Effects of Peripheral Visual Information on Performance of Video Game with Hemi-Spherical Immersive Projection Screen

Yasuhiro Seya,[1] Kotaro Sato,[2] Yusuke Kimura,[2] Akira Ookubo,[2] Hitoshi Yamagata,[2] Kazumi Kasahara,[1] Hiroya Fujikake,[1] Yuki Yamamoto,[1] Hanako Ikeda,[1] and Katsumi Watanabe[1]

[1]Research Center for Advanced Science and Technology, University of Tokyo. Komaba 4-6-1, Meguro-ku, Tokyo 153-8904 Japan
[2]NAMCO BANDAI Games Inc. Higashi-Shinagawa 4-5-15, Shinagawa-ku, Tokyo 140-8590 Japan
E-mail: seya-yasuhiro@fennel.rcast.u-tokyo.ac.jp

ABSTRACT
The recent development of immersive displays with high resolution and a wide field of view (e.g., hemi-spherical projection screen) has made it possible to play video games with higher levels of presence. However, it is not yet clear how players utilize the visual and auditory information provided by such displays for game play. In this paper, we report three experiments on an arcade video game "*Mobile Suit GUNDAM Senjyo no Kizuna*" with a hemi-ellipsoidal panoramic optical display (POD). Highly trained participants (professional game debuggers) were employed. They played the game with various visual masks (Experiments 1 and 2) and sound conditions (with and without sound; Experiment 3). In all of the experiments, the game performance (i.e., game score) was recorded as well as ratings for enjoyment, sensation of presence, and visually induced motion sickness as the game was played. The results suggest that players have a certain size of "effective visual space" in which peripheral information can be utilized. Furthermore, the results suggest that auditory information, together with a wide range of visual information, would enhance a player's enjoyment and sensation of presence during game play.

Keywords
Immersive display, effective visual space, method of restricting visual space

INTRODUCTION

The recent development of immersive displays that present visual information with high resolution on a large screen covering most of an observer's visual field (e.g., a hemi-spherical projection screen) has made it possible to play video games with higher levels of presence [3, 4]. However, it is not yet clear how players utilize visual and auditory information provided by such displays for game play. Given the miniaturization and cost reduction of immersive displays, it would be essential to estimate the minimal visual space that contributes to game play.

It is widely accepted that, in vision, a spatial range in which observers can perceive or utilize visual information is limited to a visual field to which they attend [9]. In such a range, a spatial range utilized for cognition in complicated situations, such as driving a car, is called an effective visual field [7, 10]. Previous studies examining the effective visual field during game play suggest that players have a certain size of an effective visual field within which visual information is used for game play [11, 12, 13]. For example, Yokoi, Watanabe, Kato, Kawai, Sato, Yamazaki, and Yamagata (2006) [11] measured the effective visual field during game play using a gaze-contingent window method. In this method, a circular window that restricts the peripheral visual field of an observer is presented at a current gaze position during visual tasks (e.g., game play). Yokoi et al. [11] measured game performance (e.g., game score) with various sizes of a window. They assumed the following relationship between the sizes of the window and the effective visual field. When the size of the window is smaller than that of the effective visual field, the game score should decrease because visual information utilized for the game play is limited. With increasing the size of the window, the game score should increase. However, when the size of the window is larger than that of the effective visual field, the game score would reach a plateau because, according to the definition of the effective visual field, the visual information outside the effective visual field is not processed. Therefore, the effective visual field can be estimated as the window size at which the game score is saturated. The results of their study showed that the game score increased with increasing the window size. However, the game score did not change much when the window size exceeded 20 or 30 deg in diameter, suggesting that the size of the effective visual field during game play is more than 20 deg in diameter.

Breaking New Ground: Innovation in Games, Play, Practice and Theory. Proceedings of DiGRA 2009

Unfortunately, previous studies [11, 12, 13] used a video game with a relatively small display and examined the effective visual field, particularly just after the gaze shifts. Furthermore, the effects of the auditory information on the game play were not examined. Therefore, it is not clear how players utilize the visual and auditory information at all time while playing arcade video games with the immersive display.

In this paper, we report three experiments using an arcade video game with an immersive display. In the experiments, participants played the video game with various visual masks (Experiments 1 and 2) and sound conditions (with and without sound; Experiment 3). We define an “effective visual space” as a minimal visual space in which the peripheral visual information is utilized at all time while playing the game, not just after the gaze shifts. To evaluate the effective visual space, in this study, the window restricting the peripheral visual information was presented at the center of the display, not at the current gaze position.

EXPERIMENT 1

Method

Experimental Design

Figure 1 shows the basic idea of estimating the size of the effective visual space (c.f. [11, 12, 13]). When the window size is smaller than the effective visual space, the game performance (e.g., game scores) should be low because the visual information utilized for the game play is limited. As the window size increases, the performance should increase. However, when the window size exceeds the size of the effective visual space, the performance should reach a plateau because the visual information outside the effective visual space is not utilized for the game play. According to this scenario, the size of the effective visual space can be estimated as the window size where the game performance is saturated.

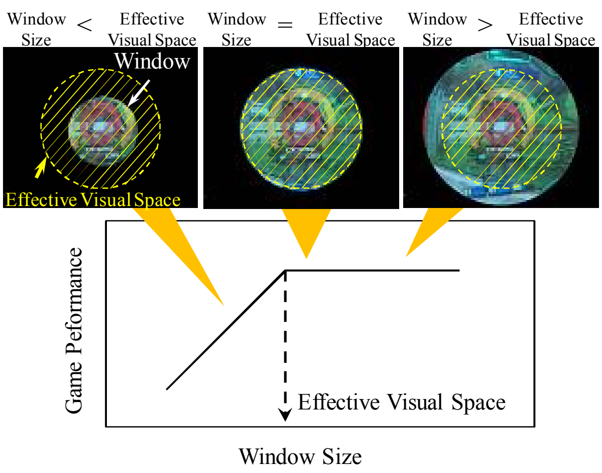

Figure 1: Estimation of effective visual space.

Apparatus and Stimuli

As an arcade video game task, we selected "*Mobile Suit GUNDAM Senjyo no Kizuna*"(NAMCO BANDAI Games Inc., Japan). This game is an action game (tactical team fighting game) played in a unique circular capsule, called a Panoramic Optical Display (P.O.D.), which is large enough to fit one player. The P.O.D. simulates the cockpit of a character and has a hemi-spherical immersive projection screen which covers most of a visual field of players. Figure 2 shows the appearance of the P.O.D. In this game, the players are required to control a character with two joysticks and foot pedals and to battle opponents in cooperation with other players on the same team. An experiment was conducted with a training mode, and two types of battle stages (Side7 stage and New Yark stage) were used.

Figure 3 illustrates a schematic view of the experimental setting. To restrict peripheral visual information on the display, a window cover was attached on the lens of a projector. The shape of the projected window was circular. The size of the circular frame (in which a gun sight was presented when the players attacked the opponents) at the center of the display was used as the criterion size of the window. Four different window sizes were employed: 1, 1.5, 2, and 2.5 times as large as the criterion size. In the experiment, the radar that indicated the locations of the opponents on the battle field was not shown on the screen under any of the experimental conditions.

Procedure

Participants were seated in the P.O.D. In an experimental session, participants were instructed to play the game while viewing the game display through the window and to obtain a game score as high as possible. The four window size conditions were randomized across participants, and 8 trials

Figure 2: Appearance of P.O.D.

Figure 3: Schematic view of experimental settings.

were repeated for each condition. The battle stage was randomized across trials. The game score (points) was measured as a game performance index.

After each window condition, the participants were asked to complete a questionnaire concerning the game play. The questionnaire was composed of 3 items: (1) the game is enjoyable; (2) the game provides a sensation of presence; and (3) visually induced motion sickness is felt. As in previous studies [2, 6, 8], each item was rated using a 7-point scale (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neither agree nor disagree, 5 = slightly agree, 6 = agree, 7 = strongly agree).

Participants

To avoid variations in the game score due to difficulties of controlling the character, 3 highly trained participants (professional game debuggers) were employed (mean age of 25.33 years, range 22–29 years). All participants had normal or corrected-to-normal vision.

Results

Figure 4 shows the mean and individual game scores. A 2 (stage) × 4 (window size) ANOVA showed significant main effects of stage, F (1, 2) = 208.76, $p < .01$, and window size, F (3, 6) = 40.66, $p < .01$, but there was no significant interaction between them, F (3, 6) = 0.46. Multiple comparisons using the Ryan method for the effect of window size showed significant differences between any pair of all window sizes ($ps < .05$), except between 2 and 2.5 time conditions.

Figure 5 shows the mean ratings for each item in the questionnaire. Data of each item were entered into one-way ANOVAs, which showed no significant main effect of window size [enjoyment, F (3, 6) = 0.63; sensation of presence, F (3, 6) = 1.82; visually induced motion sickness, F (3, 6) = 1.00].

Discussion

In this experiment, the effective visual space during the game play was estimated using the window mask to restrict the visual space of the participants. The results showed that

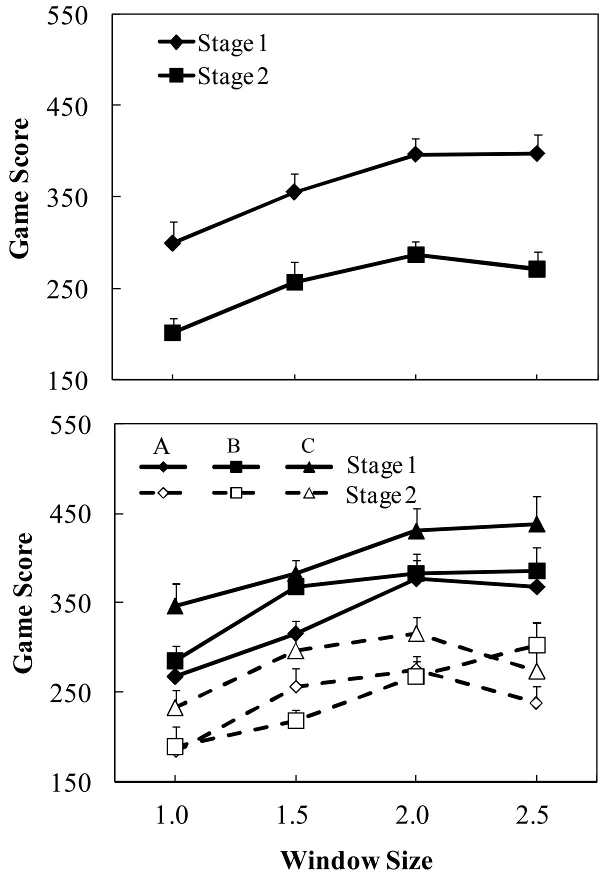

Figure 4: Mean and individual game scores. Vertical bars indicate standard errors.

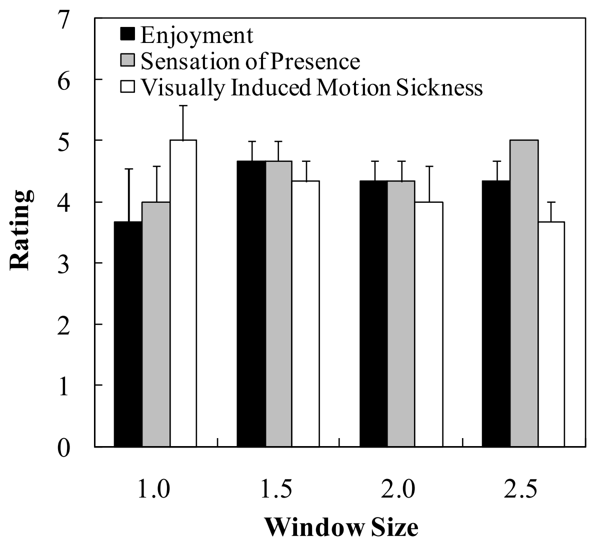

Figure 5: Mean ratings for each item. Vertical bars indicate standard errors.

the game score increased with increasing the window size but the score reached a plateau at a certain window size. In other words, with the hemi-spherical immersive projection screen, the players were able to play the video game with restricted effective visual space. This result was qualitatively consistent with the finding of previous studies using the gaze-contingent window method [11, 12, 13] and suggests that, during game play, players utilize visual information in a limited visual space rather than the entire visual space of the display.

Unlike the results of the game score, the results of the ratings showed no difference with the window size, suggesting that a player's enjoyment, sensation of presence, and visually induced motion sickness are independent of the size of the visual space during game play.

EXPERIMENT 2

Method

There were two major changes from the methodologies used in Experiment 1. First, the participants were asked to play the game with a window that restricted either the upper or the lower visual spaces of the screen from the edge of the circle presented at the center of the display (Figure 3). In addition to these window-mask conditions, an experimental condition with both upper and lower masks, with which the participants were able to view the game images through a horizontal slit, was also introduced. Second, 4 participants (all professional game debuggers) were employed (mean age of 25.25 years, range 22–29 years). Three of them had participated in Experiment 1.

Results

Figure 6 shows the mean and individual game scores. As can be readily seen in the figure, the mean scores were higher in stage 1 than in stage 2 and, on average, they were lower in the lower and upper-lower mask conditions than in the upper mask condition. It is noteworthy that there were large individual differences among the mask conditions. A 2 (stage) × 3 (window shape) ANOVA showed only the significant main effects of stage, $F(1, 3) = 447.70, p < .01$, but no significant main effect of window shape, $F(2, 6) = 1.19$. There was no significant interaction between them, $F(2, 6) = 0.01$.

Since there were large individual differences with regard to the effect of window shape, additional analyses were conducted separately for each participant. The results of participants A and C showed a significant and a marginally significant main effect of window shape, respectively [participant A, $F(2, 6) = 4.94, p = .05$; participant C, F (2,

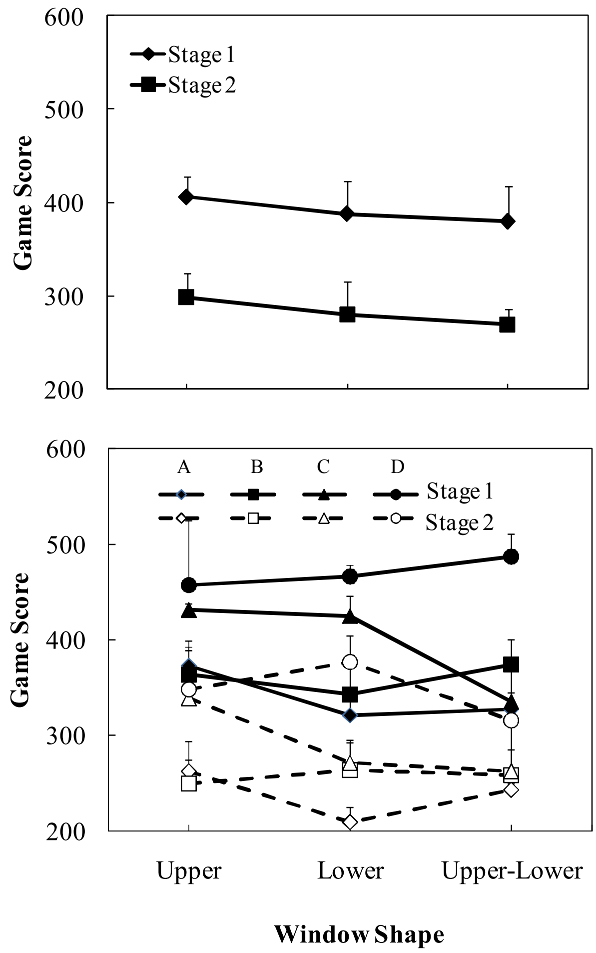

Figure 6: Mean and individual game scores. Vertical bars indicate standard errors.

6) = 4.31, p = .7]. There was no significant main effect of window shape in the other participants [participant B, F (2, 6) = 0.03; participant D, F (2, 6) = 0.51]. Multiple comparisons for the effect of window shape showed marginally significant differences between the upper and lower mask conditions in participant A and between the upper and upper-lower mask conditions in participant C (both $ps < .1$).

Figure 7 shows the mean ratings for each item in the questionnaire. One-way ANOVAs for each item showed no significant main effect of window size [enjoyment, F (2, 6) = 0.93; sensation of presence, F (2, 6) = 2.33; visually induced motion sickness, F (2, 6) = 0.53].

Discussion

Experiment 2 revealed that the game performance (i.e., score) tended to be lower when the lower or lower-upper visual space, rather than the upper visual spaces, was masked (in two participants), suggesting that the peripheral visual information from the ground played a more important role in game play. However, because some participants reported, after the experiment, that they had used the shadows of the opponents presented on the ground (lower visual space) as cues of the opponents' location, this result may have reflected game strategies specific to the game used in this study. Further studies will be needed to explore the possible effects of the game strategy on the visual space.

The results of the ratings showed no differences due to the window shape, suggesting that a player's enjoyment and sensation of presence are independent of the shape of the visual space during game play.

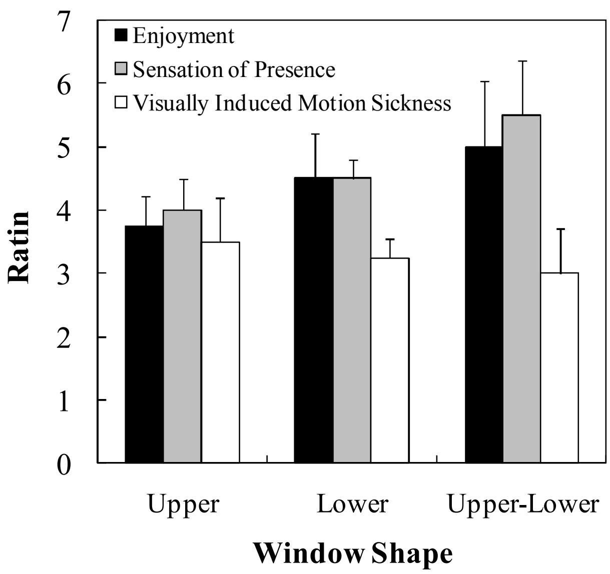

Figure 7: Mean ratings for each item. Vertical bars indicate standard errors.

EXPERIMENT 3

Method

The methodologies used in Experiment 3 were identical to those used in Experiment 2, except that the participants were asked to play the game with different sound conditions, i.e., with and without sound, without the visual mask.

Results

Figure 8 shows the mean and individual game scores. A 2 (stage) × 2 (sound) ANOVA showed only a significant main effect of stage, F (1, 3) = 140.51, $p < .01$, but no significant main effect of sound, F (1, 3) = 2.28. There was marginally significant interaction between them, F (1, 3) = 7.92, $p < .07$. Post-hoc analyses showed a significantly higher score without sound than with sound in stage 1, F (1, 6) = 7.68, $p < .05$, but not in stage 2, F (1, 6) = 0.05.

Figure 9 shows the mean ratings for each item in the questionnaire. The results showed significant differences in

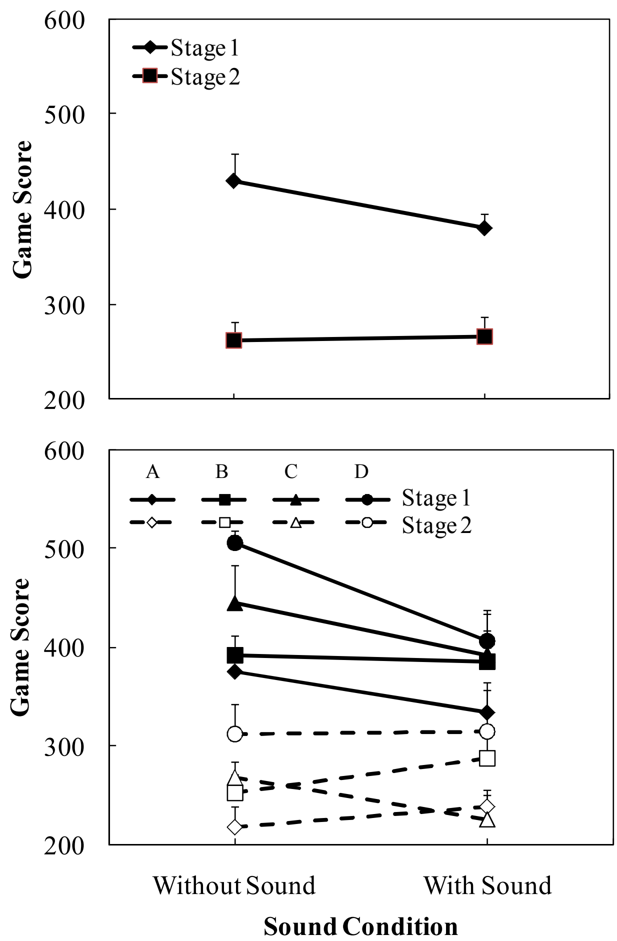

Figure 8: Mean and individual game scores. Vertical bars indicate standard errors.

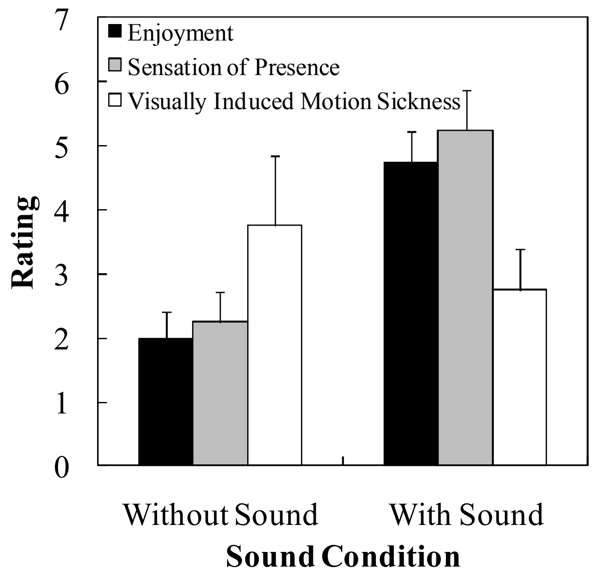

Figure 9: Mean ratings for each item. Vertical bars indicate standard errors.

enjoyment, t (3) = 5.74, p <.05, and sensation of presence, t (3) = 5.20, p <.05, between the sound conditions, but not in the visually induced motion sickness, t (3) = 1.41.

Discussion

The results of Experiment 3 showed that, when the game stage was relatively simple (stage 1), the game score was significantly lower with sound than without sound, indicating that the game sound actually resulted in distraction during game play.

The reason that the game sound caused distraction during game play is not clear. One possibility is the effect of task demand. When the game sound was presented the participants may have processed not only the visual information but also the auditory information as they played the game. On the other hand, when there was no game sound, the participants may have processed only the visual information. Therefore, the task demand during the game play may have been higher with sound than without sound. Since research has shown that performance of visual tasks (e.g., detection task) decreases with increasing the task demand [1, 7, 10], it is possible that the game play may have been distracted by the game sound, resulting in a lower game score with than without sound.

The results of the ratings showed significant differences in the enjoyment and the sensation of presence between the sound conditions, suggesting that auditory information plays an important role in a player's enjoyment and sensation of presence during game play.

GENERAL DISCUSSION

In this study, the effects of visual and auditory information on game play were examined by restricting the visual space and sound. The present results suggest that players have an effective visual space of a specific size, although they can perceive and utilize most of the peripheral visual information provided by the hemi-spherical dome screen for playing a game (Experiment 1). The results also indicated that the shape of the effective visual space changes depending on game strategies used by players (Experiment 2). Furthermore, the results indicated that a game sound, together with a wide range of visual information, would enhance a player's enjoyment and sensation of presence (Experiment 3).

Interestingly, the various ratings and game scores were not always linked. The reason for the dissociation between subjective and objective measures is not clear in this study. One possibility is prior experience of seeing similar images and scenarios provided by the game. In this study, highly trained participants (professional debuggers) who had often played the game used in this study before the experiments were employed as participants. Therefore, they may have been habituated to the various scenes and situations provided by the game. As a result, their enjoyment and sensation of presence toward the game play may not have changed much, irrespective of the visual masks. In fact, previous studies using a visual mask reported that the enjoyment and sensation of presence increased with increasing the size of the visual field [6, 14], which is not consistent with the findings of this study. Further investigation will be needed to explore the possible effects of prior experience on the enjoyment and the sensation of presence.

Finally, the present study indicates that methods of artificially restricting visual space and sound would be useful not only for evaluating how video game players utilize peripheral visual and auditory information but also for the development of immersive wide-view displays.

ACKNOWLEDGEMENTS

This study was supported by the New Technology Foundation, the Foundation for the Fusion Of Science and Technology (FOST), and Grants-in-Aid for Young Scientists (B) 21730587 to K. W. and 20730485 to Y. S.

REFERENCES

1. Abernethy, C. N., & Leibowitz, H. W. (1976). The effect of feedback on luminance thresholds for peripherally presented stimuli. *Perception & Psychophysics*, 10, 172-174.

2. Howarth, P. A., & Costello, P. J. (1997). The occurrence of virtual stimulation sickness symptoms when an HMD was used as a personal viewing system. *Displays*, 18, 107-116.

3. Kikuchi, T. (2006). Recreational video game systems

always seek higher levels of presence, taking the "Mobile Suit GUNDAM Senjyo no Kizuna" game as example. *IEICE technical report*, EID2006-32, 51-53 (in Japanese with English abstract).

4. Kosaka, T., Miyashita, H., & Hattori, S. (2007). Development and evaluation of immersive 3D wind display. *Proceedings of Interaction 2007*, 105-112 (in Japanese with English abstract).

5. Kumada, T., Kuchinomachi, Y., & Saida, S. (1995). The properties of functional visual fields on visual search: evidence from manual reaction time and saccadic eye movement. *Japanese Journal of Psychonomic Science*, l4, 75-85 (in Japanese with English abstract).

6. Lin, J. J., Duh, H., Parker, D., Abi-Rached, H., & Furness, T. (2002). Effects of view on presence enjoyment, memory, and simulator sickness in a virtual environment. *Proceedings of IEEE Virtual Reality Conference 2002*, 164-171.

7. Miura, T. (1992). Visual search in intersections - An underlying mechanism. *IATSS Research*, 16, 42-49.

8. Ohno, S., & Ukai, K. (2000). Subjective evaluation of motion sickness following game play with head mounted display. *The journal of the Institute of Image Information and Television Engineers*, 54, 887-891(in Japanese with English abstract).

9. Posner, M. (1980). Orienting of attention, *The Quarterly Journal of Experimental Psychology*, 32, 3-25.

10. Richards, E., Bennett, P. J., & Sekuler, A. B. (2006). Age related differences in learning with the useful Weld of view. *Vision Research*, 46, 4217-4231.

11. Yokoi, K., Watanabe, K., Kato, R., Kawai, T., Sato, T., Yamazaki, T., & Yamagata, H. (2006). Measuring spatial distribution of visual attention in action video game. *Kansei Engineering International*, 6, 13-18.

12. Yokoi, K., Watanabe, K., Kawai, T., Kato, R., Sato, T., Yamazaki, T., & Yamagata, H. (2006). Dynamic evaluation of distribution of visual attention during playing video game. *Advances in Computer Entertainment Technology*, Hollywood, CA, USA.

13. Yokoi, K., Watanabe, K., Kawai, T., Kato, R., Sato, T., Yamazaki, T., & Yamagata, H. (2007). Effects of video games on dynamics of visual attention. *Proceedings of International Conference on Kansei Engineering and Emotion Research 2007*, Paper no. 0043.

14. K. Watanabe. (2006). Cognitive evaluations of game laying. *Symposium on Prescription for Digital Games*, Tokyo, Japan.