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Paper

Study on Parallax Affect on Simulator Sickness in One-screen and Three-screen Immersive Virtual Environment

by

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Abstract

Virtual environment induces simulator sickness effect for some users. The purpose of this research is to study the simulator sickness relative with different parallax affect in one-screen and three-screen HoloStage™, measured by Simulator Sickness Questionnaire. The results show three-screen induced simulator sickness less than one-screen and parallax 6.50 cm decrease simulator sickness than parallax 2.00 cm. The top-three highest simulator sicknesses are eyestrain, general discomfort and fatigue. And effect from the Oculomotor (O) is more than from the Disorientation (D) and more than from the Nausea (N) or represented as O>D>N.

Keywords: Immersive virtual environment, simulator sickness questionnaire, t-test, HoloStage™

1. Introduction

Virtual environment has become currently considerable and omnipresent technology in several fields as entertainment purpose, training, medicine, architecture and telepresence.

Although this new technology is wildly used, some users indicate symptom from virtual environment. There are reseach about simulator sickness in virtual army training report [1]-[2]. And universal research as propose the reason of simulator sickness depends on frequency of simulator motion mismatch [3], effect of environment characteristics [4], effect of field of view on presense, enjoyment, memory [5]. Groups of research proposed the simulator sickness from eye gazing by adjusted the scene [7-9] or intensity [10]. These beneficial researchs help to improve future content of virtual environment.

This paper studies parallax affect of virtual environment by using post-test Simulator Sickness Questionnaire (SSQ) to evaluate the simulator sickness from the virtual animation in one-screen and three-screen HoloStage™.

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2. Methods

2.1 *Experiment*

The experiment has been done with HoloStage™ system [11] as shown in Fig. 1. The HoloStage™ has three sides of 2×4, 2×2, and 2×4 meters for front side, right side and bottom side, respectively. The system consists of five stereoscopic channels eye-tracked projection system powered by the VR4MAX extreme multi-channel rendering software.

Fig. 1 HoloStage™ system in Tokai University

The procedure tested by using VR4MAX software to set the parallax for distance between eyes in the scene period. The distance between eyes is set to 2.00 centimeters (cm) for less parallax and 6.50 cm which is normal distance between

human eyes for normal parallax for one-screen and three-screen HoloStage^{TM} system.

The animation control same virtual walking for every subject, the city-walkthrough simulation is used. The walkthrough in scene as shown in Fig. 2 includes random turn left, turn right and cross the bridge for two minutes period of time.

2.2 *Subjects*

Twenty-three healthy subjects participated in the study. The entire subjects are Japanese student in Tokai University and all of them have experienced in HoloStage^{TM} system. The authors explain a purpose and the contents of the study to subjects, and obtained consent. The gender of subjects is irrelevant referred to [12] reported that virtual environment creates the similar effect on both male and female person. The subject divided into 4 groups of testing;

1) One-screen HoloStage^{TM} system with 2.00 cm parallax; 6 subjects (5 Male persons and 1 female person) age between 21-28 years with age average of 23.67.
2) Three-screen HoloStage^{TM} system with 2.00 cm parallax; 5 subjects (4 Male persons and 1 female person) age between 22-24 years with age average of 22.80.
3) One-screen HoloStage^{TM} system with 6.50 cm parallax; 6 subjects (5 Male persons and 1 female person) age between 21-26 years with age average of 22.83.
4) Three-screen HoloStage^{TM} system with 6.50 cm parallax; 6 subjects (6 Male persons) age between 22-25 years with age average of 23.33.

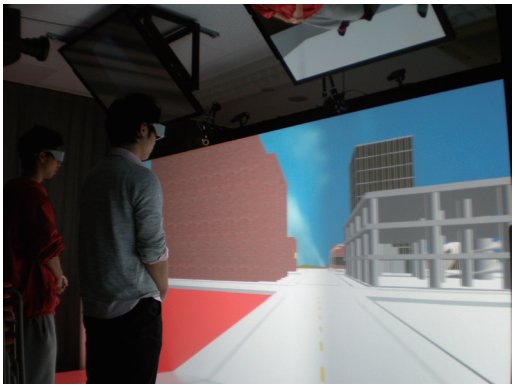

Fig. 2 Scene of experiment

One subject group is tested for only one experiment in order to avoid familiarity of the scene due to repeated exposure as suggested in [13].

3. Results

3.1 *Analysis in mean degree of symptom*

The results are evaluated by the famous Simulator Sickness Questionnaire (SSQ) [14-17] for post experiments. The SSQ consist of 16 symptom questions; general discomfort, fatigue, headache, eyestrain, difficulty focusing, increased salivation, sweating, nausea, difficulty concentrating, fullness of head, blurred vision, dizzy (eyes open), dizzy (eye closed), vertigo, stomach awareness and burping. The answer choices are none (0), slightly (1), moderate (2) and severe (3) feeling sickness in each symptom. The percentage in mean of each degree of symptom is shown in Fig. 3.

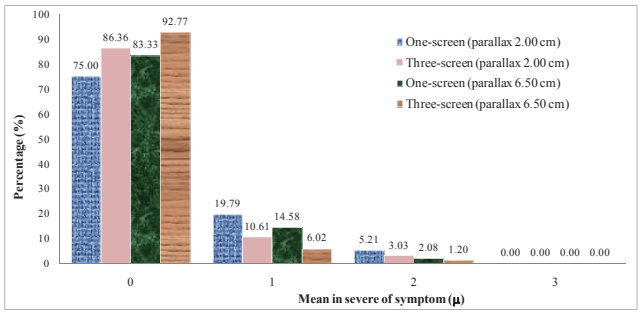

Fig. 3 The mean of each degree of SSQ symptom (0, 1, 2, 3; none, slightly, moderate, severe feeling)

For overall 16 SSQ questions, most subjects respond no effect (or 0) as 75.00%, 86.36%, 83.33% and 92.77% represent to group 1, group 2, group 3 and group 4, respectively.

The experiment reports slightly feeling sickness (or 1) as 19.79%, 10.61%, 14.58% and 6.02% and moderate sickness (or 2) as 5.21%, 3.03%, 2.08% and 1.20% in order of group 1, group 2, group 3 and group 4, respectively.

Nobody responds for severe symptom (or 3) in SSQ.

3.2 *Analysis in sixteen questions*

Mean (μ) and Standard Deviation (SD) by weighting with number of subjects in each group for sixteen equations are shown in Fig. 4 (in the last page). Three highest-means for the one-screen system with 2.00 cm parallax comes from general discomfort and fatigue (μ=0.83), fullness of head (μ=0.67) and difficulty concentrating (μ=0.50). While reporting no symptom for headache, increased salivation, sweating and burping.

Three highest-means for the three-screen system with 2.00 cm parallax are from eyestrain (μ=1.00), general discomfort and headache (μ=0.80) and fullness of head and blurred vision (μ=0.60). While reporting no symptom for vertigo, stomach awareness and burping.

Three highest-means for the one-screen system with 6.50 cm parallax are from general discomfort (μ=0.83), eyestrain (μ=0.50) and vertigo (μ=0.33). While reporting no

symptom for headache, sweating, blurred vision, dizzy (eyes closed) and burping.

Three highest-means for the three-screen system with 6.50 cm parallax comes from fatigue and eyestrain (μ=0.67), general discomfort and difficulty concentrating (μ=0.50) and difficulty focusing (μ=0.33). While reporting no symptom for sweating, nausea, dizzy (eye open), stomach awareness and burping.

However, Fig.4 (in the last page) shows graph in high mean is high standard deviation that indicate the data is spread out over a wide range of values or just few subjects have prestige severe feeling.

3.3 *Analysis in Nausea, Oculomotor and Disorientation*

Group the symptoms from the questionnaire to three distinct symptom clusters [14], by group the symptom increased salivation, nausea, stomach awareness and burping as *Nausea* (N), symptom headache, eyestrain, difficulty focusing and blurred vision as *Oculomotor* (O), and symptom dizzy (eye open), dizzy (eye closed) and vertigo as *Disorientation* (D). The average score of three distinct symptom clusters is shown in Fig. 5.

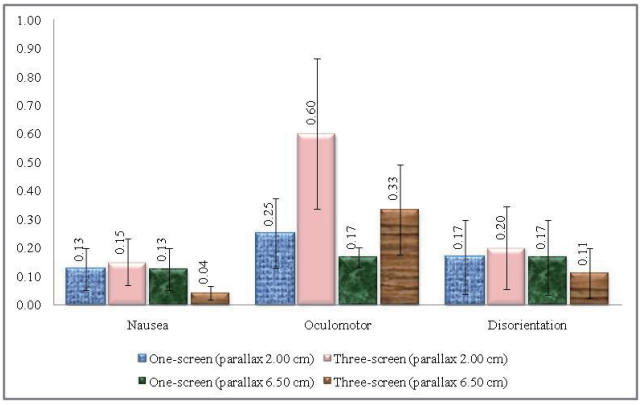

Fig. 5 The comparative results between three distinct symptom clusters

The most effect for the mean of degree of symptom for one-screen system with 2.00 cm parallax is oculomotor (μ=0.25), more than disorientation (μ=0.17) and more than nausea (μ=0.13) or (O>D>N).

The most effect for the mean of degree of symptom for three-screen system with 2.00 cm parallax is oculomotor (μ=0.60) that outstanding highest, more than disorientation (μ=0.20) and more than nausea (μ=0.15) or (O>D>N).

The most effect for the mean of degree of symptom for one-screen system with 6.50 cm parallax is oculomotor and disorientation (μ=0.17) and more than nausea (μ=0.13) or ((O=D)>N).

The most effect for the mean of degree of symptom for Three-screen system with 6.50 cm parallax is oculomotor (μ=0.33), more than disorientation (μ=0.11) and more than nausea (μ=0.04) or (O>D>N).

4. T-test Evaluation

The results of four groups; one-screen/parallax 2.00 cm, one-screen/parallax 6.50 cm, three-screen/parallax 2.00 cm and three-screen/parallax 6.50 cm are evaluation by *t* test, two tailed type, to indicate the significant difference of simulator sickness between each group in sixteen questions and Nausea, Oculomoter and Disorientation cluster.

4.1 *Analysis in sixteen questions*

We set α=0.05 then t=2.0003. Fig. 6 shows mean of simulator sickness in sixteen questions of each group experiment that connected with black line on blue virtical bar of standard error plot. Average mean of four groups is 0.30 ±0.13.

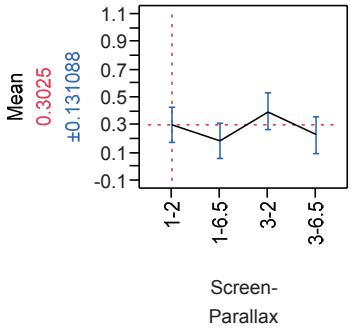

Fig. 6 Comparative relation between mean of screen-parallax pairs in sixteen quesions

Table 1 Evaluation between groups in sixteen questions

Group	Symbol		Least Sq Mean
Three-screen /Parallax 2.00 cm	A		0.40
One-screen /Parallax 2.00 cm	A	B	0.30
Three-screen /Parallax 6.50 cm	A	B	0.23
One-screen /Parallax 6.50 cm		B	0.19

The symbol letter in Table 1 shows that groups not connected by same letter have significant difference. Therefore, either first three groups above or last three groups below of Table 1 do not have significant difference of simulator sickess. Only the simulator sickness result of three-screen/parallax 2.00 cm and one-screen/parallax 6.50 cm has significant difference.

4.2 *Analysis in Nausea cluster*

In Nausea cluster, we set α=0.05 then t=2.17881 for *t* test. The mean of four groups is 0.13±0.15 shown in Fig. 7.

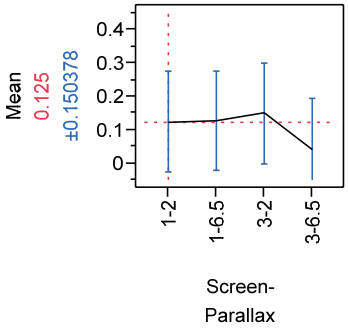

Fig. 7 Comparative relation between mean of screen-parallax pairs in Nausea cluster

Table 2 Evaluation between groups in Nausea cluster

Group	Symbol	Least Sq Mean
Three-screen /Parallax 2.00 cm	A	0.15
One-screen /Parallax 6.50 cm	A	0.13
One-screen /Parallax 2.00 cm	A	0.13
Three-screen /Parallax 6.50 cm	A	0.04

Result shows every group is connected with same letter, and then four groups do not have significant difference of simulator sickness in Nausea cluster.

4.3 *Analysis in Oculomotor cluster*

In Oculomotor cluster, we set α=0.05 then t=2.17881 for *t* test. Fig.8 shows mean of four groups is 0.25±0.26.

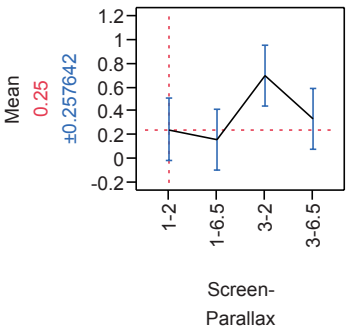

Fig. 8 Comparative relation between mean of screen-parallax pairs in Oculomotor cluster

Table 3 Evaluation between groups in Oculomotor cluster

Group	Symbol		Least Sq Mean
Three-screen /Parallax 2.00 cm	A		0.70
Three-screen /Parallax 6.50 cm		B	0.34
One-screen /Parallax 2.00 cm		B	0.25
One-screen /Parallax 6.50 cm		B	0.17

Result shows only three-screen/parallax 2.00 cm has significant difference from others; three-screen/parallax 6.50 cm, one-screen/parallax 2.00 cm and one-screen/parallax 6.50 cm that do not have significant difference of simulator sickness in Oculomotor cluster.

4.4 *Analysis in Disorientation cluster*

In Disorientation cluster, we set α=0.05 then t=2.30600 for *t* test. Fig. 9 shows mean of four groups is 0.17±0.18.

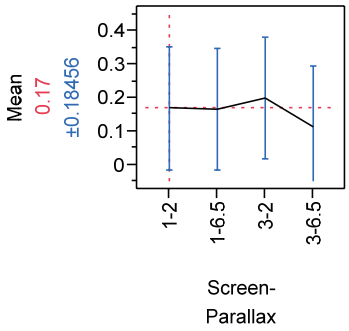

Fig. 9 Comparative relation between mean of screen-parallax pairs in Disorientation cluster

Table 4 Evaluation between groups in Disorientation cluster

Group	Symbol	Least Sq Mean
Three-screen /Parallax 2.00 cm	A	0.20
One-screen /Parallax 2.00 cm	A	0.17
One-screen /Parallax 6.50 cm	A	0.17
Three-screen /Parallax 6.50 cm	A	0.11

Result shows every group is connected with same letter, and then four groups do not have significant difference of simulator sickness in Disorientation cluster.

5. Discussion

The experimentation results show three-screen induced simulator sickness less than one-screen and parallax 6.50 cm, as normal distance between human eyes, decreased simulotor sickness than parallax 2.00 cm, as shown in Fig. 3, especially, about parallax affect in Table 1.

Parallax 2.00 cm, especially for small display like TV, is usually better than 6.50 cm. Because the distance between eyes and display is shorter than real distance between eyes and an object which is shown in display. Actually, 2.00 cm of cameras distance is usually used in a consumer 3D video camera (for example, Panasonic HDC-TM750 and VW-CLT1). However, IVE can provide a real environment according to the distance between eyes and an object (3D scene). Therefore, parallax can be set to the real distance between eyes. Conversely, 2.00 cm is too short to feel appropriate 3D sense in Immersive Virtual Environment.

On the other hand, the comparative results between three distinct symptom clusters from Fig. 5 shows the oculomotor

case, three-screen system affected to simulator sickness more than one-screen system. It caused by distortion in passenger's view. If a subject is a driver by wearing eye track glasses, the subject can be immersed in complete virtual environment. However, if a subject is a passenger, the passenger view is distorted around border of screens.

The top-three highest simulator sicknesses are eyestrain, general discomfort and fatigue, consecutively. The subject responds sweating in only three-screen with 2.00 cm parallax case, also with highest score for eyestrain. None of subjects report for burping or feel severe sickness in every symptom.

The highest effect to subjects comes from oculomotor, and are more than the disorientation and more than the nausea ($O > D > N$). This result represents "seeing" is most important problem for virtual environment.

6. Conclusion

In this study, simulator sickness in Immersive Virtual Environment was investigated according to parallax and the number of screen by using Simulator Sickness Questionnaire. The results show that parallax should be set to 6.50 cm in IVE and the most uncomfortable effect in IVE comes from Oculomotor. In addition, it is suggested that a person not wearing head tracking device feels more uncomfortable sense in multiple screens IVE due to scene distortion.

There remains an investigation about the relationship between parallax and convergence in IVE in the future.

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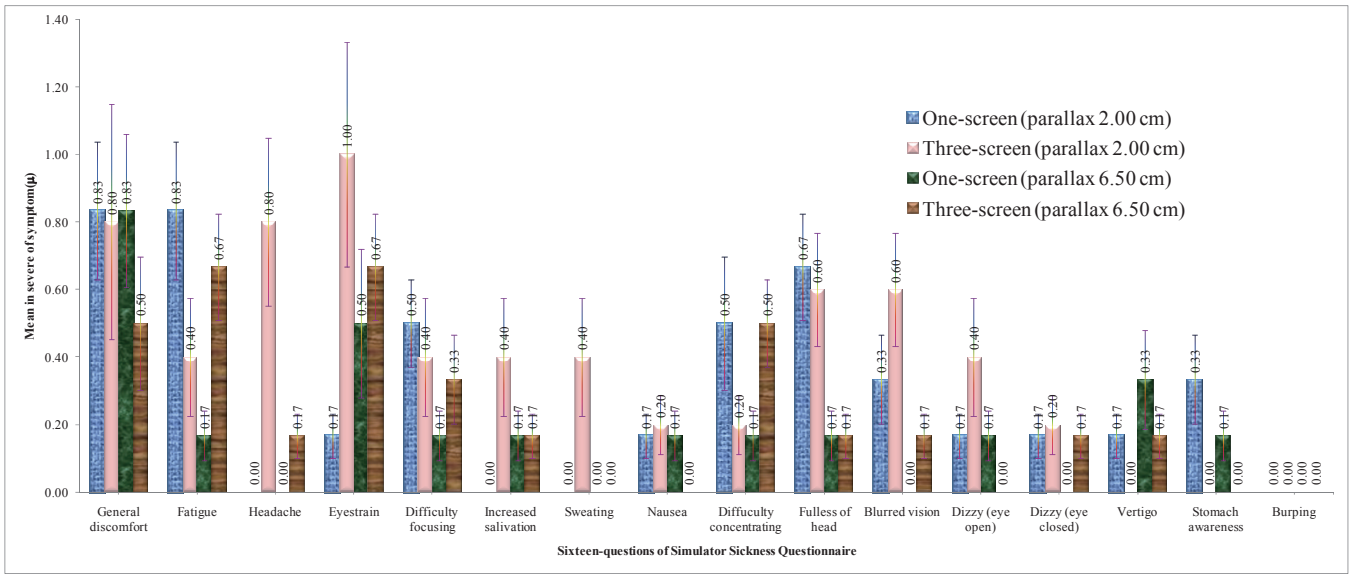

Fig. 4 Mean of sixteen questions for four-group experiments