We learned about the rich ecosystem behind the crafts and its circle from the scene of craftsmen, who are the makers of the crafts, playing in the river with children and interacting with local residents, and found a future where the circulation of forests and crafts will be connected to the next generation.

This study explored the potential of citizen-participatory workshops in shaping a sustainable future for Satoyama and its inhabitants. The Global Goals Jam Kyoto/Keihoku 2023 workshop served as a testament to the effectiveness of such workshops in cultivating creativity, environmental consciousness, and a profound appreciation for Satoyama's diverse values. Moving forward, we emphasize the significance of prioritizing participant autonomy and deep learning over mere workshop expansion. Additionally, mechanisms are crucial to translate workshop proposals into concrete actions. Citizen-participatory workshops hold immense promise as a tool for collective contemplation and action towards a brighter future for Satoyama and its people.

#### **ACKNOWLEDGMENTS**

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# THE STUDY OF EMOTIONAL RESPONSES AND BRAINWAVE CHANGES INDUCED BY DIFFERENT ESSENTIAL OILS FOR IMPROVING THE READING QUALITY OF THE INDOOR ENVIRONMENT: QUALITY OF LIFE

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# ABSTRACT

This study investigates the physiological and psychological effects on users while reading in four environments (with different essential oils: lavender, jasmine, Roman chamomile, agarwood), and analyzes the correlation between users' emotional and brainwave responses.

*Keywords:* essential oils, brainwave responses, emotional responses, correlation, reading quality

# 1 INTRODUCTION

Residents in urban areas are easily subjected to significant stress. Excessive work pressure often keeps individuals in a state of tension, irritability, fatigue, and a lack of sense of achievement, potentially leading to emotional exhaustion and various psychological and physiological discomforts. On the other hand, aromas can have a positive impact on people's moods, relieve stress, improve sleep quality, boost confidence, and enhance physical and cognitive performance (Cheng, Y., 2000).

Based on the above reasons, this study designs a reading environment that provides four different essential oil. It explores the physiological and psychological effects of these environment with different essential oil on users during reading and analyzes the correlation

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between users' emotional and brainwave responses. The future aim of this study is to establish a brainwave recognition model influenced by olfactory stimulation for future applications.

## 2 METHODS AND MATERIALS

### 2.1 The design of the experiment

In this study, a total of five reading environment groups were designed: a control group (without any essential oil), lavender group, jasmine group, Roman chamomile group, and agarwood group. Each participant could only finish one group experiment per day, with the sequence of experimental groups being randomized. All experiments were conducted between 9:00 AM and 12:00 PM. Participants were instructed to abstain from consuming foods or beverages containing alcohol or caffeine, which could affect heart rate, for three hours before the experiment. The experimenter explained all procedures to the participants before the experiment commenced.

As shown in Figure 1, each experimental time is 30 minutes, including a 10-minute rest period and 20 minutes of reading. During the entire process, the essential oil environment was maintained, and participants' brainwave signals were measured. After the experiment, participants filled out questionnaires. The experimental environment is shown as Figure 2.



Figure 1. The experimental procedure



Figure 2. The experimental environment

### 2.2 Measurements

Both objective and subjective evaluation are used to monitor the extent to which different essential oil influence participants' emotional response in this study. The brainwave analysis is the subjective evaluation during the experiment. The brainwave signals are detected from 6 points.  $F_3$  and  $F_4$  are located in the frontal lobe, which is responsible for thinking and decision-making in the brain.  $AF_3$  and  $AF_4$  are in the prefrontal lobe, which is the area of the brain involved in emotion processing.  $T_7$  and  $T_8$  are located in the temporal lobe, which is responsible for memory. The objective evaluation indicators include the SAM (Self-Assessment Manikin) emotion scale (Lang, P. J., 2008) and a self-report questionnaire.

### **3 RESULTS**

There are 4 subjects who participated in this study. The brainwave signals during the second reading period were captured to do frequency domain analysis. The results of this analysis are shown in Figure 3. In addition, the results of the questionnaires filled out by the participants are shown in Figure 4 and Figure 5.



Figure 3. The results of the brainwave analysis



Figure 4. The results of the SAM questionnaire



Figure 5. The results of the self-report questionnaire

This study simultaneously examines the psychological and physiological responses of participants while reading in different essential oil environments. The correlation analysis of the corresponding physiological and psychological parameters is shown in Figure 6.



Figure 6. The results of the correlation analysis

## 4 CONCLUSIONS

This study investigates the physiological and psychological effects of different essential oil environments on users while reading, and analyzes the correlation between users' emotional and brainwave responses. In the future, the number of participants will continue to be accumulated to facilitate big data analysis and the development of a brainwave recognition model for emotional influence.

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# THE APPLICATION OF TWO-TIER TESTING AND WSQ INSTRUCTIONAL STRATEGY IN VISUAL COMMUNICATION DESIGN WITH THE ASSISTANCE OF EDUCATIONAL ROBOTS

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## ABSTRACT

This study explores how digital learning, combined with two-tier testing and the WSQ (Watch-Summary-Question) instructional design, enhances students' outcomes in the visual communication design certification exam. Traditional teaching methods often lack personalization and interactivity, leading to low motivation. Robot-assisted teaching increases engagement and provides personalized feedback. Two-tier testing assesses analytical and problem-solving abilities, while WSQ promotes active learning and critical thinking. By integrating educational robots, this study aims to improve exam preparation efficiency and performance through simulated exams and real-time feedback.

Keywords: two-tier test, WSQ, educational robots

## **1 RESEARCH MOTIVATION**

With technological advancements and evolving educational concepts, traditional teaching models face challenges such as failing to meet personalized learning needs and lacking interaction and practical opportunities. Students often show low motivation and shallow understanding. To address these issues, robots have been introduced into teaching to boost students' interest and efficiency through interactivity and novelty (Atman et al., 2023). Research shows that robots can enrich content, enhance interactivity, provide personalized experiences,

and improve learning efficiency and motivation (Belpaeme et al., 2018).Traditional testing methods focus on memory rather than deep understanding and application skills, lacking immediate feedback and comprehensive assessment. The two-tier test emphasizes thinking and application skills, providing personalized feedback and improving teaching effectiveness (Adodo, 2013; Chu & Chang, 2014). Digital learning, with high flexibility and interactivity, can be tailored to students' needs for a personalized experience.In traditional design courses, teachers provide one-to-many tutoring, teaching design theories and practical skills, and guiding students for visual communication design certification. This study uses the WSQ (Watch-Summary-Question) instructional design to stimulate active learning and critical thinking, cultivating analytical and problem-solving abilities (Chang et al., 2022). By combining digital learning and WSQ, educational robots are used to conduct simulated exams and provide real-time feedback on visual communication design certification topics, helping students effectively prepare for the exam.

### 2 LITERATURE REVIEW

### 2.1 Educational Robots

Educational robots are designed to enhance learning through interaction, simulation, and practice in educational settings. Integrating various sensors and AI algorithms, these robots provide personalized learning experiences and are commonly used in STEM education across all educational levels. According to Mubin et al. (2013), educational robots can boost student motivation, engagement, and learning outcomes by offering interactive and immediate feedback. They assist teachers by handling repetitive tasks, allowing more focus on individual student needs, and make learning more enjoyable through gamification and personalization. Effective human-robot interaction is crucial, with successful robots needing natural interaction capabilities and adaptability to various teaching scenarios and student needs (Woo et al., 2021). Despite their benefits, challenges include high costs and the need for educators to continually update their skills due to rapid technological advancements. Future research should aim to reduce costs, improve usability, and better integrate educational robots into existing educational systems and methods (Belpaeme et al., 2018). This study uses the Kebbi Air S, produced by NUWA ROBOTICS, as the research tool.Moreover:

### 2.2 WSQ (Watch-Summary-Question) Instructional Strategy

The WSQ (Watch-Summary-Question) instructional strategy enhances students' self-directed learning and understanding. This method divides learning into three stages: Watch, Summary, and Question. In the Watch stage, students view videos related to the learning content, which may include pre-recorded lectures or instructional videos. This stage aims to facilitate autonomous knowledge acquisition and improve comprehension and memory through visual and auditory input (Chang et al., 2022; Hsia et al., 2022). In the Summary stage, students summarize the content they watched, helping them organize, consolidate, and internalize knowledge. This process also enhances their writing and thinking skills. In the final stage, Question, students pose questions based on the learned content. This encourages active

thinking, deeper understanding, and identification of learning gaps. Questioning also fosters student interaction, discussion, and motivation.

### 2.3 Two-Tier Test

The two-tier test consists of two parts: the first tier assesses students' basic knowledge, while the second tier requires students to explain the reasons for their chosen answers. This approach not only tests students' knowledge acquisition but also evaluates their reasoning and understanding abilities (Adodo, 2013). Research indicates that this testing method can more accurately reveal students' conceptual understanding and misconceptions, helping teachers to make targeted instructional improvements and thereby enhancing students' learning outcomes. Additionally, two-tier testing has been proven effective in digital gamified learning environments (Wang et al., 2023). In a study on environmental education, the use of two-tier tests combined with digital game-based teaching methods significantly improved students' academic performance and learning motivation, with particularly notable benefits for low-achieving students (Wang et al., 2023). This approach not only reduces students' cognitive load but also enhances their learning experience, further confirming the value of two-tier testing in modern education.

### **3 EXPECTED OUTCOMES**

This study aims to enhance students' learning outcomes and motivation by integrating the Kebbi Air S educational robot with two-tier testing and the WSQ instructional strategy. The goal is to shift from memorization to deep understanding and application, particularly in the visual communication design certification exam. By introducing two-tier testing, the study seeks to better assess and enhance students' analytical and problem-solving skills, accurately revealing their conceptual understanding and misconceptions, thus enabling targeted instructional improvements. Additionally, the study anticipates a significant increase in students' interest and motivation by addressing the low engagement often associated with traditional teaching models that lack interaction and practical opportunities. The WSQ instructional strategy, which involves watching instructional videos, summarizing content, and posing questions, stimulates active learning, critical thinking, and promotes student interaction and discussion, thereby boosting motivation. The study also aims to provide a more flexible and personalized learning experience through the Kebbi Air S educational robot, enabling dynamic interaction and personalized feedback. This enriches teaching content and allows for instructional adjustments based on individual student needs, making the learning process more enjoyable and efficient. Lastly, the study seeks to innovate teaching methods in visual communication design by combining digital learning, two-tier testing, and the WSQ instructional strategy. This approach aims to improve learning outcomes and motivation while offering a model for broader educational innovation, providing new ideas and directions for the future development of education, positively impacting education quality and student learning effectiveness. Integrating these strategies, the study aspires to significantly enhance learning outcomes and motivation, offer a personalized learning experience, and foster innovative development in visual communication design education.

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# NEW INTERACTIVE EVOLUTIONARY ALGORITHM

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### ABSTRACT

We apply the YUKI algorithm as a new approach in interactive evolutionary computation. The YUKI algorithm searches for the optimal solution by balancing convergence and divergence of the current optimal solution candidates. We investigate the performance evaluation of the proposed algorithm through numerical simulations using a pseudo-user model which evaluates the candidate solution instead of real users. The simulation results indicate that, compared to traditional interactive genetic algorithm and interactive tabu search algorithm, the proposed algorithm can effectively balance convergence and diffusion in the search for candidate solutions, resulting in a tendency for higher evolutionary performance.

Keywords: Interactive evolutionary computation, YUKI algorithm, Pseudo user model

### **1** INTRODUCTION

Interactive evolutionary computation (IEC) system is useful for generating user preferred object with user *Kansei* information (Takagi, 2001). The IEC system dynamically generates objects that user preferred like clothes designs as candidate solutions of EC method. Especially, the IEC uses user preference information (likes or dislikes). Previous studies in IEC method aimed to reduce user evaluation loads and proposed various improvements including EC algorithms that are efficiency of candidate solutions retrieval and retrieval multimodal candidate solutions (Takenouchi, 2023).

In this study, we propose a new IEC algorithm with YUKI algorithm (YA) to demonstrate more efficient candidate solutions retrieval. The YA method retrieves optimal solutions based on the current optimal solution balancing both convergence and diffusion of candidate solutions

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(Benaissa, 2021). The YA method also applies to elastostatic and dynamic crack identification (Benaissa, 2021) and *Kansei* data analysis(Benaissa, 2023) and shows higher performance from the viewpoint of EC algorithm compared with a genetic algorithm (GA), a typical EC method. When the IEC system employes YA method, we investigate evolutionary performances and candidate solutions retrieval behavior and studies possibility of application in IEC. The YA method retrieves the optimal solution balancing both convergence and diffusion regularly. This is useful for retrieval object that matches user preferred in the IEC.

We perform the numerical simulations to evaluate evolutionary performance of interactive YA (IYA) method. The simulations employ a pseudo user who consists of mathematical model and evaluate candidate solutions instead of real users. The IEC has a constraint of very small generations and candidate solutions considering user evaluation loads compared with the normal EC method that evaluates candidate solutions with evaluation function. This study investigates the IYA performance compared with other IEC algorithms under this constraint.

#### 2 PROPOSED SYSTEM

Figure 1 shows the schematic of the IYA method. First, the proposed method generates the initial candidate solutions at random. The gene rows of the proposed method consist by a bit string. Then, a user evaluates the candidate solutions by his/her *Kansei* and chooses the most favorite candidate ( $X_{best}$  of the current generation) from the presented candidate solutions. The  $X_{best}$  is saved in the elite list. After that, the proposed method calculates the local retrieval area,  $d_{local}$ , the average Hamming distance between the  $X_{best}$  and other candidates. In step 4, the proposed method generates the neighboring candidates,  $X_{loci}$ , within  $d_{local}$  from the  $X_{best}$ . In the last step, the proposed method determines whether inside or outside retrieval for each neighboring candidate probabilistically. The inside retrieval indicates to retrieve closing to  $X_{best}$ , and the outside retrieval means to retrieve away from  $X_{best}$ . Finally, candidates that retrieves inside or outside are presented to the user again. These operations are repeated several times and generates user favorite object.



Figure 1. Schematic of the proposed algorithm

#### **3 NUMERICAL SIMULATION**

#### 3.1 Outline

The simulations employ the IYA as the proposed method, the IGA and interactive tabu search (ITS) (Takenouchi, 2013) that is a local search method as compared methods and evaluate evolutionary performances of these three methods. Table 1 shows the simulation parameters. We simulated 100 times for each method and resulted the average values of each measurement.

	IYA	IGA	ITS
Candidate evaluation	Winner-based paired comparison	10-stage evaluation	Choice favorite one
Candidates	10		
Gene length	20, 30, 40 bits		
Range of neighboring candidates	_	_	1 bit
Inside/outside retrieval rate	50%	-	_
Selection	-	Roulette + Elite preservation	-
Crossover	_	Uniform crossover	-
Mutation rate	-	5%	-
Elite (Tabu) list size	8	_	8

#### 3.2 Pseudo User Model

We used a multimodal *Kansei* space model expressing the pseudo user *Kansei* model (Takenouchi, 2023). This model assigns several weight values (0.0 - 1.0), evaluation value of the pseudo user) to several bit patterns in the solution space and assigns evaluation values to other bit patterns (no assigned weights) for calculating weighted average values using the Hamming distances between each weighted bit pattern and each bit pattern. The simulation sets the number of weights to 10 (1.0 X 1, 0.8 X 1, 0.7 X 3, and 0.1 X 5). This model imitates user *Kansei* evaluation that has a single favorite object and some objects he/she likes a lot.

#### 4 RESULTS

Figure 2 shows the results of simulations. In Figure 2(a), the IYA and ITS methods had higher evolutionary performances than the IGA method in each gene length. When the gene length was 20 bits, the performances of the IYA and ITS were almost equal, however, when the gene lengths were 30 and 40 bits, the ITS had a slightly higher performance than the IYA.

However, in Figure 2(b), the average Hamming distance rates (rate to each gene length) of each candidate of the IYA was longer than that of the ITS. This was caused that the ITS retrieves only local area around the current best candidate and the IYA can retrieve both candidates locally and globally. The IYA method can evolve candidate solutions while maintaining some diffusions. From the results, the simulation results showed a possibility of using the YA method as a new algorithm in IEC.



(a). Evaluation values

(b). Rates of Hamming distances

Figure 2. Results of the simulations

#### 5 CONCLUSIONS

We proposed the IYA method as a new IEC algorithm that retrieves candidates with both convergence and diffusion simultaneously. The simulation results showed the effectiveness of the IYA method from the viewpoint of retrieval various candidates. In future works, we will investigate the effectiveness more clearly and tunes each parameter and the algorithm.

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## CO-CREATE WITH AI: EXPLORING THE IMPACT OF GENERATIVE AI IN INDUSTRIAL DESIGN IDEATION PROCESS

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#### ABSTRACT

Generative AI (GAI) systems are increasingly recognized for their potential to enhance creativity in design. This study examines the impact of GAI on the design ideation process within industrial design, employing behavioral research methods and qualitative analysis methods. The results show GAI enhance design ideation by stimulating creativity and providing diverse inspirations. It assists designers in spark inspiration and discover possibilities, refining and iterating design concepts, and visualizing detailed ideas.

Keywords: Generative artificial intelligence, Industrial Design, Ideation, Inspiration, Creativity

#### **1** INTRODUCTION

In recent years, generative AI has been widely discussed and applied across various fields. Generative AI allows users to quickly generate high-fidelity images using natural language, and it has been proven to serve as a design tool with the potential to stimulate designers' creativity (Cai et al., 2023; Chiou et al., 2023). However, in the field of industrial design, there are several challenges associated with using image-generating AI that need to be addressed. Brisco et al. (2023) point out that the generated images often fail to consider the practical structural feasibility, and the process of developing concepts relies heavily on the designer's evaluative and decision-making abilities. Additionally, some literature suggests that high-fidelity generated images can have adverse effects, leading to design fixation (Matthew et al., 2023; Velloso, 2024). Understanding how designers collaborate with AI and the types of creative inspiration that emerge from this interaction requires more empirical studies.

#### 2 LITERATURE REVIEW

#### 2.1 GAI as a Source of Inspiration

Recent literature highlights generative AI's (GAI) role in the design process as a significant source of inspiration. GAI promotes unexpected inspirations, aids in creative thinking, and assists in early-stage "thumb sketches" (Lai et al., 2023). Cai et al. (2023) found AI-generated images to be more inspirational, enjoyable, and useful than traditional image searches. Matthew K. et al. (2023) also emphasize GAI's value in offering fresh and innovative ideas, making it a valuable tool for designers.

#### 2.2 High-Fidelity Images and Design Fixation

However, high-fidelity AI-generated images can cause design fixation, limiting creative exploration and making designers overly reliant on initial concepts (Matthew K. et al., 2023). Additionally, the automatic generation of diverse ideas may be less valuable as designers spend more time converging their thoughts (Cai et al., 2023)

#### 3 METHODOLOGY

#### 3.1 Experimental Process Using Behavior Research Methods

The experimental process began with a brief interview about participants' past experiences, followed by AI software introduction and AI co-creation design process. The image generated AI software used in this experiment is Midjourney. The process concluded with a post-design interview focused on the participants' behavior collaborating with AI. The entire process lasted approximately 120 minutes.

#### 3.2 Sampling Structure

Given the emerging nature of AI in design and its recent application in assisting design, finding experienced participants is challenging. The inclusion criteria were industrial designers with over one years of experience, familiarity with image-generating AI, and experience in mass production product design. According to the sampling criteria, three designers were selected for interviewees in this study.

#### 3.3 Data Analysis

This study employed a qualitative coding analysis method based on grounded theory to thoroughly explore and understand the interaction between participants and AI tools.



Figure 1. Types of collected data

#### 4 RESULTS

GAI tools are utilized differently across various stages of the design ideation process, reflecting the goals and needs of designers. The findings indicate that there are three types of designers (A, B, and C), each with different objectives and varying degrees of creative stimulation achieved.

#### 4.1 A Type Designers: Discover Stage

Designers classified as A Type lack an initial design concept and use GAI to spark inspiration and explore new possibilities. AI generates visual images from text descriptions, aiding in the broad exploration of several ideas and providing unexpected inspiration.

Al can stimulate designers' deep reflection and broaden their thoughts. For example, a transparent helmet covering the face reminded a participant of a theory emphasizing the importance for the elderly to see others' facial expressions while communicating. The generated image assist designers recall relevant memories and gain inspiration.

By utilizing AI in the discovery stage, A Type designers can explore a wide range of ideas and perspectives, ultimately leading to more innovative and thoughtful design concepts.



Figure 2. Al-Generated Helmet Designs for the Elderly Showcasing Various Concepts

#### 4.2 B Type Designers: Ideation Stage

B Type designers have a rough design direction and utilize GAI to clarify and iterate on their design concepts. GAI aids in expanding ideas and exploring various options, which is crucial for refining and enhancing details throughout the design process. Al-generated images prompt designers to consider the meanings of specific forms and their functions. For instance, a participant perceived the shape covering the ear in one of the Al-generated designs as a headphone that could be used as a hearing aid for the elderly.

Through such targeted stimuli, designers can gradually piece together a complete and cohesive concept.



Figure 3. Al-Generated Concepts Showcasing Diverse Features and Functionalities

#### 4.3 C Type Designers: Ideation & Deliver Stage

C Type designers have a clear design concept and use GAI primarily to visualize and refine these concepts. AI generates high-quality images that present complete and detailed design ideas, assisting in clear expression and effective presentations to collaborators and stakeholders.

GAI can be use as form, material, and color references, helping designers explore various detailed possibilities quickly



Figure 3. Al-Generated Concepts serves as form, material and color reference

#### 5 CONCLUSION

The experiment demonstrated that generative AI enhances design ideation by stimulating creativity and providing diverse inspirations. However, challenges such as imprecise text-to-image interpretation need to be addressed. Future research should focus on real case studies to explore diverse AI applications in design and strategies to integrate AI tools more effectively with human creativity.

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