Analysis of Simulator Sickness in IVE by PCA

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1 Introduction

Virtual environment persuaded users feeling similar within the real world. Unfortunately, it also induces simulator sickness for some users. Kennedy and Fowlkes state that the prevalence of sickness symptoms in simulator users ranges from 20% in the “best” simulator to 60% in the “worst” [1]. The impact of influential factors on virtual reality-induced symptoms and effects are virtual reality system, virtual environment, and individual participant characteristics [2]. There are researches published the sickness related as the older participants had a greater likelihood of simulator sickness than younger participants [3], subjects exhibited more postural disturbance with increasing field-of-view [4], parallax and number of display screens effect to simulator sickness [5]. Even though several factors effect to simulator sickness but they are not present what is the most important factor of sickness.

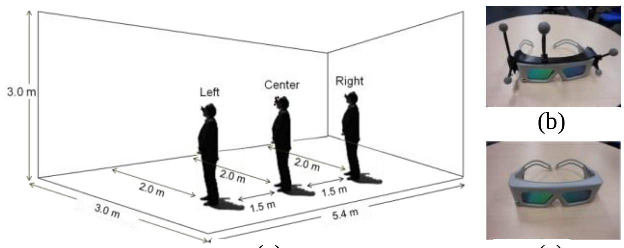
Therefore, main purpose of this paper is to analyze simulator sickness results for specify the important influential factors of sickness, then proposal for safety immersive virtual environment.

2 Method and Results of Experiment 1

The immersive virtual environment is tested by three-screen (front-right-floor) HoloStage™ system in Tokai University, Takanawa Campus. The condition is one group of three subjects stand in left, center, and right position by randomly assigned, but grouped entirely male or female first, then mixed the residual. The center subject called driver wears controlled glasses that synchronize scene movement related with their head movement. The left and right subjects called passengers wear stereo glasses that can see the 3D but not control the scene movement. The subjects standing are shown in Fig.1. All subjects were healthy, as determined by health questionnaire and had normal or corrected to normal vision. They were not ate food or drunk caffeine at least 2 hours prior the experiment. We explained content details and obtained consent from all subjects prior to the experiment. One subject was tested for only one experiment in order to avoid familiarity of the scene due to repeated exposure and also people habituate to the visual appearance of motion [6].

After virtual content experimented with no audio, subjects are request to answer Simulator Sickness Questionnaire (SSQ) within 5 minutes. The SSQ was proposed by Kennedy et al.[7] consisted of sixteen symptoms; general discomfort, fatigue, headache, eyestrain, difficulty focusing, increased salivation, sweating, nausea, difficulty concentrating, fullness of head, blurred vision, dizzy (eyes open), dizzy (eyes closed), vertigo, stomach awareness, and burping. The SSQ results were measured only post-test experiment because simulator sickness after immersion in a virtual environment are much greater when both pre- and post- questionnaires are given than when only a post-test questionnaire is used.

All subjects were asked to do not move their heads during the experiment and allow eliminating anytime when they feel too severe sickness



(a) (b) (c)

Fig. 1. Subject positions in HoloStage™ experiment.
(b) controlled glasses (c) stereo glasses.

2.1 Experiment 1

The simulator sickness affects by different parallax was used VR4MAX software to set the parallax as distance between eyes in the scene period. The parallax are set as 2.0 cm (common parallax for 3D image in commercial cameras), 6.5 cm (normal distance between human left and right eyes), and 9 cm (severe parallax) for three-screen HoloStageTM system with wide-road animation content as shown in Fig. 2 for 4 minutes long.

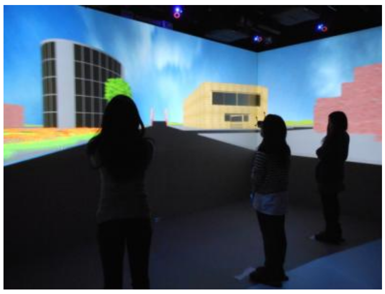


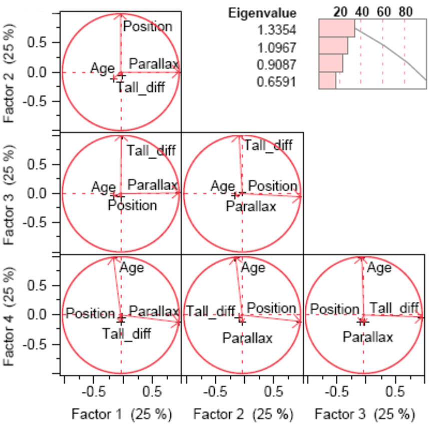
Fig. 2. The 1st experiment with wide road content.

Subjects are twenty-eight students and lecturers from Tokai University, Japan and KMITL, Thailand in age between 19-37 years old (avg.=23.61years, variance=25.34), 20 males and 8 females, height 152-181 cm (avg.=168.89 cm, variance=57.84), 14 Japanese and 14 Thai, and they are 16 experienced and 12 non-experienced in HoloStage™ system.

2.2 Experiment Results 1

The elder subject prone to sickness more than younger one, however, the moderate group (26-30 years old) also has high sickness. Passenger that taller than driver, prone to get higher sickness than the shorter one. Gender and nationality are no significant difference and experience affect in immersive virtual environment is significant difference. Simulator sickness from parallax affect in nausea, oculomotor, and disorientation (NOD) are presented by ascending order as 6.5 cm<2.0 cm<<9.0 cm. Furthermore, the most important effect factors of Age, Tall_diff (tall difference between passenger and driver), Position, and Parallax are analysis by principal component analysis (PCA).

2.3 Result 1 Analysis by PCA



	Factor 1	Factor 2	Factor 3	Factor 4
Age	-0.125168	-0.112636	-0.032920	0.985171
Position	0.000352	0.992405	-0.054649	-0.110211
Parallax	0.992410	0.000308	0.011176	-0.122460
Tall_diff	0.011047	-0.053678	0.997995	-0.031651

Fig. 3. PCA of 1st experiment results.

The Eigenvalue of factors in descending order are Parallax (33.38%), Position (27.42%), Tall_diff (22.72%), and Age (16.48%). Then, the most important factors of sickness are Parallax, Position and Tall_diff, respectively, in total 83.52%. Figure 3 shows comparing of each factor, that higher parallax, right position, higher passenger than driver, and elder subject prone to higher sickness.

3 Method and Results of Experiment 2

3.1 Experiment 2

Simulator sickness affect by different positions are repeated experimented with new subject group in three-screen HoloStageTM system. The content was changed to narrow road animation walkthrough as shown in Fig. 4 that added more near-road details and color, testing for 5 minutes long.

Subjects are fifteen students from Tokai University in age between 22-34 years old (avg. =24.13 years, variance=6.88), 11 males and 4 females, 12 Japanese, 2 Thai, and 1 Indonesian, height 154-178 cm (avg. =168.47 cm, variance=45.63) and they are 13 experienced and 2 non-experienced in HoloStage™ system. The author explained purpose and obtained consent from all subjects before the experiment.

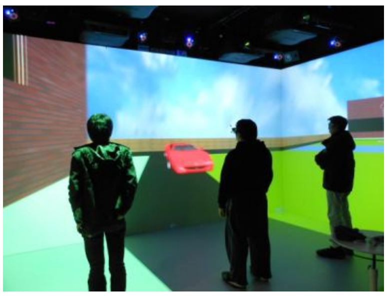


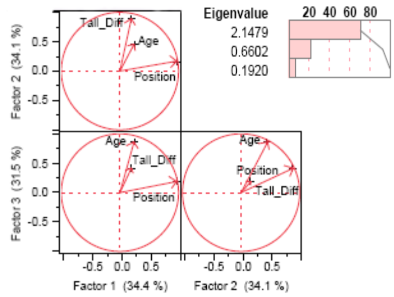
Fig. 4. The 2nd experiment with narrow road content.

3.2 Experiment Result 2

The passenger taller than driver prone to has got higher sickness. The elder subject prone to has got higher sickness than younger one. Simulator sickness in positions center<left<<right. Moreover, the most important effect factors of Age, Tall_diff and Position are analysis by principal component analysis (PCA).

3.3 Result 2 analysis by PCA

The Eigenvalue of factors in descending order are Position (71.59%), Tall_diff (22.01%), and Age (6.40%). Then, the most important factors of sickness are Position and Tall_diff in total 93.60%. Figure 5 shows comparing of each factor, that right position, higher passenger than driver, and elder subject prone to higher sickness.



	Factor 1	Factor 2	Factor 3
Age	0.2401086	0.4530016	0.8585671
Tall_Diff	0.1947183	0.8889237	0.4146076
Position	0.9675592	0.1678606	0.1888173

Fig. 5. PCA of 2nd experiment results.

4 Conclusion

From experiment results analysis by PCA, the most important factor for simulator sickness is parallax, that high parallax as 9.0 cm induced higher sickness than less parallax. If irrespective of parallax, from both experiment 1's and 2's results, the next important factors are position and then tall difference between passenger and driver, respectively. Right position suffers higher sickness. The subjects in right position that standing near three borders of screen is the worst or prone to get higher sickness. Finally, passenger who is taller than driver sustains higher sickness than shorter passenger.

Proposal for safety IVE are set parallax as 6.5 cm, set passenger that shorter or similar with driver's height, or better set for bird's eyes view and avoid the position that near connected several borders. The relation of convergence and simulator sickness will research in future work.

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