ICIC Express Letters
Part B: Applications
Volume **8**, Number **10**, October **2017**

ICIC International ©2017 ISSN 2185-2766
pp. 1395–1400

DO INTERACTION MODES INFLUENCE THE DEGREE OF VIRTUAL REALITY SICKNESS?

Mungyeong Choe[1], Yeongcheol Choi[1], Hyun K. Kim[2]
Jaehyun Park[1,*] and Heejin Jeong[3]

[1]Department of Industrial and Management Engineering
Incheon National University
Academy-ro 119, Yeonsu-gu, Incheon 22012, Korea
{ mgyeong; yc.choi }@inu.ac.kr; *Corresponding author: jaehpark@inu.ac.kr

[2]Department of Industrial and Management Engineering
Pohang University of Science and Technology
Cheongam-ro 77, Nam-gu, Pohang, Gyeongbuk 37673, Korea
emokubi@postech.ac.kr

[3]Department of Industrial and Operations Engineering
University of Michigan
1205 Beal Ave., Ann Arbor, MI, USA
heejinj@umich.edu

Received April 2017; accepted July 2017

Abstract. *Motion sickness is a typical side effect of exposure to virtual environments, and there have been ongoing efforts to minimize it. While research has mainly focused on improving the technical design of virtual reality (VR) devices, there is little research on the interaction modes between the users and the VR environment. In this study, we conducted human subject research to investigate the impact of the input method and the size of the target object on VR sickness. Twenty subjects performed four tasks that consisted of pressing a randomly highlighted button among 25 buttons in a 5 × 5 array on a VR screen, with two types of input methods (manual-selection and gaze-selection) and two button sizes. After each task, participants were asked to report simulator sickness questionnaire scores. Experimental results showed that the motion sickness scores were significantly dependent on button size, but not on the input method type. The results of this study can help improve the design of VR environments in order to reduce VR sickness.*

Keywords: Virtual reality (VR), Virtual reality sickness, Motion sickness, Simulator sickness questionnaire (SSQ), Interaction

1. Introduction.

Virtual reality (VR) is a technology that enables a user to experience a virtual world through artificially created situations similar to those in the real world, or those that cannot be experienced in the real world due to time or space constraints [1]. Recently, advances in VR have had a significant impact on developments in computing and network services, as well as in the development of high resolution displays. Moreover, a wide range of VR devices using the head mounted display (HMD) method, which Sutherland proposed earlier [2], are available in the market. Although a VR HMD has the advantage of instantly recording the user's movements and displaying them on the screen, thereby immersing the user in a life-like experience, it also has the side effect of causing motion sickness. One of the most compelling reasons suggested for VR sickness is the discrepancy between the visual information obtained by the eyes and the sense of equilibrium and somatic sensation felt by the body while experiencing VR [3,4]. In order to minimize VR sickness, research has been carried out to improve the VR hardware, and certain techniques have been developed in this regard. A technique to reduce the VR latency, i.e., the time lapse until the user's motion is reflected on the screen, in order to eliminate the gap between the two sets of sensory information [5], has been developed. Another technique sends galvanic vestibular stimulation to the internal ear, depending on the visual information of VR [6]. Furthermore, there are also techniques that can be applied to VR software to reducing motion sickness: for example, blurring the background around the subject being viewed [7,8], and artificially adjusting the field of view at the instant when it can cause motion sickness [9]. However, there are few studies researching VR sickness based on the interaction modes between the user and the VR environment, such as the input method or the size of the input object. This study investigates whether the degree of motion sickness is influenced by the input method or the size of the object selected by the user while wearing a VR headset. For this purpose, we compared the manual-selection and the gaze-selection methods, which are the most popular input methods used in the VR market, and we compared the users' experiences while selecting two different button sizes on the screen. The remainder of this paper is organized as follows. In Section 2, the simulator sickness questionnaire (SSQ) which has been widely used for measuring motion sickness is described in detail. In Section 3, participants, experimental devices and protocols are explained. In Section 4, SSQ scores are compared according to the input method and button size. The results of this study are expected to help in defining design guidelines for future VR environment creation. In Section 5, a discussion on the experiment is shown, and the conclusion is made in the last section.

2. **Simulator Sickness Questionnaire (SSQ).** Kennedy et al. [10] modified the evaluation criteria in the motion sickness questionnaire (MSQ), which is a conventional motion sickness measurement tool, to fit a simulator environment in order to measure the motion sickness levels in the simulator environment. As a result, the SSQ was reduced to 16 questions from the 28 questions of the MSQ, which were divided into three categories: Nausea (symptoms associated with gastrointestinal disorders), Oculomotor (symptoms due to visual discomfort), and Disorientation (symptoms related to vestibular disorders). Table 1 shows the categories of the 16 evaluation items for determining the level of motion sickness and the method to calculate the score of each category.

In addition, Stanney et al. [11] classified the severity of symptoms through the calculated total score (Table 2). Symptoms were divided into six categories, based on their severity. If the sample size is 50 or more, the SSQ score is compared with the average of the scores. Otherwise, it is recommended to compare it with the median or the log-transformed value.

3. **Methods.** Experimental data were collected from 20 participants (male: 10, female: 10). The participants' ages ranged from 18-24 years, with the average age being 22.4 (±1.9) years. Prior to conducting the experiment, the preliminary questionnaire answered by the participants revealed their general susceptibility to motion sickness on a 5-point scale (1 point: Not at all, 2 points: Slightly, 3 points: Moderately, 4 points: Very, and 5 points: Extremely). The average score obtained was 2.2 (± 1.5). Among the participants, 12 respondents answered that they had some VR experience, and one of them said that he/she owns VR devices.

In this experiment, the VR devices used were mainly Samsung Gear VR (SM-R322) and Galaxy S7 (SM-G930). When a smartphone is mounted on a VR headset, it receives data from the inertial measurement unit (IMU) sensor of the smartphone and reflects the head movement of the user on the screen. The VR headset had a viewing angle of 96°, and the smartphone had a resolution of 2560 p × 1440 p. Experimental software was designed and implemented using Unity and C#.

There were two input methods in the VR environment. In the first method, when the target is stared at for a certain period, the target button is selected; this method is

Table 1. Symptoms of SSQ and computation of SSQ scores (Kennedy et al. [10])

SSQ Symptom	Weight		
	Nausea (N)	Oculomotor (O)	Disorientation (D)
1. General discomfort	○	○	
2. Fatigue		○	
3. Headache		○	
4. Eyestrain		○	
5. Difficulty focusing		○	○
6. Increased salivation	○		
7. Sweating	○		
8. Nausea	○		○
9. Difficulty concentrating	○	○	
10. Fullness of head			○
11. Blurred vision		○	○
12. Dizzy (eyes open)			○
13. Dizzy (eyes closed)			○
14. Vertigo			○
15. Stomach awareness	○		
16. Burping	○		
Total Score	(1)	(2)	(3)
	$N = (1) \times 9.54$ $O = (2) \times 7.58$ $D = (3) \times 13.92$ $\text{Total Score} = [(1) + (2) + (3)] \times 3.74$		

Table 2. Categorization of SSQ scores (Stanney et al. [11])

SSQ Score	Categorization
0	No symptoms
< 5	Negligible symptoms
5-10	Minimal symptoms
10-15	Significant symptoms
15-20	Symptoms are a concern
> 20	A bad simulator

called "gaze-selection method". In the VR environment employed in our experiment, this method allowed participants to move the cursor fixed at the center of the screen through head movements. In other words, placing the cursor on the target by moving one's head for a certain period was the way to make the selection. The gaze-time for selecting the target was set to 1 s. The second method, called "manual-selection method", is to select the target by touching the VR headset's touchpad by hand, after hovering the cursor over the target. Twenty-five buttons in a 5 × 5 array were placed on the viewing area at a viewing angle of 90°. The size of the button was set to one of the two levels. The viewing angle of the large button was set to $3^\circ 49' 4''$, and the small button was set to $2^\circ 23' 24''$.

Participants were asked to evaluate their motion sickness using the SSQ questionnaire for each task. The 16 questions asked about the level of physical symptoms the participants felt while performing the tasks. Participants answered each question by rating them as follows: 0 for no symptoms at all, 1 for slight feelings, 2 for normal, and 3 for severe.

Based on the evaluation results, the motion sickness evaluation scores were obtained for each category based on the score calculation method shown in Table 1.

The study participants basically performed four tasks. These were a combination of two methods of input (manual-selection method and gaze-selection method) and two levels of button size. The order of experiments was defined using a Latin square balancing technique to minimize the effect of learning. Prior to conducting the experiment, the participants practiced the manipulation until they were judged capable of completing the tasks well. When the experiment started, the target button that was highlighted with a specific color, among the buttons displayed on the screen, was selected. When the target button was selected four times, one sub-task was completed. Twenty-five sub-tasks were repeated for one task. The participants were asked to complete the SSQ questionnaire at the end of each task, to minimize the motion sickness due to the previous task, and they took a two-minute break before starting the next task.

4. **Results.** ANOVA was employed for each category score of SSQ to investigate the effects of input method and button size on motion sickness (see Table 3). The result of the analysis showed that the input method had no significant impact in the Nausea, Oculomotor, and Disorientation categories. On the other hand, the motion sickness score showed statistically significant difference in all SSQ components depending on the button size.

Table 3. Effect testing between input method and button size (*p < .05)

Factors	Nausea	Oculomotor	Disorientation	Total
Input method (A)	.449	.765	.505	.786
Button size (B)	*.026	*.003	*.004	*.003
A × B	.062	.455	.138	.162

($\alpha = .05$)

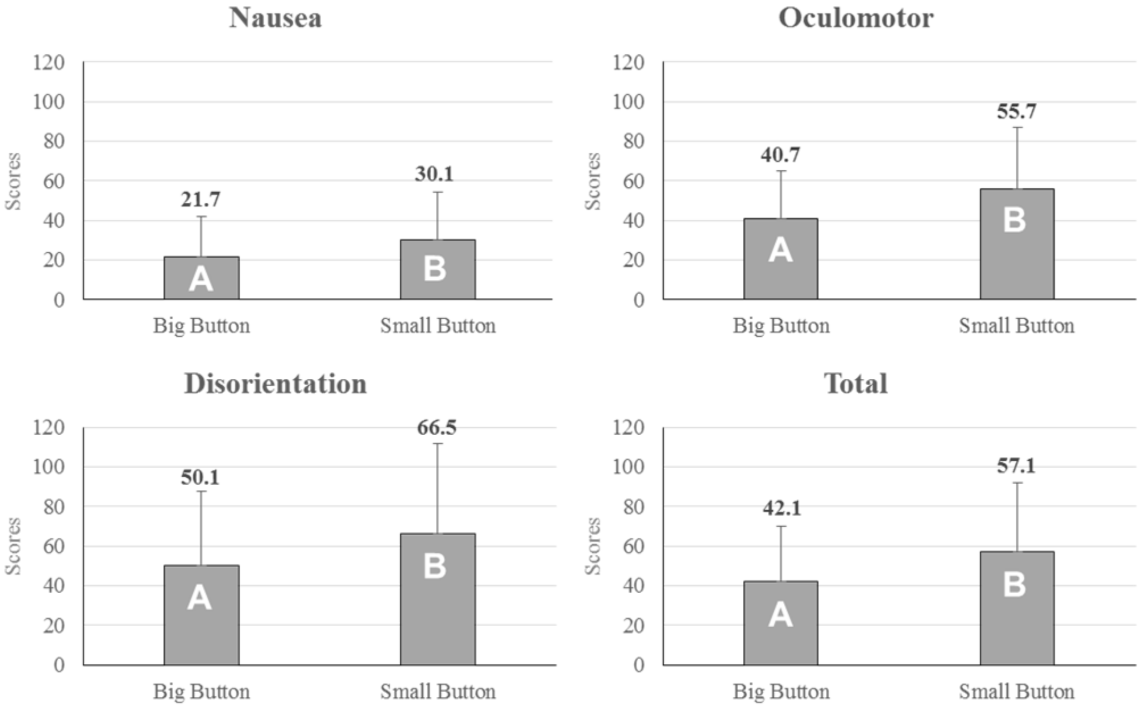

Figure 1. SSQ scores by each button size (Different letters indicate a statistically significant difference)

We compared the mean of the SSQ components for the button sizes showing significant differences in the ANOVA (Figure 1). Consequently, it was confirmed that the small button had a relatively high motion sickness score across each of the categories. The Nausea score was 21.7 points for the big button and 30.1 for the small button. Oculomotor showed 40.7 points and 55.7 points for the big and small buttons respectively, while Disorientation showed 50.1 points for the big button and 66.5 points for the small button. In addition, the total score was 42.1 points for the big button and 57.1 points for the small button. Thus, it was found that the severity of motion sickness was higher when the small button was used.

5. **Discussion.**

In this study, we conducted an experiment that consisted of tasks to press a randomly highlighted button among 25 buttons placed in a 5 × 5 array in a 90° field of view. The results showed that there was an effect of the button size, but no effect of the input method, on motion sickness. There was a difference in the SSQ score between the small button and the big button, with the motion sickness level being higher when the small button was used. In addition, the median SSQ total score derived from this experiment was more than 20 points in all tasks when the small button was used (see Table 4). Therefore, all these tasks were classified as "A bad simulator" according to the categorization listed in Table 2. This means that all experiments pointed to a single factor that was likely to cause a significantly high degree of motion sickness.

Table 4. Median total scores for each experiment

Input method		Button size	
Gaze-selection	44.9 (±34.6)	Big button	37.4 (±28.6)
Manual-selection	41.1 (±32.2)	Small button	52.3 (±35.41)

In this experiment, the button used was one of two sizes. However, in order to check the tendency of motion sickness to depend on button size, it is necessary to further vary the levels of button size. Additional studies may be able to determine the most appropriate size of a button to minimize motion sickness in a VR environment. It is expected that when designing VR environments such as shooter games where random targets appear anywhere within the entire area of the screen, it will be possible to determine the optimal target size to minimize motion sickness by considering the results of this study. In addition, previous research results postulate that the degree of motion sickness felt by the user is dependent on the viewing angle [12,13], and the degree of immersion is also influenced by the viewing angle [14]. Considering these points, a study may be conducted in the future to determine a viewing angle that can significantly lower the level of motion sickness.

6. **Conclusion.**

In this study, we investigated the motion sickness level while using a VR device, depending on two types of input method and two button sizes. The two input methods included gazing at the target for 1 s, or manually touching the VR headset's touchpad after hovering the VR cursor on a 5 × 5 button through head movements. The buttons used were of two different sizes. ANOVA results showed that input method is not a factor that directly influences motion sickness. On the other hand, button size was identified as statistically significant between two levels in all SSQ components (Nausea, Oculomotor, and Disorientation), with the degree of motion sickness being more severe when the button was small. In future studies, more button sizes will be considered, and the influence of the button size on motion sickness will be examined in detail. The results of this study may be applied in the design of VR environments that aim to reduce motion sickness symptoms.

Acknowledgment. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2015R1C1A1A01054148).

REFERENCES

[1] G. Chryssolouris, D. Mavrikios, D. Fragos and V. Karabatsou, A virtual reality-based experimentation environment for the verification of human-related factors in assembly processes, *Robotics and Computer-Integrated Manufacturing*, vol.16, no.4, pp.267-276, 2000.

[2] I. E. Sutherland, A head-mounted three dimensional display, *Proc. of the Fall Joint Computer Conference, Part I*, pp.757-764, 1968.

[3] E. L. Groen and J. E. Bos, Simulator sickness depends on frequency of the simulator motion mismatch: An observation, *Presence*, vol.17, no.6, pp.584-593, 2008.

[4] R. A. Ruddle, The effect of environment characteristics and user interaction on levels of virtual environment sickness, *Proc. of Virtual Reality*, pp.141-285, 2004.

[5] T. Waltemate, I. Senna, F. Hülsmann, M. Rohde, S. Kopp, M. Ernst and M. Botsch, The impact of latency on perceptual judgments and motor performance in closed-loop interaction in virtual reality, *Proc. of the 22nd ACM Conference on Virtual Reality Software and Technology*, pp.27-35, 2016.

[6] M. Cevette, J. Stepanek and A. Galea, *U.S. Patent No. 9,564,059*, U.S. Patent and Trademark Office, Washington, D.C., 2017.

[7] T. Blum, M. Wieczorek, A. Aichert, R. Tibrewal and N. Navab, The effect of out-of-focus blur on visual discomfort when using stereo displays, *The 9th IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp.13-17, 2010.

[8] K. Carnegie and T. Rhee, Reducing visual discomfort with HMDs using dynamic depth of field, *IEEE Computer Graphics and Applications*, vol.35, no.5, pp.34-41, 2015.

[9] A. S. Fernandes and S. K. Feiner, Combating VR sickness through subtle dynamic field-of-view modification, *IEEE Symposium on 3D User Interfaces (3DUI)*, pp.201-210, 2016.

[10] R. S. Kennedy, N. E. Lane, K. S. Berbaum and M. G. Lilienthal, Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness, *The International Journal of Aviation Psychology*, vol.3, no.3, pp.203-220, 1993.

[11] K. M. Stanney, R. S. Kennedy and J. M. Drexler, Cybersickness is not simulator sickness, *Proc. of the Human Factors and Ergonomics Society Annual Meeting*, vol.41, no.2, pp.1138-1142, 1997.

[12] J. W. Lin, H. B. L. Duh, D. E. Parker, H. Abi-Rached and T. A. Furness, Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment, *Proc. of Virtual Reality*, pp.164-171, 2002.

[13] A. F. Seay, D. M. Krum, L. Hodges and W. Ribarsky, Simulator sickness and presence in a high FOV virtual environment, *Proc. of Virtual Reality*, pp.299-300, 2001.

[14] D. A. Bowman and R. P. McMahan, Virtual reality: How much immersion is enough?, *Computer*, vol.40, no.7, 2007.