A Proposal for Discreet Auxiliary Figures for Reducing VR Sickness and for Not Obstructing FOV

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Abstract. We aim to reduce the virtual reality (VR) sickness by superimposing discreet auxiliary figures: “gazing point” on the center of the user’s field of view, “dots” on the four corners of the field of view, “user’s horizontal line” links a line to the user’s head movement, and “real world’s horizontal line” links to the real-world horizontal line. We conducted an experiment to evaluate the degree to which these figures could reduce VR sickness in a VR environment on a head-mounted display (HMD) by using Simulator Sickness Questionnaire (SSQ) and skin conductance (SC) on the user’s palm. The results show that the VR sickness tended to reduce by the superimposition of “dots.”

Keywords: Virtual reality sickness, auxiliary figure, Simulator Sickness Questionnaire, skin conductance.

1 Introduction

In recent years, the market size for virtual reality (VR) technologies, such as head-mounted displays (HMDs) and VR contents, has been increasing. Major VR manufacturers have released stand-alone low-cost HMDs. Therefore, users who previously avoided VR devices because of their complexity and high price have started using them.

However, the spread of VR devices, has also given rise to certain specific health concerns. A number of users have been affected by VR sickness, and this number is expected to increase in the coming years. VR sickness refers to the deterioration of HMD user’s health because of operating the virtual space on a large display and viewing 360° videos on an HMD. The typical symptoms of VR sickness are mild headache and heartburn followed by dizziness and nausea, which eventually leads to vomiting. These symptoms and processes are very similar to motion sickness [1].

The cause of motion sickness has not yet been completely elucidated, but one powerful theory is the sensory conflict theory proposed by Reason and Brand [2]. Sensory conflicts theory classifies motion sickness into two parts: a conflict between the ear canal and otoliths and a conflict between the vision and the vestibular system. Other theories concerning the causes of motion sickness include the subjective vertical conflict theory [3] and the ecological theory of motion sickness [4].

Sensory conflicts are considered a major cause of VR sickness as in the case of motion sickness. In a VR environment in which HMDs and other visual systems are the main stimuli, the vestibular system does not perceive the acceleration of motion even when the visual system perceives the motion. To solve this problem, researchers have proposed methods of moving the user's body directly to stimulate the vestibular system [5, 6]; another methods have been proposed of presenting a visual effect to reduce the degree of conflict in the visual system [7-15]. Moving a user's body is a costly method that requires a large space. On the other hand, presenting a visual effect does not require a large space and costs.

Based on this reasoning, we aim to reduce the VR sickness by superimposing discreet auxiliary figures (see Fig. 1), such as dots and a horizontal line, in a VR space on an HMD. We hypothesized that the superimposition of the figures could reduce the VR sickness without disturbing the user's FOV too much.

Then, we conducted an experiment to measure the degree of VR sickness in a VR environment on an HMD by using Simulator Sickness Questionnaire (SSQ) and skin conductance (SC) to measure mental sweating [16, 17, 18] on the user's palm as evaluation metrics to confirm the reduction effect of each of the auxiliary figures. In the following sections, we describe some related studies, the designs of the four auxiliary figures, the details of our experiment, and the results.

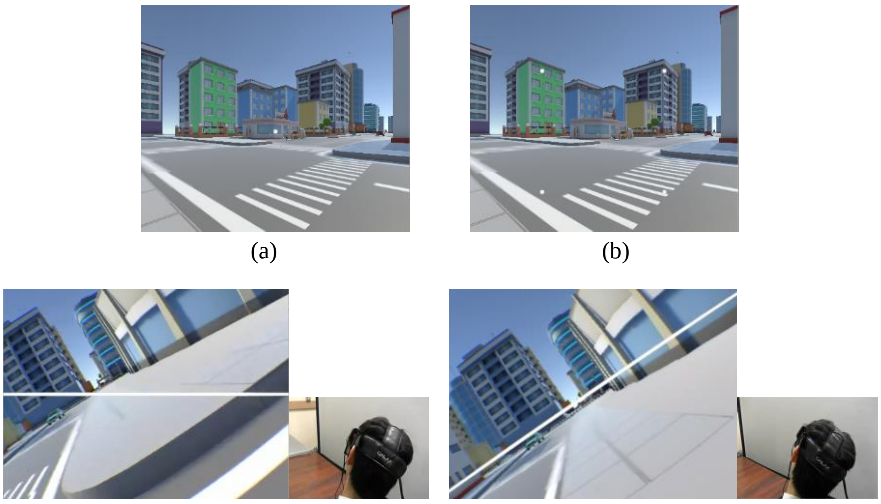
(a) (b) (c) (d)

Fig. 1. Proposed four auxiliary figures with the superimposition of (a) Gazing point, (b) Dots, (c) User's horizontal line, and (d) Real world's horizontal line.

2 Related Work

As a method to change a user's field-of-view, Bos et al. hypothesized that appropriate visual information on self-motion was beneficial in a naval setting and conducted and experiment a ship's bridge motion simulator with three visual conditions: an Earthfixed outside view, an inside view that moved with the subjects, and a blindfolded condition [7]. As the results, sickness was highest in the inside viewing condition, and no effect of sickness on task performance was observed. Norouzi et al. investigated use of vignetting to reduce VR sickness when using amplified head rotations instead of controller-based input and whether the induced VR sickness is a result of the user's head acceleration or velocity by introducing two different modes of vignetting, one triggered by acceleration and the other by velocity [8]. The results show generally indicating that the vignetting methods did not succeed in reducing VR sickness for most of the participants and, instead, lead to a significant increase. Duh et al. suggested that an independent visual background (IVB) might disturbance when conflicting visual and inertial cues [9]. They examined 3 levels of independent visual background with 2 levels of roll oscillation frequency. As the results, there were statistically significant effects of IVB and a significant interaction between IVB and frequency. Sargunam et al. compared three common joystick rotation techniques: traditional continuous rotation, continuous rotation with reduced field-of-view, and discrete rotation with fixed intervals for turning [10]. Their goal is to investigate whether there are tradeoffs for different joystick rotation techniques in terms of sickness, preferences in a 3D environment. The results showed no evidence of differences in orientation, but sickness ratings found discrete rotations to be significantly better than field-of-view reduction. Fernandes et al. explored the effect of dynamically, yet subtly, changing a physically stationary person's field-of-view in response to visually perceived motion in a virtual environment [11]. Then, they could reduce the degree of VR sickness perceived by participants, without decreasing their subjective level of presence, and minimizing their awareness of the intervention. Budhiraja et al. proposed Rotation Blurring, uniformly, uniformly blurring the screen during rotational movements to reduce cyber-sickness caused by character movements in a First Person Shooter game in virtual environment [12]. The results showed that the blurring technique led to an overall reduction in sickness levels of the participants and delayed its onset.

On the other hand, as a method to add a figure on user's field-of-view, Whittinghill et al. placed a three-dimensional model of a virtual human nose in the center of the fields of view of the display in order to observe that placing a fixed visual reference object within the user's field of view seems to somewhat reduce simulator sickness [13]. As the results, users in the Nose experimental group were able, on average, to operate the VR applications longer and with fewer instances of stop requests than were users in the no-nose control group. Cao et al. designed a see-through metal net surrounding users above and below as a rest frame to reduce motion sickness reduction in an HMD [14]. They showed that subjects feel more comfortable and tolerate when the net is included than when there was no rest frame. Buhler et al. proposed and evaluated two novel visual effects that can reduce VR sickness with head-mounted displays [15]. The circle effect is that the peripheral vision shows the point of view of a different camera. The border between the outer peripheral vision and the inner vision is visible as a circle. The dot effect adds artificial motion in peripheral vision that counteracts a virtual motion. The results showed lower means of sickness in the two effects; however, the difference is not statistically significant across all users.

As mentioned above, in many studies, entire view is changed, or figures are conspicuously superimposed. There are some superimposed figures that imitate the user's nose, which are not so obvious, but it is not effective in some situations, or can only be used for a first-person's view. Therefore, we designed a more discreet static figure in virtual space and a scene-independence figure connecting the virtual world and the real world.

3 Design of Discreet Auxiliary Figures

We designed four types of discreet auxiliary figures to reduce VR sickness (see Fig. 1).

3.1 Gazing Point

The gazing point is superimposed on the center of the virtual space on an HMD (see Fig. 1a). The aim is to suppress eye movements of the user. We subjectively selected the size and color of the point so that it would most likely not interfere with the user's content-viewing experience and was also not difficult to see. Sprite is the knob of the Unity standard [19]. The distance from the avatar in the virtual space was 0.31; the coordinates of the point were x = 0.05, y = 0.05 in the Unity scale, and it was white in color.

3.2 Dots

Four dots, one at each corner, are superimposed on the four corners of the view of virtual space (see Fig. 1b). By making the user aware of the center of the relative view from the four dots, it is expected that eye movement can be suppressed as well as the gazing point. Additionally, unlike the display of the gazing point, nothing is displayed at the center of the view, so it does not interfere with the content viewing, and it is thought that the decline in the sense of immersion can be suppressed. The size and color of each dot is the same as the gazing point. The positions of the dots are at x = 2.5 or -2.5 and y = 2.5 or -2.5 in the Unity scale.

3.3 User's Horizontal Line

The horizontal line linked to the user's head movement was superimposed on the center of field of view (see Fig. 1c). When the user tilts his/her head, a conflict occurs between the user's memorized information of the horizon of the real world and the vestibular and visual information of the tilt of the virtual space. Therefore, the superimposed horizontal line linked to the user's head movement can reduce the conflict. The horizontal line passes from the screen edge to the screen center and reaches the opposite screen edge. We subjectively selected the thickness and color of the line so that it would not be bothersome or hard to view. Sprite is the knob of the Unity standard. In the virtual space, the distance from the avatar was 0.31; the coordinates were x = 5, y = 0.0025 in the Unity scale, and the color was white.

3.4 World's Horizontal Line

In the virtual space, we superimposed a line that always showed the horizontal line of the real world (see Fig. 1d). This line clarified how much of the user's head was tilted from the real world's horizon by always presenting the real world in the virtual space. The user could correct his/her autonomous head tilt and become aware of the degree of the tilt. The size and color of the line was the same as that of the user's horizontal line.

4 Evaluation Experiment

We verified the hypothesis that the SSQ score, which is an index of VR sickness, could be significantly reduced by superimposing each of the auxiliary figures on the field of view in the VR space. Therefore, we investigated the SSQ scores of the five conditions by including the condition without superimposition for the four types of auxiliary figures described in the Section 3.

SSQ is a metric that can calculate three sub-scores (oculomotor, nausea, and disorientation) and the total score by asking the participants to score approximately 16 symptoms caused by VR sickness on a four-point scale [20]. These scores have different calculation methods, and it is difficult to compare the extent to which the scores differ. In this experiment, the results were expressed as a percentage with the upper limit value being 100% in each score.

We also measured the palmar sweating as an objective psychophysiological metric (see Fig. 2). The reason for using SC as one of the indexes of sickness is that it is known that motion sickness induces sweating [16, 17], and that emotional sweating is caused by stress and anxiety [21].

Fig. 2. Experimental equipment and scene.

4.1 Equipment and the VR space

We used a computer (Intel Corei36100 3.70 GHz, GeForce GTX 1050 Ti, Windows10) to construct and output two 3D VR spaces: a dark tunnel generated from "Modular Metro Tunnels [22]" and a bright cityscape generated from "Simple Town Pack [23]"; these spaces were published on Unity Asset Store. We used Unity (ver. 2018.3.1f1) [19] for the construction of 3D spaces and superimposition of the auxiliary figures. The HMD was GALAX VISION Developer Edition (1920 × 1080 pixels, 60 Hz); it had a viewing angle of 100° and a delay of 25 ms. This device was equipped with an input high-definition multimedia interface, a gyroscope, and an accelerometer. Typical in-ear type earphones (Final, E-1000) were used to play environmental sounds in the spaces.

For the SC measurement, two electrodes of an SC sensor (Thought Technology Ltd.) were attached to the forefinger and the ring finger of the participant's non-dominant hand during the experiment.

To eliminate the influence of temperature on VR sickness, the room temperature was adjusted to a constant 20 °C using an air conditioner.

4.2 Task

The experimental task was to find white boxes with numbers in the VR spaces. The movement of the avatar in the spaces was automatic, and the participant was only allowed to rotate the view by head tracking. The task of using only head rotations to search for a box forced the participants to look around in the VR spaces.

The avatar first moved automatically in the dark tunnel, and when it reached a specific point, the scene changed to a bright cityscape. Then, the avatar also moved automatically in the cityscape. Finally, the movement stopped when the avatar reached a specific point, and the task was finished. We added a pitch of 1.5 Hz to the view all the time. The pitch is a frequency that easily induces motion sickness [24]. The amplitude was set subjectively so that it was natural similar to the head pitching.

4.3 Procedure

The experiment was conducted as a within-subject design; therefore, all the participants performed the experimental task under five conditions. We randomized the order of the five conditions for each participant.

The task performance time for each condition was approximately 10 min and 30 s. To avoid the influence of the immediately preceding condition, we introduced a rest time of approximately 40 min between conditions. If the participant did not recover even after 40 min, the rest time was extended. However, even if 40 min had not passed, when the participant recovered, the rest time was shortened, and the task was performed in the following condition. The conditions were spread over two days to avoid lengthening the experiment. Two experiments were performed on the first day, and the remaining three were performed on the second day. In addition, to avoid the influence of ingested food, the participants were asked to refrain from eating one hour before the start of the experiment.

At the start of the experiment, the experimenter took the informed consent of each participant and told the participant that he/she could immediately stop the task at any time if he/she felt unwell during the experiment. Then, each participant was asked to respond to the Motion Sickness Susceptibility Questionnaire (MSSQ) [25], and the questionnaire survey on the participant's VR experience. Then, the experimenter attached an SC sensor to the participant's non-dominant hand and measured the sweating data on his/her palm for 2 min at rest; this was the baseline data.

The experimental scene is shown in Fig. 2. The participants answered the SSQ before and after the task execution under each condition. In the SSQ before the execution, the experimenter asked the participants to fill in '1' for all the items and to memorize their current physical conditions. The SSQ was used to evaluate how much the physical condition deteriorated after the task execution. After all the conditions were performed by the participants, each participant ranked the five conditions of "difficulty of developing VR sickness" and "immersion in VR environment."

4.4 Participants

The participants were nine undergraduates (six men and three women) aged 20 to 33 years who did not have any history of problems with vision and vestibular sensations.

5 Results and Discussions

5.1 Difficulty rankings to VR sickness

Fig. 3 shows the results of the responses of all participants based on the order of difficulty of developing VR sickness. From this figure, although we can say that the dots condition was less likely to develop VR sickness as a high-order tendency, there was no significant difference between the conditions (Friedman's test, N=9, df=4, p > .05).

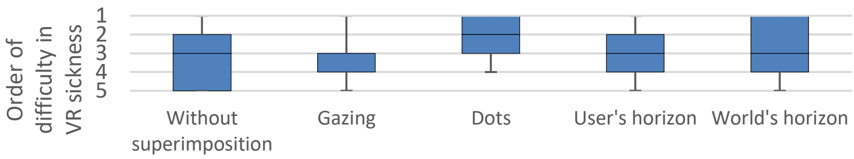

Fig. 3. Results for the order of difficulty in developing VR sickness.

5.2 SSQ

Fig. 4 shows the results of the SSQ. No significant difference was found between the conditions (Friedman's test, N=9, df=4, p > .05), but the without-superimposition condition had the largest symptom of VR sickness, and the dots condition had the smallest symptom.

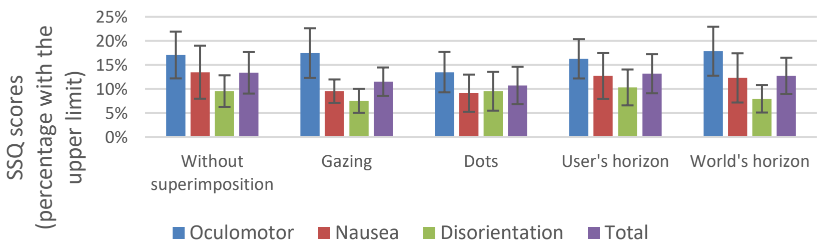

Fig. 4. SSQ total score percentages.

By grouping the rankings for the difficulty to develop VR sickness, we found that the SSQ was affected by the participants' preferences for difficulty. Moreover, we found that the dots condition relatively reduced the VR sickness, although there were no major differences among the conditions.

The results of the grouping based on the total scores of SSQ were probably influenced by the presence or the absence of the presentation in the center of the field of view. In our proposed auxiliary figures, only the dot condition was not superimposed on the center of the field of view. Therefore, the participants who do not easily develop VR sickness felt uncomfortable about the obstruction more than the reduction effect of VR sickness.

5.3 Sweating rate

Fig. 5 shows the changes in the sweating rates from the state of rest for each auxiliary figure. Although no significant difference was found, the superimposition of auxiliary figures tended to suppress sweating. In particular, under the user's and world's horizontal conditions, the sweating was suppressed to almost the same level as that at rest.

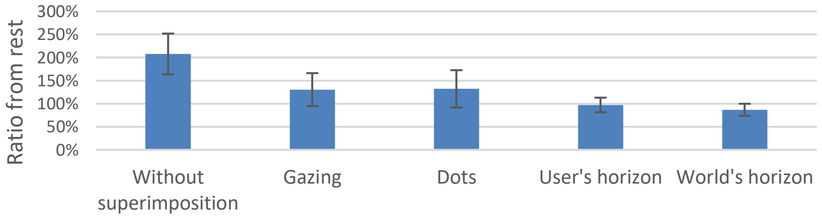

Fig. 5. Result of the sweating ratio of each condition from the state of rest.

6 Conclusion

We designed the discreet auxiliary figures to aim to reduce the VR sickness and not to obstruct the field of view on an HMD. In the evaluative experiment, although there was no significant difference between the without-superimposition group and the auxiliary figures-imposed groups, we found that the VR sickness tended to reduce by the superimposition of dots design. Although there were individual differences in whether or not the dots were suitable, VR sickness did not increase for the dots superimposition case even when the participants did not think the dots useful.

The experimental results were classified according to the SSQ scores although it was possible to reduce the sickness of the participants who easily got sick when the auxiliary figures were used. The sickness of the participants who did not easily get sick became strong. From these results, we concluded that the presence of an auxiliary figure in the central field of view influenced intensity of the VR sickness; the VR sickness did not intensify even in participants who did not easily develop VR sickness under the dots condition.

References

1. Andrew, B., Gresham, C.: Prevention and treatment of motion sickness. American family physician 90(1), 41-6 (2014).
2. Reason, J. T., Brand Joan J.: Motion sickness. Academic Press, (1975).
3. Bles, W., Bos, J. E., Graaf B. de, Groen, E., Wertheim. A. H.: Motion sickness: only one provocative conflict? Brain Res Bull 47(5), 481-487 (1998).
4. Riccio, G. E., Stoffregen, T. A.: An ecological Theory of Motion Sickness and Postural Instability, Ecological Psychology, 3, 3, 195-240 (1991).
5. Nakayama, Y., Aoyama, K., Kitao, T., Saito, M., Nagata, K., Yamagishi, K., Ando. H.: Zentei denki shigeki ga VR-yoi ni ataeru koka no kento. The 23rd Annual Conference of the Virtual Reality Society of Japan, 14B-5 (2018). (in Japanese).
6. Virtual Reality Lab. in University of Tukuba. String Walker, http://intron.kz.tsukuba.ac.jp/stringwalker/stringwalker.html, last accessed 2021/4/11.
7. Bos, J. E., MacKinnon, S. N., Patterson, A.: Motion sickness symptoms in a ship motion simulator: effects of inside, outside, and no view. Aviat Space Environ Med. 76(12), 1111–1118 (2005).
8. Norouzi, N., Bruder, G., Welch, G.: Assessing vignetting as a means to reduce VR sickness during amplified head rotations. In Proceedings of the 15th ACM Symposium on Applied Perception (SAP '18). Association for Computing Machinery, New York, NY, USA, Article 19, 1–8 (2018).
9. Duh, H. B., Parker, D. E., Furness, T. A.: An "independent visual background" reduced balance disturbance envoked by visual scene motion: implication for alleviating simulator sickness. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '01). Association for Computing Machinery, New York, NY, USA, 85–89 (2001).
10. Sargunam, S. P., Ragan, E. D.: Evaluating joystick control for view rotation in virtual reality with continuous turning, discrete turning, and field-of-view reduction. In Proceedings of the 3rd International Workshop on Interactive and Spatial Computing (IWISC '18). Association for Computing Machinery, New York, NY, USA, 74–79 (2018).
11. Fernandes, A. S., Feiner, S. K.: Combating VR sickness through subtle dynamic field-of-view modification. IEEE Symposium on 3D User Interfaces (3DUI), Greenville, 201-210 (2016).
12. Budhiraja, P., Miller, M. R., Modi, A. K., Forsyth, D.: Blurring: use of artificial blurring to reduce cybersickness in virtual reality first person shooters. arXiv preprint arXiv:1710.02599 (2017).
13. Whittinghill, D. M., Ziegler, B., Moore, J., Case, T.: Nasum Virtualis: a simple technique for reducing simulator sickness, https://www.gdcvault.com/play/1022287/Technical-Artist-Bootcamp-Nasum-Virtualis, last accessed 2021/4/11.
14. Cao, Z., Jerald, J., Kopper, R.: Visually-induced motion sickness reduction via static and dynamic rest frames. IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Reutlingen, 105-112 (2018).
15. Buhler, H., Misztal, S., Schild, J.: Reducing VR sickness through peripheral visual effects. IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Reutlingen, 517-519 (2018).
16. Takov, V., Prasanna, T.: Motion Sickness. StatPearls, StatPearls Publishing, (2020).
17. Golding, J. F.: Motion sickness. Handbook of clinical neurology. 137, 371–390 (2016).
18. Laviola Jr., J. J.: A discussion of cybersickness in virtual environments. SIGCHI Bulletin. 32(1), 47-56 (2000).

19. Unity Technologies. Unity, https://unity.com/, last accessed 2021/4/11.
20. Kennedy, R. S., Lane, N. E., Berbaum, K. S., Lilienthal, M. G.: Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness, The International Journal of Aviation Psychology, 3(3), 203-220 (1993).
21. Wilke, K., Martin, A., Terstegen, L., Biel. S. S.: A short history of sweat gland biology. In International Journal of Cosmetic Science. 29(3), 169–179 (2007).
22. Unity Technologies. Unity Asset Store, Modular Metro Tunnels, https://assetstore.unity.com/packages/3d/environments/urban/modular-metro-tunnels-130591, last accessed 2021/4/11.
23. Unity Technologies. Unity Asset Store, Simple Town Pack, https://assetstore.unity.com/packages/3d/environments/urban/simple-town-pack-91947, last accessed 2021/4/11.
24. Ikuko, T., Aizawa K., Matsuzaki N., Shigemasu H., Harasawa M., Kawashima T., Morita T., Ito T., Saito T., Sato T.: The analysis of global motion for videos inducing motion sickness. In Proceedings of The Institute of Image Information and Television Engineers Annual Convention, 8-3 (2004).
25. Golding, J. F.: Predicting individual differences in motion sickness susceptibility by questionnaire. Personality and Individual Differences, 41(2), 237–248 (2006).