Effects of Video Games on Dynamics of Visual Attention

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Abstract: Playing a video game is attentionally demanding, so that the visual system acquires information by frequently shifting its gaze. Although a few researchers attempted to characterize dynamics of visual attention involved in video game playing, it still remains largely unknown due to the methodological limitations. In this study, we developed a novel experimental system that enabled gaze-contingent window masking on dynamic game screen, so that the dynamic distribution of visual attention while playing a video game was measured.

Eye movements were recorded while a player performing one of three types of commercially available video game. The visual field was restricted to an area around the gaze by circular masks with various spatial extents (10 ~ 40 degrees in diameter). On-line gaze position data was fed into a computer that combined the video game screen and the window by a chromakey video mixer. The basic idea was to estimate the effective visual field, the size of window with which a person was able to play a video game without loss of performance.

Our results showed that the scores tended to rise with the window size. However, the effect of window size was different between the played games. These results demonstrate that attentional distribution differs significantly between different video games. Furthermore, analyses on eye-movement data indicated qualitative differences of attentional allocation among types of video game. Thus, this study indicates the applicability of the gaze-contingent window method for the online evaluations of performance and dynamic allocation of attention in playing video game.

Key words*: *Visual Attention, Video Game, Eye Movement, Gaze-contingent Window

1. Introduction

Video games are one of the most popular amusement activities in modern life. In recent times, it has had a great impact not only on entertainment but also on other factors such as training, education, and health. While there are growing concerns with regard to the possible negative effects resulting from abusive use of video games [1-3], some researchers suggest that playing video games could also have a positive influence on cognitive processes [4-6]. For example, Green and Bavelier (2003) suggested that video-game players possessed a higher capability in visual-attention tasks. In their experiment, the spatial distribution and the capacity of visual attention were measured by the "useful field of view" task [7]. This task evaluates the range of a visual field where a subject can detect an eccentric target among various distractions. This task has been generally adopted to evaluate the spatial properties of visual attention in natural environments, in particular, situations involving driving a car [7-9]. However, for this task, the subjects need to perform two tasks simultaneously: a central task to simulate the supposed task load (e.g. driving a car in a traffic jam) and a peripheral task to evaluate the useful field of view.

The measurement of the useful visual field by the dual-task paradigm has methodological limitations. The size of the useful visual field of view is derived from a simplified detection task (e.g. detection of a small visual flash in the peripheral visual field) that is considered to be irrelevant to the central task. However, there is highly likely that the peripheral task unexpectedly influences the central task. It is then impossible to simulate the performance of the central task in an actual situation since the eye movements are restricted. In addition, the size of the useful field of view depends on the flash properties, such as duration, luminance, and size [7-9]. Therefore, it is uncertain whether the derived useful field of view reflects the properties that support actual performance (e.g. driving a car or playing a video game).

In order to overcome these difficulties, we adopted a gaze-contingent window method. In this study, the peripheral visual field was masked, so that only the central region around fixation was visible through the window [10,11]. By shifting the window synchronously with eye movement, subjects could explore the stimulus freely. Here, we define an “effective visual field” as the spatial extension around the central visual field from which visual information is extracted to perform a cognitive task (to distinguish from the previously used “the useful field of view”). The size of the effective visual field can then be directly evaluated without an irrelevant dual-task nor restriction of eye movements during the cognitive task. By changing the size of the window, this method enables us to clarify the size of the effective visual field.

The purpose of this study is to investigate the effective visual field during video game playing and to clarify the relation between video games and the spatial distribution of visual attention. The characteristics of eye movements while playing a video game are also discussed.

2. Method

2.1 Experimental Design

Figure 1 shows the basic idea of estimating the size of an effective visual field. The horizontal axis represents the size of the gaze-contingent window and the vertical axis represents the game performance (e.g., game score or race time). When the window size is smaller than the effective visual field (left panel), the performance is expected to decrease because the acquired visual information is limited. As the window size approaches the supposed size of the effective visual field, the performance should increase (center panel). However, it is assumed that there is a point where the performance reaches a plateau because, by definition, the visual information outside the effective visual field is not processed (right panel). Thus, the size of an effective visual field can be estimated as the window size where the performance is saturated.

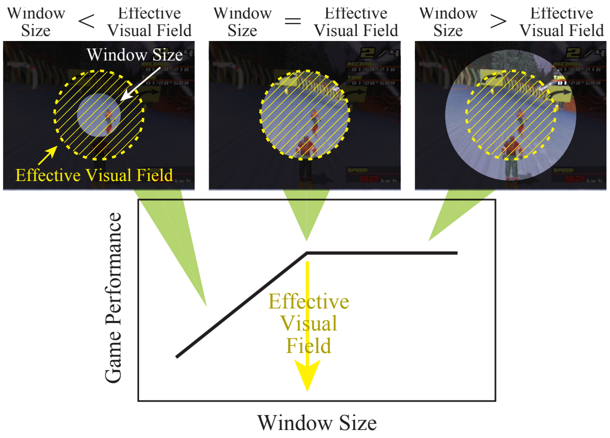

Fig.1 Estimation of Effective Visual Field.

2.2 Apparatus

A schematic view of the experimental setup is shown in Figure 2. The windowed game screen was displayed on a 21-inch CRT at a viewing distance of 57cm. Eye movements were recorded at a sampling rate of 250 Hz by using a gaze tracking system EyeLink II (SR Research Inc., Canada). On-line gaze position data was available within 6-ms delay. The movement of the head was not restricted. Video games were operated by Playstation2 (Sony Computer Entertainment Inc., Japan) and the subject used the game pad. The game sound was provided by a pair of headphones.

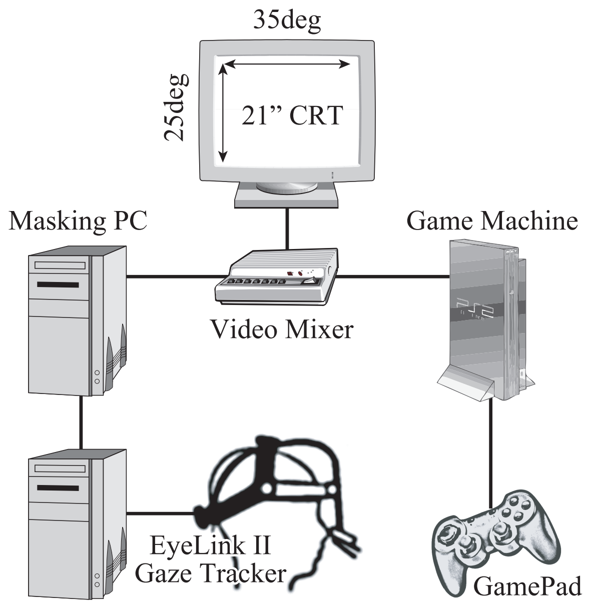

Fig.2 Schematic View of Experimental Apparatus.

2.3 Stimulus

We selected three types of commercially available video game: ski racing game “Alpine Racer 3”, rhythm action game “Taiko no Tatsujin: Atsumare! Matsuri da!! Yondaime”, and word puzzle game “Mojipittan” by NAMCO BANDAI Games Inc., Japan). Alpine Racer 3 features downhill races with the 3D rendered first-person view. The player controls the direction of a character to avoid obstacles. The race time represents the skill of the player. In the rhythm action game - Taiko no Tatsujin, icons are moved horizontally along a timeline of a music. The player needs to push the appropriate button at the precise timing as indicated by the icons. Successful play raises the score. Mojipittan is a kind of crossword puzzle. The player selects one of the Japanese characters and puts it on a pattern of cells to build words. Longer words get higher points.

The entire video game screen subtended 25 (H) x 35 (W) degrees. The shape of the window was circular. Five window sizes were employed: 10, 20, 30, 40 (degrees in diameter), and full-view condition as control in which the whole screen was visible. The external area of the window was covered by an opaque black mask. Four different stages were played in each game.

2.4 Procedure

Prior to the experiment, the gaze tracker was carefully adjusted. The calibration error was less than 1 degree. The subject fixated the centre of the screen and pushed a button to start a trial. The game score or the race time was registered as a performance index. The eye movements were recorded continuously throughout the trial.

The type of video game was fixed in a session. The five window conditions and the four stages were randomly interleaved. A total of 20 trials were performed for each type of video game. Six subjects (five males and one female, whose ages ranged between 24 and 34 years) participated in the experiment. All the subjects had a normal or corrected visual acuity and had never played the selected video games before the experiment. They were given sufficient practice trials before collecting data.

3. Results and Discussion

The three types of video game were qualitatively different, so that the game performances were not directly comparable between them. Therefore, we calculated the z-transformed game performance as a function of window size (Figure 3). For the ski racing game, the normalized z-scores of the race time were plotted in Fig. 3(a). Higher z-scores correspond to faster race time. As expected, the scores increased with the window size. A one-way ANOVA was performed to analyze the influence of the window size and the significant main effect was found ($F(4,20) =37.84$, $p<0.001$). Post-hoc Tukey’s HSD test revealed that only the smallest window size (10 degrees) degraded the game performance ($p<0.05$) and the race time reached a plateau at 20 degrees. This pattern was observed from all subjects. Thus, the size of the effective visual field was estimated to be about 20 degrees.

For the rhythm action game, the results were similar to the ski racing game but more gradual (Fig. 3 (b)). We found the significant effect of the window size ($F(4,20)=18.85$, $p<0.001$). Only the difference between 10-degree and 20-degree condition reached the significant level ($p<0.05$), however, the difference between 20-degree and 30-degree was marginal. Hence, the effective visual field was considered to be more than 20 degrees.

For the word puzzle game, the result was quite different from other games. Figure 3(c) suggests that the window size did not affect the game performance (F(4,20)=0.65, p=0.63). It is reasonable to assume that the subject did not use the visual information in the peripheral field and the effective visual field was less than 10 degrees.

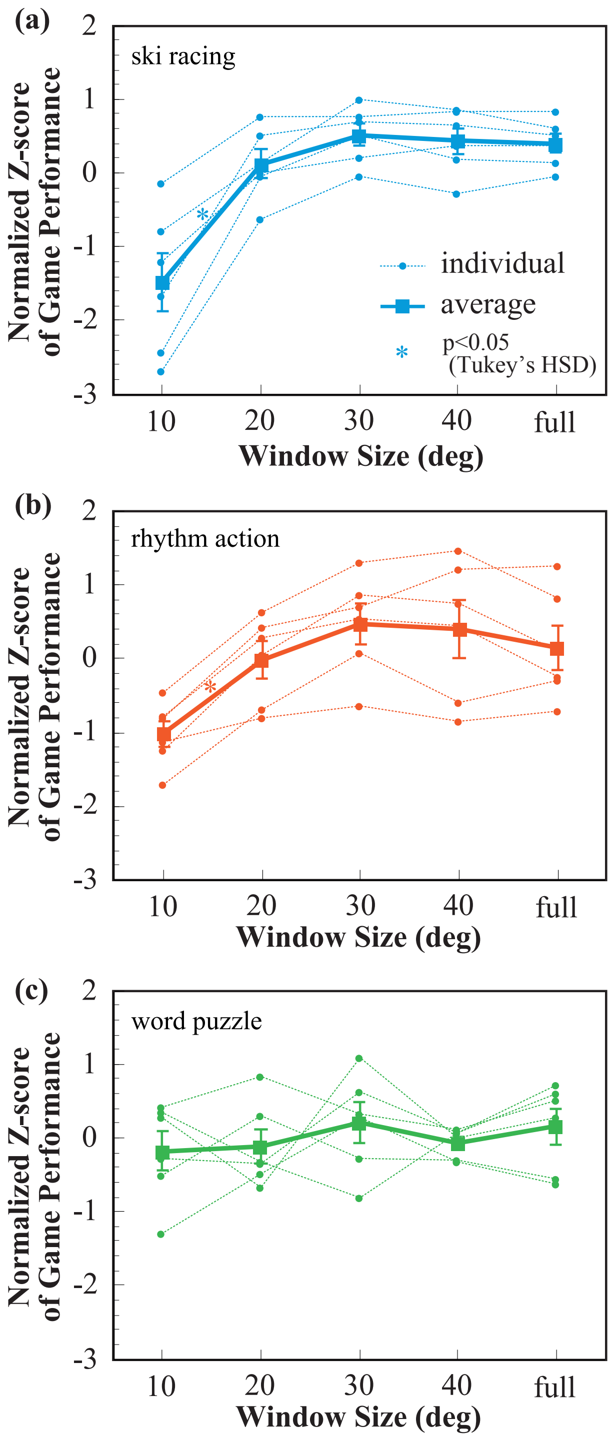

Fig.3 Normalized Game Performance against Window Size. (a) Ski Racing, (b) Rhythm Action, and (c) Word Puzzle. Dotted lines indicate the z-scores of six subjects. The thick line indicates the averaged z-score.

These results demonstrate that attentional distribution differs significantly between different video games. To explore dynamics of visual attention, we analyzed the eye movement behavior. Figure 4(a) shows the mean fixation duration during each video game. For the rhythm action game, the window size did not influence the fixation duration (F(4,20)=2.58, p=0.069), however, we found the significant effect in the other video games (ski racing: F(4,20)=6.70, p<0.01; word puzzle: F(4,20)=20.08, p<0.001). Especially, the fixation duration under the 10-degree condition showed characteristic differences to compensate lack of visual information (Tukey's HSD, p<0.05). For the ski racing game, the obtained data suggested that the subjects moved their eyes more

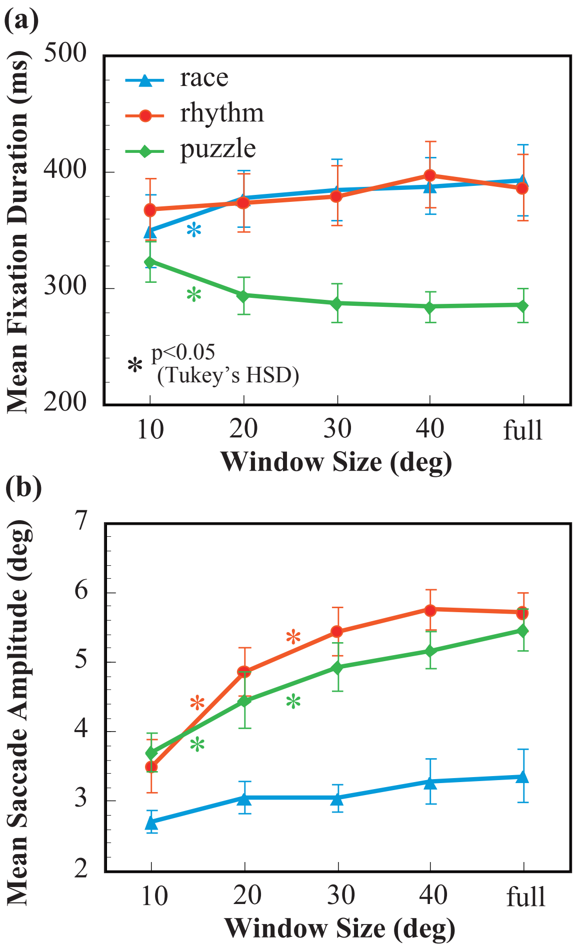

Fig.4 Eye Movement Analysis. (a) Mean Fixation Duration and (b) Mean Saccade Amplitude.

frequently by reducing the fixation duration. On the contrary, the subjects extended their fixations to process the visual information during the word puzzle game. This discrepancy suggests what information the visual system required during the video game. In the ski racing game, the player had to avoid obstacles which were approaching rapidly. So it must be important to find the location of obstacles, not the detail feature of them. However, in the word puzzle game, the precise recognition of characters should be necessary to build a word.

Figure 4(b) indicates the mean saccade amplitude for each game. it was found that the mean saccade length increased with the window size in all games ($F(4,20)>3.06$, $p<0.05$). This tendency implies that peripheral visual field is important to guide visual attention. For the rhythm action game and the word puzzle game, the significant increase of saccade amplitude was observed under the window conditions less than 30 degrees (Tukey's HSD, $p<0.05$). In contrast, for the ski racing game, the increase of saccade length was not clear. Moreover, the mean amplitude was about half of the other games. This result may suggest that the gaze was concentrated on the tangent point on the course [12].

The size of the effective visual field was about 20 degrees or more both in the ski racing game and in the rhythm action game. Saida and Ikeda (1979) examined the static scene perception through the gaze-contingent window [11]. Although there are essential differences of stimuli (e.g., static drawings vs. dynamic videos), they reported that the performance reached the plateau when the window size occupied about 50% of the whole picture. In this experiment, it is approximately 24 degrees in diameter that the window covers the half of the entire game screen. Thus, our results support the idea that about 50% of the screen is needed to recognize the entire scene. For the word puzzle game, however, the effective visual field was quite small than the half of the screen. This may imply that the recognition of the entire game screen was not necessary because only the adjacent characters were essential to build a word.

4. Conclusion

In this study, we measured spatial distribution of visual attention during playing video games by the gaze-contingent window method. We found that the distribution of visual attention was significantly affected by the types of video game and the eye movement was informative to clarify the dynamics of visual attention. Our results suggest the applicability of the method for the direct evaluation of visual attention and kansei properties.

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