Effects of Types of Active Control of Self-motion Direction on VR Sickness

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ABSTRACT

We conducted two experiments measuring VR sickness using HMD, manipulating active control types of self-motion in VR environment. The results showed the averaged SSQ-TS is the smallest in active control using head movement followed by active control using controller lever and then passive observation.

1 INTRODUCTION

The purpose of the present study is to investigate whether different types of active control of navigation in virtual reality affect virtual reality (VR) sickness differently.

Recent advanced technology of moving images developed head mounted displays, HMDs, with higher resolution, lighter weight, and less expensive, which promotes experience of VR at home, especially in entertainment field. One of the primary characteristics of VR is to let viewers “move around” virtual world actively. In fact, in some types of VR facility, people walk around, and in other types, they “move around” by active control of navigation using controller.

The literature reported that active control of navigation in VR space reduces the severity of VR sickness[1, 2], which may be explained by widely accepted hypothesis of sensory conflict[3]. This hypothesis suggests that sickness occurs when the pattern of sensory signals do not correspond to the pattern expected from the past experience. In the situation of navigation in VR, people often suffer from VR sickness, because only visual information indicates their motion, while such visual information is intrinsically produced in combination, for example, with proprioceptive information of “walking”. However, in the situation of active control of navigation, VR sickness can be alleviated because active control provides the prediction for the direction of travel, which might reduce the mismatch between obtained and expected sensory patterns.

Active control of navigation, however, can be possible in various ways; some can be intuitive and others not, some can involve bodily actions and others use controllers, some can be easier to get used to control and others may be harder. To investigate the effects of different types of active control of self-motion direction on VR sickness, we used two different types of active control methods: (a) head movement, and (b) controller lever. They are compared with passive viewing of the same route with active control of navigation.

2 METHODS

2.1 Participants

Twenty-eight adults (9 females and 19 males, aged 24.6±9.0 years), in Experiment 1, and fifty-nine adults (14 females and 45 males, aged 28.2±3.7 years), in Experiment 2, were participated after providing informed written consent, in accordance with the provisions of the Ergonomics Experiment Policy of the National Institute of Advanced Industrial Science and Technology (AIST). The participants were free to withdraw at any time during the experiments. The experimental protocol was approved in advance by the Institutional Review Board of AIST. The participants were naïve as to the purpose of the experiment, and had normal or corrected-to-normal visual acuity.

2.2 Apparatus and stimulus

Moving images, simulating self-forward motion of participants, were CG images produced with Unity graphics software on a Windows10 PC (Core-i7) with a graphics card (GeForce GTX1080), and were presented on a HMD (Oculus, Oculus Rift CV1). The size of the visual field was approx. 110 deg diagonal, and frame rate was 90 fps.

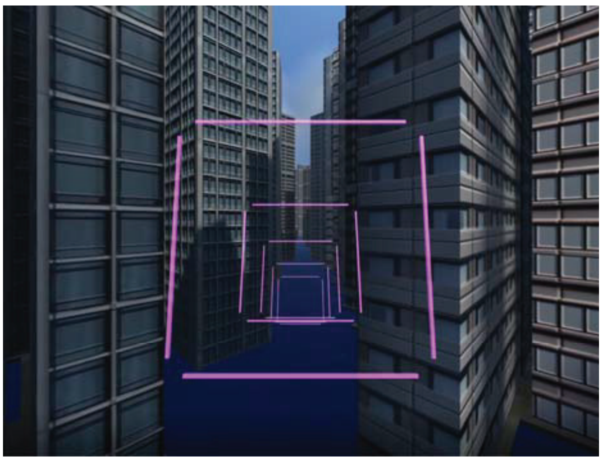

Fig. 1 Stimulus image presented on the HMD

The images were a first person view simulating flying through a group of buildings (see Fig. 1). In the image, there is a series of red-colored square frame indicating the path the first person view image is going through. The surrounding buildings emphasize the vertical (gravity) direction. By going through the square frame, optic flow of the images, which was almost common in all the experimental conditions, showed pitch motion. In an experimental trial of 270 s, both turning up of 22.5 deg and turning down of 22.5 deg were included 24 times each. Therefore, there were a total of 540 deg turning up and 540 deg of turning down.

2.3 Stimulus conditions

There were mainly three different experimental conditions: “Passive”, “Active-HM”, and “Active-C” conditions. In “Passive” condition, virtual camera shooting the image moved forward with changing its moving direction in pitch (turning up/down) automatically so that the first person view of the image went through at the center of the square frame. In this condition, participants viewed the stimulus image on the HMD without any active control or head movement. In “Active-HM” condition, the virtual camera moved forward with changing its moving direction in pitch according to the pitch angle in which the participants turned the head, so that the first person view of the image went through at the center of the square frame. In this condition, however, the direction of “virtual camera” was accidentally remained level different from other two conditions in which “virtual camera” pointed in the direction of travel, which needs to be considered for evaluating the results. In “Active-C” condition, the virtual camera moved forward with changing its moving direction in pitch according to the angle at which the controller lever was tilted by the participants, so that the first person view of the image went through at the center of the square frame. In those two active conditions, the participants practiced how to adjust the moving direction using head movement or controller lever before starting experimental sessions.

2.4 Procedures in Experiment 1

Each participant performed in all the three conditions in one day. The three conditions were performed in three different sessions; each session consisted of a trial of either of the conditions. The order of performing three conditions was pseudo-random among the participants.

Each trial consisted of performing Simulator Sickness Questionnaire (SSQ) just before and after viewing image for 270 s. Electrocardiogram was also measured during viewing image. Between each session, there were 45 min of resting period.

2.5 Procedures in Experiment 2

Each participant basically performed in two of the three conditions in two days, one for each day. The two conditions assigned to each participant was performed on two days; one condition was performed in three consecutive sessions held in each of the days. Between each session, there were 5 min of resting period. SSQ was applied just before and after the three sessions, and also between the sessions. Electrocardiogram was also measured during viewing image.

2.6 Preprocessing of SSQ data

Some of the individual SSQ data set obtained in each condition were not included in the analyses, when either of the following conditions was fulfilled:

- SSQ total score (SSQ-TS) before starting the first experimental session in each condition exceeded the value of 10.
- SSQ data set was not completed because of severity of sickness.

3 RESULTS

3.1 Experiment 1

The difference of SSQ total score (SSQ-TS) was obtained by subtracting the score before starting the first experimental session in each condition from those after participating sessions. The SSQ-TS was averaged among the participants for each of the three different conditions, and are presented in Fig. 2a. The mean score of the SSQ-TS is the largest in “Passive” condition, followed by that in “Active-C” and in “Active-HM”. We confirmed the result in statistics; the one-way ANOVA indicates significant main effect of stimulus condition ($F(2, 56) = 4.62$, $p < .05$).

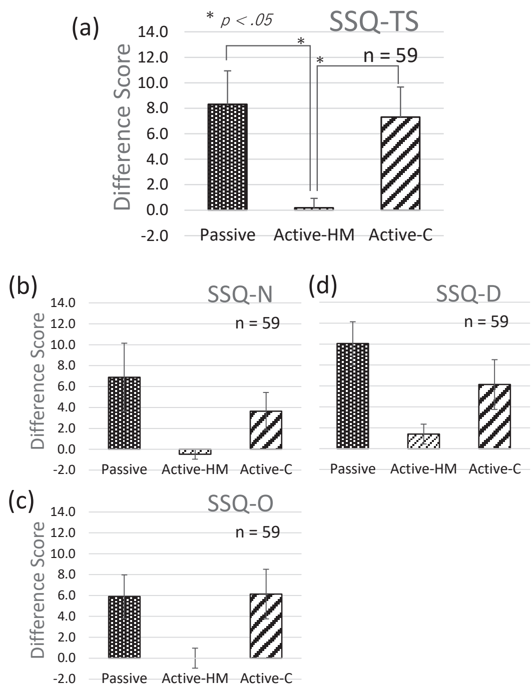

Fig. 2 SSQ scores in Experiment 1
The difference scores of (a) SSQ-TS, (b) SSQ-N, (c) SSQ-O, (d) SSQ-D obtained in three different experimental conditions.

The other SSQ sub-scores are also shown in Fig. 2b to Fig. 2d. The one-way ANOVA indicates significant main effect of stimulus condition in SSQ-O (F(2, 56) = 3.33, *p < .05*), while no significance in SSQ-N (F(2, 56) = 3.10, *n.s.*) and SSQ-D (F(2, 56) = 2.51, *n.s.*).

3.2 Experiment 2

The difference of SSQ total score (SSQ-TS) was obtained by subtracting the score before starting the first experimental session in each condition from those after participating sessions. The SSQ-TS was averaged among the participants for each session and of the three different conditions, and are presented in Fig. 3. The scores increases in each measurement, and again, the score seems to be the largest in “Passive” condition, followed by that in “Active-C” and in “Active-HM”. The two-way ANOVA indicates significant main effect of stimulus condition (F(2, 76) = 5.03, *p < .01*) and of measurement order (F(1.5, 113) = 14.00, *p < .001*), and not significance in the interaction (F(3.0, 113) = 1.00, *n.s.*) between them.

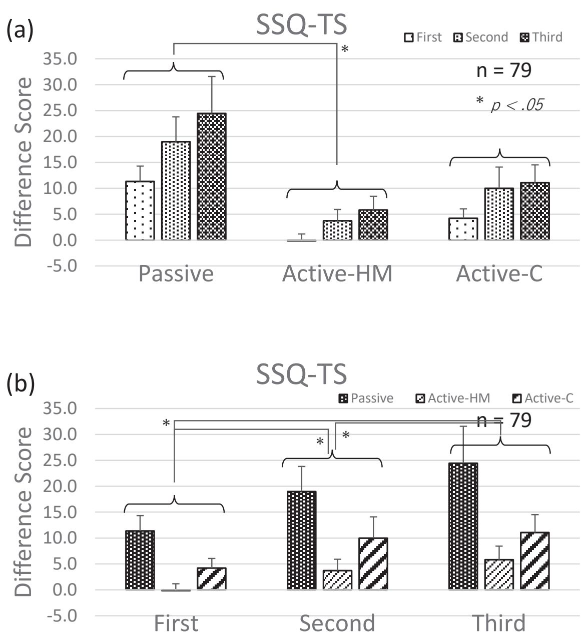

Fig. 3 SSQ total scores in Experiment 2

Identical difference scores of SSQ-TS are plotted (a) for each condition and (b) for the order of the measurement

4 DISCUSSION

Active control of self-motion in virtual reality environment has been reported to alleviate VR sickness (e.g. [1, 2]). However, most of such study compared the effect of active viewing with that of passive viewing, or between active control using two different types of devices (e.g. [4]). The present study suggests that active control of self-motion using body movement, or head movement, have larger effect than active control using controller.

According to the sensory conflict hypothesis, sickness occurs when the pattern of sensory signals do not correspond to the pattern expected from the past experience. People generally and inherently move around by walking and running. In the situation, it has been often discussed that efferent signal from the central nervous system (CNS) reaches effector, or muscle of leg which makes steps forward. Then, re-afferent signal from the sensor in the leg transfers the movement information of feet into CNS. This sensory information is compered with the expected movement information based on efferent signal. In the absence of a disturbance, the information from the two sources are basically matched based on past experience. From that viewpoint, active control navigation without “walking” does not inherently have effect on self-motion, and people learn or adapt to the situation in which active control has effect on self-motion. Then, the different effects of different types of the active control may be the results of the adaptation to each type of control.

Although the result indicates that the SSQ-TS was the lowest in the “Active-HM” among the three conditions, we need to further examine this condition, partly because the visual motion among the three conditions were not perfectly identical.

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