Effect of Controlled Consciousness on Sense of Presence and Visually Induced Motion Sickness While Viewing Stereoscopic Movies

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Abstract. In our previous study, we found it is possible to have an effect of change in the condition of consciousness (allocation of consciousness) on visually evoked postural response (VEPRs) Then, in this study, we verified effect of controlling consciousness on VEPRs, visually induced motion sickness (VIMS), a sense of presence while viewing 3D movies. Participants watched 3D movie consisted of several colored balls sinusoidal moving at 0.25 Hz in the depth direction for 3 min each under condition following pre-instruction. The detail of the pre-instruction were "sway body in a parallel/opposite direction". The position of the body sway center of pressure was continuously recorded. As subjective evaluation, participants completed a simulator sickness questionnaire and reported three feelings (the sense of presence, motion and interactive) by using a visual analog scale. The results clearly showed that (1) The influence of pre-instruction appeared much stronger than that of VEPRs, and (2) The relationship between change in body sway and degree of VIMS or the feeling of presence do not always match under the situation included multi factors related to sense information or the condition of consciousness.

Keywords: Visually Evoked Postural Response (VEPR) · Body sway
Visually Induced Motion Sickness (VIMS) · Sense of presence
Consciousness

1 Introduction

With recent advances in display technologies, users can enjoy virtual experiences that provide feeling of presence defined as "sense of being there," [1] whether at home or at amusement parks. As a result, there has been an increase in the presentation of symptoms similar to motion sickness, often referred to as visually induced motion sickness (VIMS) or cybersickness [2, 3], which are experienced by users during or after enjoying these virtual activities. Stanney reported that 88% of virtual environment participants developed VIMS when viewing virtual reality movies for an hour [4]. Thus, in their current state, virtual experiences with the purpose of amusement often become stressors instead.

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The pathogenic mechanism of VIMS and the reasons for the onset of its complex symptoms are not sufficiently understood. However, one of the leading hypotheses involves sensory conflict theory, which suggests that the complex symptoms are caused by the presence of conflicts among the afferent inputs of the sensory modalities (vision, equilibrium sense, somatosensation) and the subject's perception [5, 6]. In particular, VIMS is evoked when information relayed by the visual system is contradictory to information from the other senses.

Postural responses that are induced by visual information, such as motions or gradients, are called visually evoked postural responses (VEPRs) [7] and are among the body responses related to VIMS or feeling of presence [8, 9]. Although there are various theories as to the reason for the appearance of VEPRs, our past study suggested the possibility that VEPRs were a conflict correction response aimed at matching the information from the other senses [10]. If the conclusions of the past study are correct, imposing suppression or acceleration of the conflict correction response (VEPRs) may be a method of preventing VIMS. Moreover, control of VEPRs might be useful for adjustment of the feeling of presence. In our previous study, we found it is possible to have an effect of change in the condition of consciousness (allocation of consciousness) on VEPRs [11]. In a similar example, Hoshikawa reported that when subjects devoted more attention to their own bodies, body sway induced by a visual stimulus lessened [12]. In this study, we verified the effect of controlling consciousness on VEPRs, VIMS, a sense of presence while viewing stereoscopic movies.

2 Material and Method

2.1 Participants

Seven university students (2 males and 5 females; 21–22 years old) who did not have vision or equilibrium problems participated in this study. The study was approved by the Research Ethics Committee at Gifu University of Medical Science. Oral and written consent was obtained from the participants after the purpose and significance of the study and the nature and risk of the measurements were explained. In addition, the study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

2.2 Visual Stimulation

A screenshot of the movie as visual stimulation used in this study is shown in Fig. 1. The visual stimulation was delivered via a movie created using 3ds Max 2017 computer graphics software (Autodesk, San Rafael, CA, USA). The movie consisted of several colored balls displayed at random positions. We designed the movie with the balls sinusoidal moving at 0.25 Hz in the depth direction and was generated by moving camera-simulated ocular globes (the balls themselves did not move). The amplitude of the sinusoidal motion was set to 200 as the software setting.

The experimental setup utilized in this study is shown in Fig. 2. We performed the experiments in a controlled environment (illuminance: under 10 lx) in order to limit the

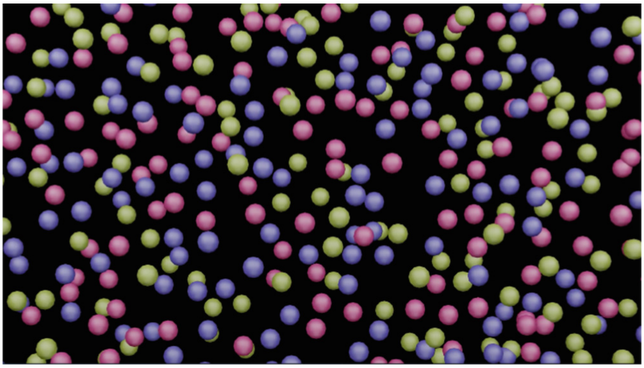

Fig. 1. Screenshot of the movie used in this study. A large number of balls were located at random positions, The motion in the movies was sinusoidal at 0.25 Hz in the depth direction.

variations to visual input. The movie was displayed on an LCD monitor (42LW5700, LG, Seoul, Korea) 50 cm in front of the participant. The displayed movie size was 99.30 cm × 52.62 cm with a resolution of 1,920 × 1,080. The participants watched the experimental 3D movies using circularly polarized glasses.

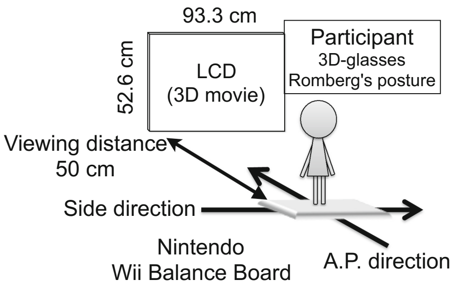

Fig. 2. Experimental session diagram. The movie was displayed on an LCD monitor 50 cm in front of the participant. The participants watched the experimental 3D movies using 3D-glasses. In order to measure the position of the center of pressure (CoP), participants were asked to stand on a Wii Balance Board with Romberg's posture. Points to the left or posterior to CoP were expressed as negative values.

2.3 Procedure and Design

The study protocol is shown in Fig. 3. For Task 1, a participant stood on the Wii Balance Board and watched a static (nonmoving) movie for 1 min as the pretest. Task 2 was divided into three tasks, For Task 2-A, participants watched the motion movie for 3 min under uncontrolled their consciousness. For Task 2-B, participants watched that for 3 min based on a pre-instruction (sway your body in a parallel direction with ball moving phase while maintaining Romberg's posture). For Task 2-C, participants watched that for 3 min based on the pre-instruction (sway your body in a opposite direction with that while maintaining Romberg's posture). Participants performed the three tasks (Task 2-A to 2-C) in a random sequence to avoid the order effect. Task interval was set at more than 5 min.

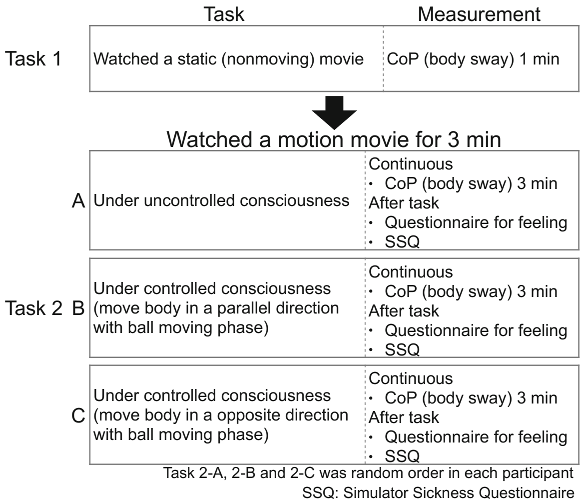

Fig. 3. Study protocol and measurements.

2.4 Measurement and Analysis

The position of the body sway center of pressure (CoP) was continuously recorded with the Wii Balance Board using stabilometry software custom-built with WiimoteLib in each Task. The CoP measurements were recorded at 20 Hz, which is a basic sampling setting in clinical gravimetric tests. The continuous CoP data were separated by intervals of 1 min of viewing time to analyze each time segment. CoP data were analyzed for instability of postural maintenance and body sway periodicity. Area and total locus length were measured as indexes of the postural instability, and the power spectral density (PSD) at 0.25 Hz in depth direction calculated from a fast Fourier transform with a Hamming window assessed the body sway periodicity. Wilcoxon signed-rank tests with Šidák correction were performed using ORIGIN Pro 8.5 (OriginLab, Corporation, Northampton, MA, USA) among each Task 2 in same time segment.

As VIMS symptoms, participants completed a simulator sickness questionnaire (SSQ) after each Task 2. The total score and three subscores (nausea, oculomotor discomfort, disorientation) were calculated. Then, Wilcoxon signed-rank tests with Šidák correction were performed among each Task 2.

As the sense of presence, participants reported three feelings (the sense of presence, motion and interactive) as that word or similar meaning words) by using a visual analog scale (VAS) that ranged from 0 to 10 after each Task 2 after the sensory scale was explained (0: not at all, 10: very much). Then, Wilcoxon signed-rank tests with Šidák correction were performed among each Task.

3 Results

A typical stabilogram result calculated from the CoP data (from a 21 year-old female) is shown in Fig. 4(a)–(d). Each panel shows a different condition. The graph in Fig. 4(a) (nonmoving) shows the most stable trial, with the shortest locus change and smallest area of body sway. By contrast, the largest area and the longest locus were found in Fig. 4(c) (controlled consciousness (same direction)). Comparing Fig. 4(d) (controlled consciousness (opposite direction)) with Fig. 4(b) (uncontrolled consciousness (same direction)), the locus change in the anteroposterior direction was larger in the trial under controlled consciousness than under uncontrolled consciousness despite of opposite direction as counter instruction to VEPRs. Thus, it was assumed that the

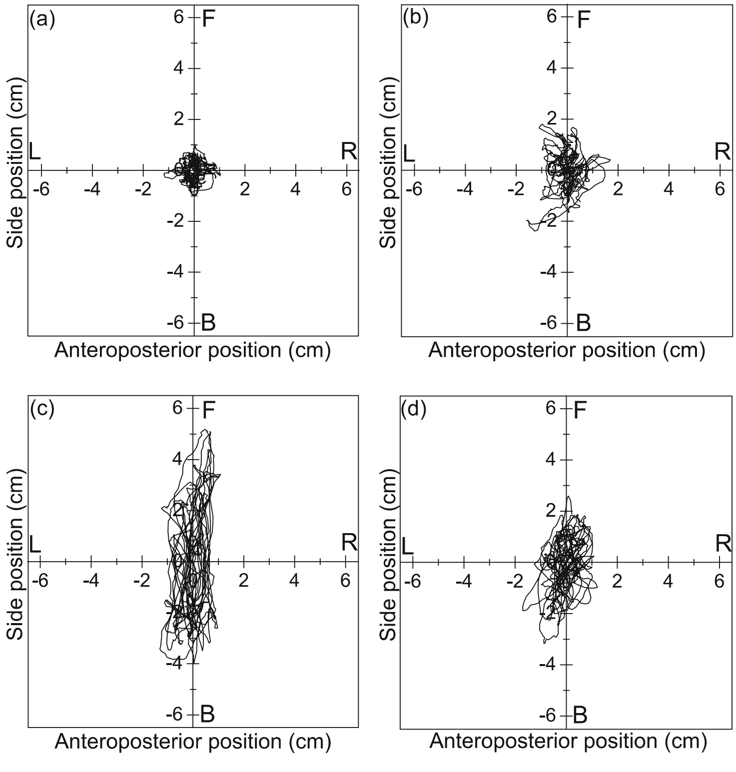

Fig. 4. A typical stabilogram result (21 year-old female). “F, B, R, and L” in each stabilogram represent “front”, “back”, “right”, and “left”, respectively. (a) Task 1: nonmoving (pretest), (b) Task 2-A: uncontrolled consciousness, (c) Task 2-B: controlled consciousness (same direction), and (d) Task 2-C: controlled consciousness (opposite direction).

pre-instruction has an especially strong influence, comparing information from other senses.

Figure 5 shows the change in postural instability at different the pre-instruction. Figure 5(a) and (b) show area and total locus length, respectively, and Fig. 5(c) shows the power spectral density (PSD) at 0.25 Hz as index of body sway periodicity, which were obtained from the frequency analysis. These results indicated similar tendencies. The results of the controlled consciousness (same direction) task showed the highest postural instability and the body sway periodicity among all tasks, and the results of the uncontrolled consciousness were lowest. Then, compared with the uncontrolled consciousness task, both of the controlled consciousness tasks indicated significantly increases in postural instability and body sway periodicity ($P < 0.05$). Moreover, temporal change in the index was only seen in the same direction task.

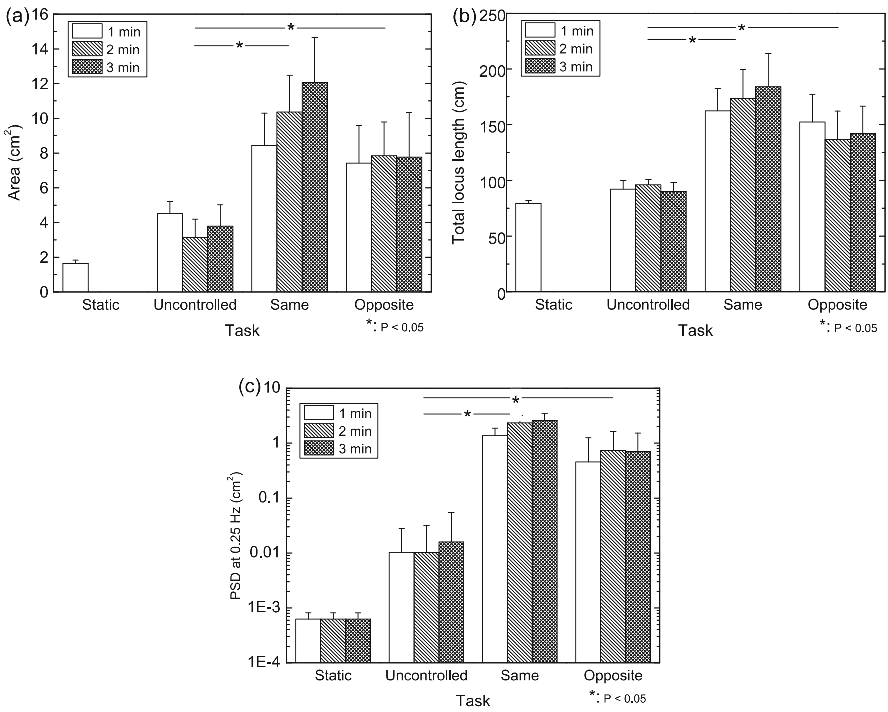

Fig. 5. Postural instability and body sway periodicity at different the pre-instruction and temporally changes. (a) Area, (b) Total locus length, and (c) PSD at 0.25 Hz

Figure 6 shows SSQ results (total score and three subscores) at different the pre-instruction as box plot. Each box plot represents maximum, 75th-percentile, median, 25th- percentile and minimum from the top, respectively, and small square in the box represents average score. All SSQ scores indicated the same tendencies, regardless of kind of SSQ score. First, median score and 75th-percentile value increased in the following order: uncontrolled task < same direction task < opposite direction task. However, significantly changes in all SSQ scores were not found in between tasks. Second, individual bias of SSQ score was large in all tasks.

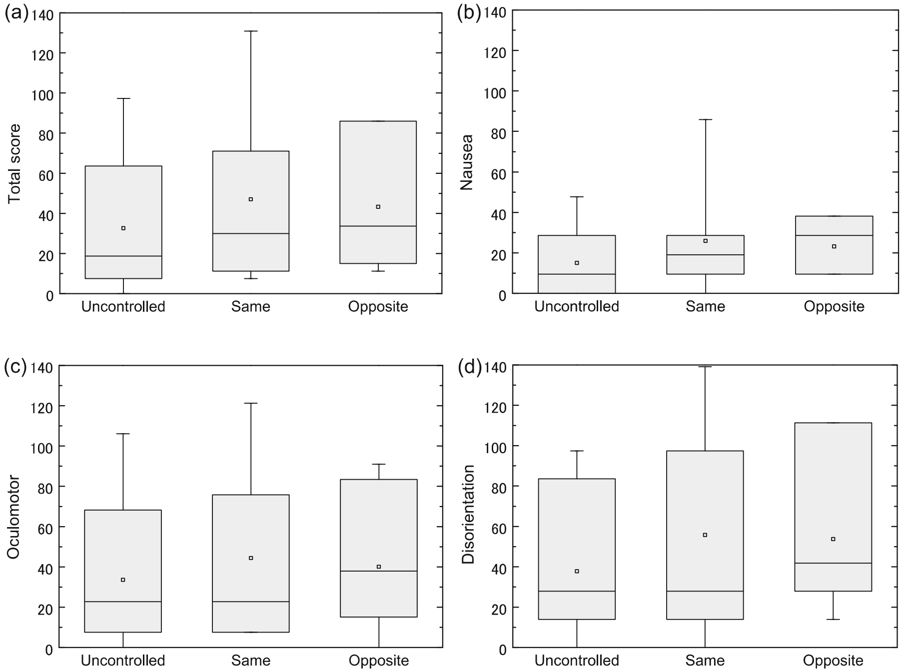

Fig. 6. The results of Simulator sickness questionnaire (SSQ). (a) Total score, (b) Nausea (Subscore), (c) Oculomotor (Subscore), and (d) Disorientation (Subscore)

Figure 7 shows results for the sense of presence at different the pre-instruction as box plot. Each box plot represents maximum, 75th-percentile, median, 25th-percentile and minimum from the top, respectively, and small square in the box represents average value. The results for feeling of presence showed different tendencies different from the SSQ results. Median VAS scores both presence and interactive increased in the following order: uncontrolled task < same direction task < opposite direction task, as with the results of SSQ. By contrast, that for of motion increased in the following order: same direction task < opposite direction task < uncontrolled task. All sense items (presence, motion and interactive) also had huge individual bias.

4 Discussion

In this study, we verified the effect of controlling consciousness on VEPRs, VIMS, the sense of presence while viewing 3D movies with the balls sinusoidal moving at 0.25 Hz in the depth direction. For the controlling consciousness, we instructed that maintaining Romberg's posture under uncontrolled consciousness, that under

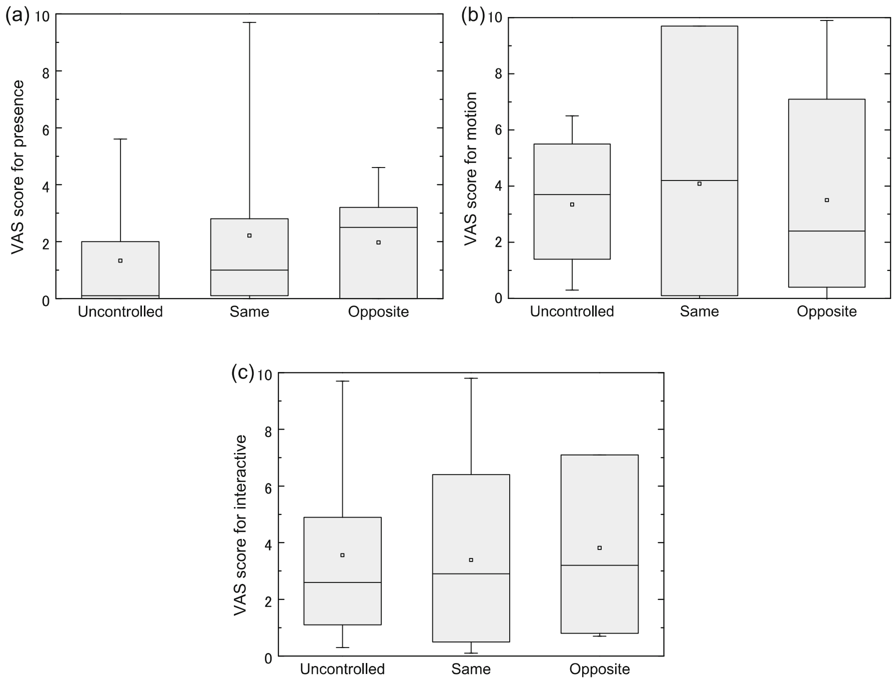

Fig. 7. The results for the sense of presence. (a) feeling of presence, (b) feeling of motion, and (c) feeling of interactive.

controlled consciousness (sway your body in a parallel direction with ball moving phase), or that under controlled consciousness (sway your body in a opposite direction with that) while viewing the experimental movie in each Task. The results of stabilogram, indexes of the postural instability such as area and total locus length and the frequency analysis showed increase in locus length and area as indexes of postural instability and body sway periodicity following order: same direction task > opposite direction task > uncontrolled task. The influence of pre-instruction appeared much stronger than that of VEPRs because the results related measurement of body sway in opposite direction task were larger than that in the uncontrolled direction task. In the opposite direction task, these results assumed that VEPRs had counter role to the intentional body sway under control. Thus, the pre-instruction had strong influence. In other words, the condition of consciousness (allocation of consciousness) was important factor for the relationship between vision and equilibrium sense.

As the results of SSQ, all SSQ scores indicated the same tendencies that disagreed with the results of body sway, although individual variation existed (uncontrolled task < same direction task < opposite direction task). Compared to the uncontrolled task, the task with controlled consciousness increased in the sensory conflict because participant swayed advisedly based on the pre-instruction. In same direction task, participant swayed larger than their supposition because VEPRs were added to body sway evoked the pre-instruction. In opposite direction task, increase in conflict between vision information and body sway lead to further sensory conflict. These results suggest that degree of VIMS symptoms can be adjusted by adjustment of intentional motion.

As the results of sense of presence, both the feelings of presence and interactive indicated the same tendencies that disagreed with the results of body sway (uncontrolled task < same direction task < opposite direction task). By contrast, the feeling of motion showed different tendencies that accorded with the results of body sway (uncontrolled task < opposite direction task < same direction task). Lessiter et al. reviewed previous studies that defined presence in various ways [13]. Thus, we verified three feelings (the sense of presence, motion and interactive) as that word or similar meaning words related the sense of presence. In general, it is supposed that the sense of presence and VIMS have deep relationship. Further, it is considered that the evaluation of the change in body sway can detect VIMS or increase in the feeling of presence. However, it needs to consider that the relationship between change in body sway and degree of VIMS or the feeling of presence do not always match under the situation included some factor related to sense information or condition of consciousness such as this study case.

5 Conclusion

In this study, we verified the effect of controlling consciousness on VEPRs, VIMS and the sense of presence while viewing 3D movies. The following conclusions can be drawn:

1. The influence of pre-instruction appeared much stronger than that of VEPRs because the results related measurement of body sway in the opposite direction task were larger than that in the uncontrolled task. The pre-instruction had strong influence to the relationship between vision and equilibrium sense.

2. The relationship between change in body sway and degree of VIMS or the feeling of presence do not always match under the situation included multi factors related to sense information or the condition of consciousness such as this study case.

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