

Can human remove the barrier of "VR sickness" in order to gain access to new spaces?

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ABSTRACT

This presentation clarifies the mechanism of VR sickness, which is one of the obstacles to the diffusion of VR technology and to gain trust. This presentation consists of research to achieve as follows: (1) suppressing the sickness caused by the oscillation of the avatar during the first-person viewpoint (2) clarifying the mechanism of sickness with the aim of recovering as quickly as possible after the symptoms of sickness.

1 INTRODUCTION

As Japan aims to become an "all-participating society" in which all people, regardless of gender, age, or disability, can maximize their diverse abilities and play an active role, various problems such as regional fatigue and decline, rapid population decline, and super-aging are piling up. The author believes that the cause of many of these problems is that all people are bound by the constraints of time and space. Therefore, the author has focused on virtual reality (VR) technology, which has the potential to free people from these constraints, and has worked to solve social problems in several fields. For example, the development of educational materials to solve the lack of technical skills of newly graduated nurses and the hindrance of potential nurses returning to clinical practice, and the optimization of evacuation signs in underground spaces are examples. Although these studies have shown the potential of VR educational materials in nursing education and clarified the characteristics of human behavior, including the use of evacuation guide lights during disasters, there are several issues that need to be resolved in order to implement VR products and systems based on these research results in society. In particular, VR sickness is a major obstacle to the diffusion of VR technology itself and to gaining social trust, and is a type of motion sickness with negative effects on the human body, such as sweating, facial pallor, nausea, and vomiting. It has been generally believed that motion sickness is caused by the accumulation of discrepancies between the self-motion information to each sense and the predicted self-motion information on past experience, which is called "sensory conflict theory". The author believes that it is necessary for VR to be used continuously in order for VR technology itself to spread and to gain social trust, and conducted research to clarify the mechanism of sickness with the objectives of (1) suppressing sickness caused by

the vibration of the avatar in the first-person viewpoint, and (2) recovering as quickly as possible after the symptoms of sickness.

2 Examination of the effects of the directional and frequency components of oscillation on VR sickness

VR technology is expected to be one way to solve problems in various fields. However, the observer is often exposed to the VR sickness. Specific symptoms of VR sickness include eyestrain, headache and vertigo, nausea are mentioned as a concrete symptom. These symptoms are similar to carsickness and seasickness and are considered to be one of motion sickness [1, 2]. If the observer cannot use VR technology comfortably with VR sickness, it will not spread in our society. In fact, VR technology is only used in some applications and will not significantly change our living environment. VR sickness is caused by visual stimuli presented to HMD, it can be considered as the same mechanism as visually induced motion sickness (VIMS), which is motion sickness induced by visual stimuli. The mechanism of the occurrence of VIMS has not been clarified in detail, but the theory of sensory discrepancy has been proposed as the cause [3]. Sensory conflict theory is a theory that motion information input to vision and other senses is different from the prediction, causing conflict and inducing motion sickness. In order to minimize the influence of VR sickness on viewers wearing HMD, it is desirable to predict the degree of VR sickness of the observer in advance and to take measures to reduce the discrepancy between motion information inputting visual and other sensory. In this study, we focused on the oscillation generated during vehicle and walking, and conducted an experiment to clarify the oscillation direction and frequency in which VR sickness is likely to occur.

2.1 Apparatus

We used an head mounted display (HMD)(HTC Vive, HTC) to project a visual stimulus placed inside the semi-dark room (1.1 × 1.4 × 1.8 m (width × depth × height)). We installed a chair at the center of the semi-dark room so that an observer sitting upright had her/his feet touching the floor. We measured the observer's postural

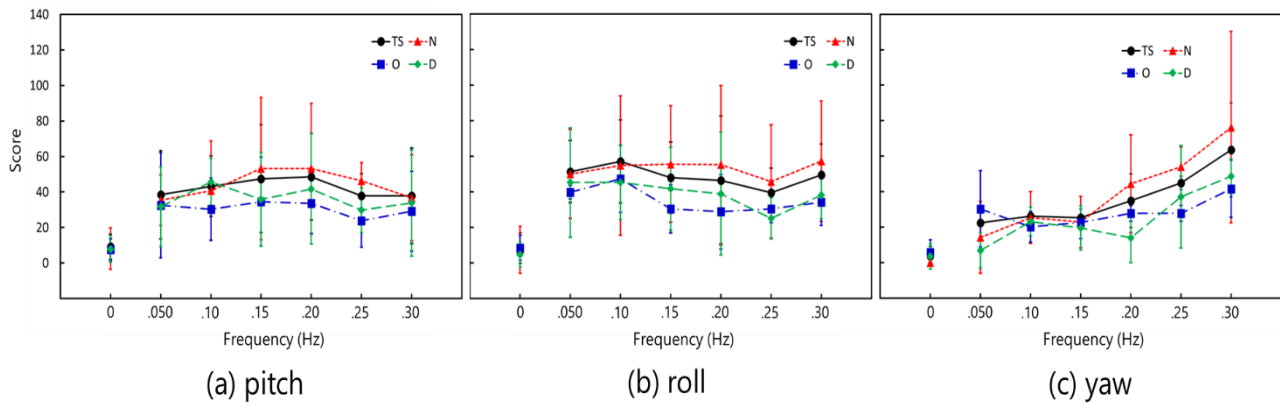


Figure 1. The effect of frequency of three different oscillation types on SSQ's Score
Total Score: TS, Nausea: N, Oculomotor: O, Disorientation: D

movements was measured by a force platform system (Wii Balance Board, Nintendo), which recorded center of foot pressure (COP) data for four different points on the platform at 90 Hz using strain gauges.

2.2 Visual stimulus

A visual stimulus that simulated the motion that participant goes straight (7 (m/s)) with oscillation on an ordinary mountain road rendered as stereoscopic images on Windows-based PC (LITTLEGEAR i330SA4, GTUNE) with Unity. As for the visual stimuli, frame rate was 90 (fps), height was 110 (deg), and width was 110 (deg).

2.3 Experimental Conditions

A visual stimulus oscillated by the rotation of three different types of global motions, such as pitch, roll, yaw axes. We used seven different types of frequency condition (0, 0.05, 0.10, 0.15, 0.20, 0.25, 0.30 Hz). The frequency conditions were decided from previous studies. Amplitude of the oscillation varied according to the frequency conditions so that maximum velocity induced by the oscillation did not exceed 50 (deg/s) in pitch, roll and yaw axes.

2.4 Participants

In the condition of oscillating in the pitch direction, twenty-seven adults (twenty-four male, three female; 21.90 ± 0.97 years) participated in the experiment. In the condition of oscillating in the roll direction, thirteen adults (thirteen male; 21.70 ± 0.72 years) participated in the experiment. In the condition of oscillating in the yaw direction, eleven adults (eleven male; 21.70 ± 0.72 years) participated in the experiment. All participants participated in the study after providing informed written consent, in accordance with the provisions of the Ergonomics Experiment Policy of the Niigata University. The participants were naïve to the purpose of the experiments and had normal or corrected-to-normal visual acuity.

2.5 Procedure

Before starting the experiment, the participants seated on a seat in a semi-darkened room and allowed his/her eye to adjust to the darkness for 10 minutes. Then, the participants fixed his/her head on the chin rest and put the HMD on his/her head.

The participants observed the visual stimuli presented on the HMD for 300 seconds. The participants evaluated the VIMS strength as Simulator sickness questionnaire (SSQ) before and after viewing the visual stimulus. The SSQ questionnaire consisted of 16 questions which were adjusted Japanese translation of previous study and four choices of answers (none, slight, moderate, severe) on VIMS.

Upon completion of these tasks, each participant rested for 20-minute in the quasi-dark room. Under each experimental condition, all the participants participated on four different days, with two trials per day. However, only on day 4, the participants conduct one trial.

2.6 Results and Discussion

When the rotational oscillation axis of the visual stimulus differs from the gravity axis, the tendency of VIMS strength differs. In the condition of oscillating in the pitch direction, there was a statistically significant difference between the frequency conditions in the Total Score and three sub scores (Total Score: $F(6, 90) = 6.311, p = 0.00001$). In the condition of oscillating in the roll and yaw direction, however, there was no statistically significant difference between the frequency conditions in the Total Score and three sub scores (Total score (roll): $F(6, 84) = 1.115, p = 0.72$, Total Score (yaw): $F(6, 65) = 2.552, p = 0.056$). These results suggested that VIMS induced in the condition of oscillating in the pitch and roll direction are increased by the conflict between information from the visual system and from the semicircular canals and otolith organs.

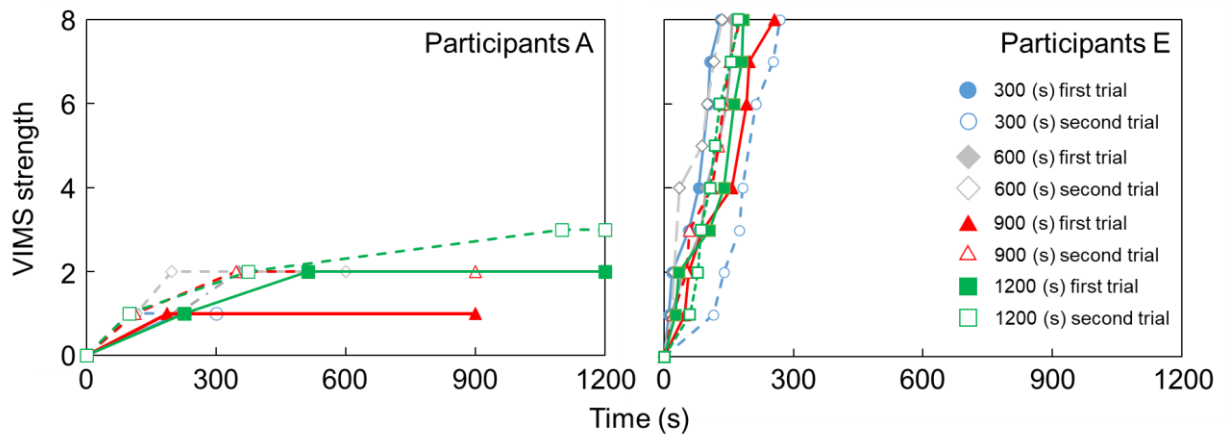


Figure 2. The typical data of changes in severity over time in the onset process of VIMS

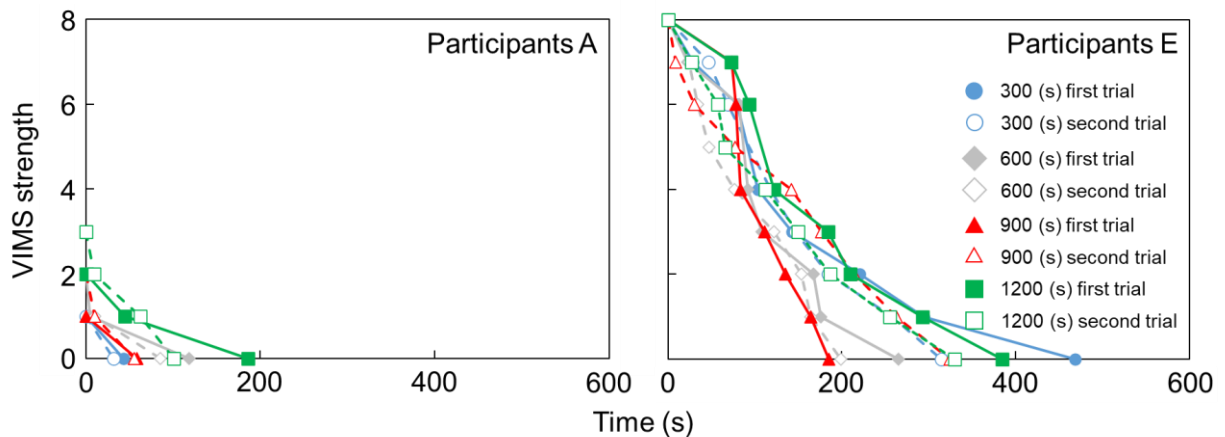


Figure 3. The typical data of changes in severity over time in the recovery process of VIMS

3 Examination of the recovery process of VIMS

When we experience VR contents, it is desired that VIMS does not occur. However, because the detailed mechanism of VIMS has not been clarified, it is impossible to create VR contents that does not cause VIMS in anyone. Therefore, it is important to elucidate the mechanism of the recovery process of VIMS, such as how much time is needed to recover from VIMS. In this study, we focused on the relationship between the occurrence of VIMS by the simplest visual motion stimulus and the recovery process.

3.1 Apparatus

We used an head mounted display (HMD)(HTC Vive Pro 2, HTC) to project a visual stimulus placed inside the semi-dark room (1.1 × 1.4 × 1.8 m (width × depth × height)). We installed a chair at the center of the semi-dark room so that an observer sitting upright had her/his feet touching the floor.

3.2 Visual stimuli

A visual stimulus that simulated rotation of the participant around the observer's the yaw, pitch, roll axes at 70 (deg/s) on an ordinary mountain road rendered as

stereoscopic images on Windows-based PC (LITTLEGEAR i330SA4, GTUNE) with Unity. As for the visual stimuli, frame rate was 90 (fps), height was 110 (deg), and width was 110 (deg).

3.3 Participants

In the condition of rotating in the yaw direction, ten adults (ten male; 22.5 ± 1.12 years) participated in the experiment. In the condition of rotating in the roll direction, ten adults (ten male; 22.5 ± 1.84 years) participated in the experiment. In the condition of rotating in the pitch direction, ten adults (ten male; 21.9 ± 0.88 years) participated in the experiment. All participants participated in the study after providing informed written consent, in accordance with the provisions of the Ergonomics Experiment Policy of the Niigata University. The participants were naïve to the purpose of the experiments and had normal or corrected-to-normal visual acuity.

3.4 Procedure

Before each trial begun, participants were adapted to darkness for 10 minutes by sitting in a quasi-dark room

while wearing an eye mask. After the adaptation, the participant fixed his/her head on the chin rest and wore the HMD on his/her head. At the beginning of each trial, the participants observed the visual stimuli presented on the HMD for four different presentation durations (300, 600, 900, and 1200 (s)) and evaluated the change in VIMS strength over time on an 11-point scale. On that scale, the value "0" indicates "did not feel anything strange", and "10" indicates "feeling sick and nauseous (like motion sickness)". The observers then expired the presentation of visual stimulus when the VIMS strength was greater than the value "8" or after 20 minutes. After the presentation of visual stimulus, the participants observed a dark screen on the HMD until the VIMS strength was the value "0".

Upon completion of these tasks, each observer rested for 20-minute in the quasi-dark room. Under each experimental condition, all the observers participated on four different days, with one trial per day.

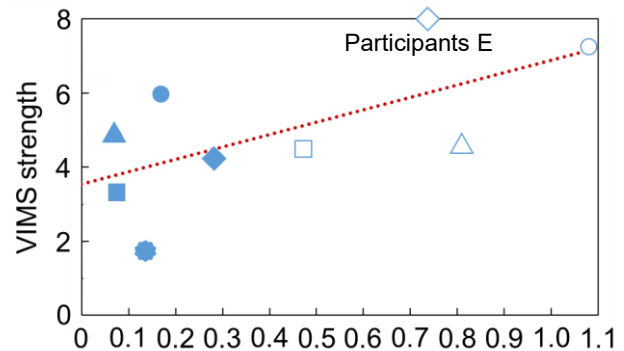
3.6 Results and Discussion

The VIMS strength varies linearly in both the onset and recovery processes (Figure 2, 3). In order to see the correspondence between the onset and recovery processes of VIMS, the ratio of the slope of the VIMS strength onset process to the slope of the recovery process was approximated linearly by the least-squares method. As a result, the standard deviation of the slope was smaller in the group in which the slope of the VIMS onset process/the slope of the recovery process was less than 1, and the standard deviation of the slope was larger in the group in which the slope of the VIMS onset process/the slope of the recovery process was greater than 1. Furthermore, a moderate positive correlation was found between the standard deviation of the slope of the VIMS onset process/recovery process and the mean peak severity ($r = 0.647$).

Based on the results of this study, the group with a large standard deviation of the slope of the onset/recovery process is considered to be the group with a high susceptibility to VIMS, and the group with a small standard deviation of the slope of the onset/recovery process is considered to be the group with a low susceptibility to VIMS. The group with high susceptibility to VIMS may not be able to adjust the gain in the observer appropriately, based on the observer theory [4, 5]. In observer theory, the gain of an observer works to reduce the difference between the actual output of the sensory organs and the output of the observer. If the gain is not properly adjusted, the difference may not be reduced, and either discrepancies are likely to accumulate or it may take time for the discrepancies to be reduced. On the other hand, if the standard deviation of the slope of the generation process/recovery process is small, the gain adjustment in the observer is considered to be appropriate.

4 Conclusion

In this conference presentation, it was shown that the mechanism of VR sickness was clarified from the perspective of both the process of VR sickness onset and the process of recovery. As these research show, it is not easy to remove the barrier of "VR sickness" from VR



The SD of the ratio of $\frac{\text{the slope of the VIMS onset process}}{\text{the slope of the VIMS recovery process}}$

Figure 4. The relationship between the average of VIMS-strength and the SD of the ratio of VIMS onset process to VIMS-recovery process

* Each plot shows each participant

technology applied contents. Therefore, the author has changed the concept and developed a VR system that resolves the inconsistency of self-motion information input to each sense. I hope that this method will be a new solution to remove VR sickness, and we will also continue to elucidate the mechanisms of VR sickness to help human gain access to new spaces.

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