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Analysis of Video Image Based Element for Motion Sickness

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Abstract

Prior research [1] has been shown the positive effects of dynamic Field-of-view (FOV) on reducing motion sickness in the linearly moving condition. This work focuses on reducing motion sickness for rotating movements in addition to linear ones. In this work, we also design and test types of masks and traveling methods. Nine types of masks are used along with two traveling methods in three different designed visual scenes. To analyze the effects of masks on reducing motion sickness, the study is divided into preliminary and main experiments. From the preliminary experiments, we identified candidate mask types that could effectively reduce the motion sickness. The main experimental results show that even with the decreased image area per frame with masks, the level of presence remains at the same. Nausea was effectively reduced when a certain mask was applied to a group with high sensitivity to motion sickness.

Introduction

With the recent development of hardwares, using light-weight Virtual Reality (VR) devices for immersive interaction experience is getting more popular. The amount of VR contents and applications is significantly increasing in various fields, such as games, real estate, broadcasting, and education. However, one of practical issues to make current consumer Head-mounted Display (HMD) to be accepted pervasively is the motion sickness. Particularly, most of VR contents involves traveling and movement interactions, which significantly introduces motion sickness.

Motion sickness is a symptom caused by cognitive dissonance. Cognitive discordance occurs due to the visual signals seen by the user conflicts with the physical motion signals sensed by the inner ear vestibular system. Many studies have been carried out to reduce the motion sickness in virtual reality. For example, Fernandes et al. [1] proposed to use dynamic Field-of-View to reduce motion sickness. The size of the mask shown in the HMD is changed from 155 ° to 80 °, and the visible screen area is reduced when the user moves using the keyboard. Laviola Jr. et al [2] studied on brightness and visibility that helped to grasp the depth. There are many factors that can reduce the motion sickness phenomenon like the previous studies described above. Sharples et al[7] shown the effects of using HMD, desktop and projection on reducing motion sickness. In addition, Kenedy et al[5] and Graeber et al[6] studied the degree of nausea according to gender. There are many factors that can reduce the motion sickness phenomenon like the previous studies described above.

In this paper, we propose to apply a mask to moving and rotating condition. We tried to evaluate different types of masks for user movements. In addition to results of previous work, we apply rotational movement with physical head movements. The experiment is divided into the preliminary experiment and main experiment. In the preliminary experiment, the goal is to examine the effects of various masks on reducing motion sickness. We also investigated how the degree of nausea changes according to the mask setting method, and the effects of masks on immersion and presence.

Experimental Environment

To test level of motion sickness, we designed the stages in different environments and with different interaction methods to see whether the motion sickness is reduced when the mask was applied to visual scenes.

Mask size

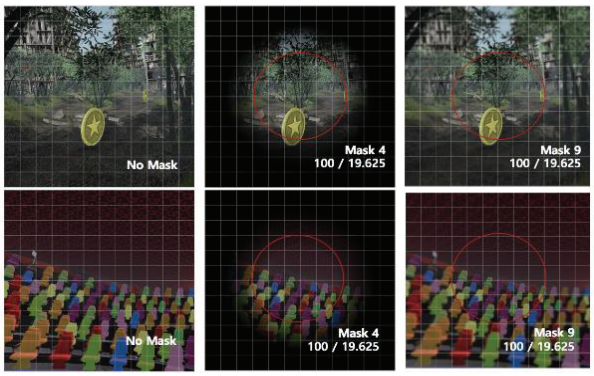

Figure 1. 'Combating VR Sickness through Subtle Dynamic

To utilize masks with HMDs, the main goal is to adjust the size of mask as to adjust Field of View (FOV). If the FOV is reduced, the amount of data that user visually perceives is smaller which might reduce the level of the presence. In other words, the motion sickness is induced usually when the user is moving in the virtual environment. Therefore, it is designed to reduce the FOV only when the user is moving and rotating. When the user is standing still, he/she will see the scene in full detail. The detail is reduced with masks when he/she is starting to move. Fig 2 shows that the different types and size of the mask. The red circle is a visible area with the reduced FOV by applying mask.

To test effects of the reduced FOV and therefore the mask, we designed two different virtual worlds.

Stage 1

The stage 1, "the coin map" is designed and used in Pre- and Main-experiments. In this map, users are required to acquire coins by moving around the map by using keyboard, mouse and head movement. This environment consists of buildings and terrains with moving grass and trees. The reason to use this environment is that the animated leaves and grass can induce motion sickness significantly. This stage is created using assets provided in Unity3D.

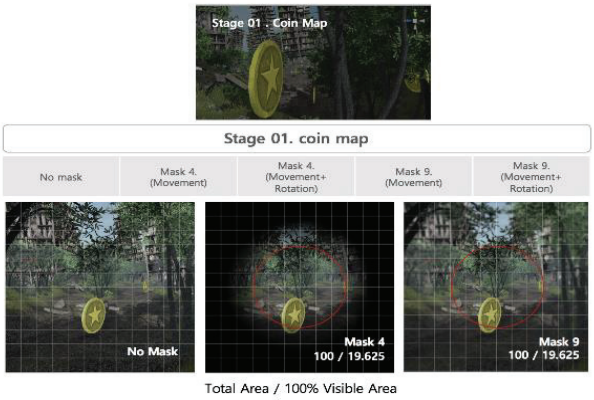

Figure 2. Coin Map (Stage 1)

Stage 2 and 3

The stage 2 and 3, "the cinema map" is used in the Main-experiment, and the interaction methods is different from Stage 1. We designed this stage as significantly many participants did not experience motion sickness in Stage 1. This environment allows participants to rotate their headset to navigate to select the targets, which induce the significant motion sickness. Particularly, the chairs with mixed colors in such narrow space contributed to motion sickness. Participants were asked to choose the available targeted chairs with the given color. The target color is informed in-prior and the target chairs are selected randomly when participant was doing the experiment. These two stages are only allowed rotations of the head rather than translations to minimize other aspects of motion sickness.

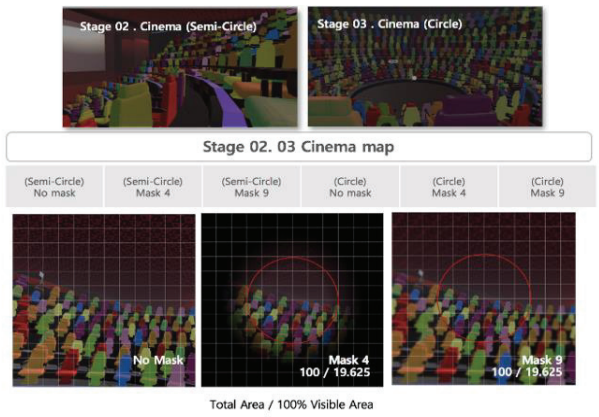

Figure 3. Cinema Map (Stage 2, 3)

The difference between stage 2 and 3 is the height of the view point, so that it is set on the chair in Stage 2, while the viewpoint is standing on the first floor in Stage 3. Second, since stage 3 has more chairs than stage 2, the amount of visual data received by the participant is high, therefore the nausea could be more severe.

Pre-Experimental Design

In the previous work [1], they only used one type of mask. In this work, we were curious on how the rate of motion sickness reduction would be different depending on the types of masks. However, since there are many types of masks that we designed, the goal of the pre-experiment is to examine which masks contribute the most to reducing motion sickness. We choose the most effective masks that reduce motion sickness and the one induced the motion sickness (see Fig 7). Pre-experiment was conducted on Stage 1. The reason for this is that we must examine the side effects during the experiment before proceeding the main-experiment, due to there are more virtual objects and different interaction methods between stage 1 and stage 2, 3. The average age of participants were about 20 years old. Because motion sickness sensitivity is affected by age, other than gender[8].

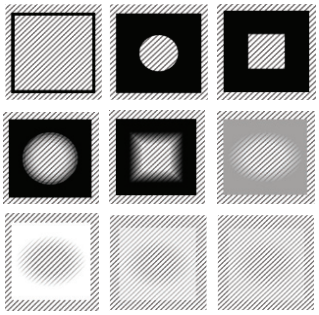

Figure 4. 9 kinds of mask used in the pre-experiment

Participants

The pre-experiment was conducted on 12 participants for three days. The age of participants were between 20 to 29 years old, with nine men and three women. The experiment was carried out 12 times for each individual (total 12x12=144 trials), and it takes about 30 minutes per each trial. Figure 6 shows the information of participants in pre-experiment.

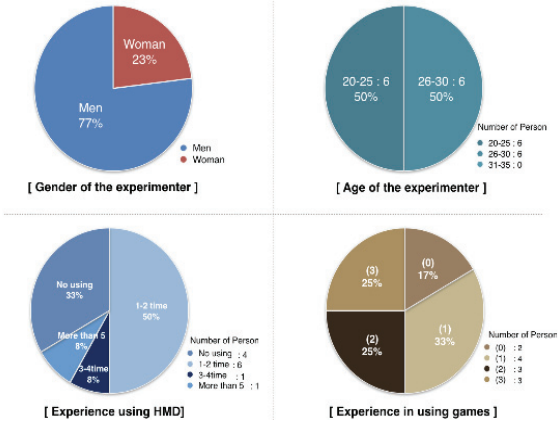

Figure 5. Participants information in pre-experiment

Task Procedure

In pre-experiment, the participants were asked to navigate with the map through the keyboard, mouse, and tilt interactions to access a coin, and change the mask every time after accessing five coins. When a participant acquires a total 45 coins, a trial is finished. After each trial, a questionnaire was used to evaluate the motion sickness range from 1 to 9 to indicate the effects of mask on reducing the motion sickness.

Pre-Experimental Results

Mask 4 (black circular blur), Mask 9 (Gaussian blur), and Mask 1 (No mask) were selected from pre-experiment, as they are the most effective masks for reducing motion sickness during 12 subjects. The above three kinds of masks are used in the Main-experiment.

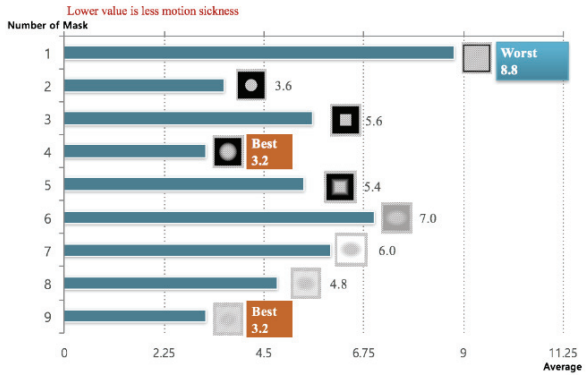

Figure 6. 9 kinds of mask used in the pre-experiment

Main Experimental Design

Main experiment aims to effectively reduce the motion sickness with the investigated variables and hypothesis. The variables are presented in Table 1. The CQ, SSQ[3], MSSQ[9] and average rotational speed per frame were collected during the main-experiment. CQ is a simple questionnaire made for this experiment which surveying gender, age, HMD usage experiences, FPS game time per week, and mask preference (see the last page).

Table 1: Predictor variables and controls.

Predictor variable	Control
Sensitivity to motion sickness	MSSQ Survey progress
Concentration to the experience	Collecting the subjects' rotation angle per frame
Age and gender	CQ(Self-Made) survey
Experience using FPS games or HMDS	CQ(Self-Made) survey
Accumulation of motion sickness with experiment	Conducting experiment in random order for 5 days
Learning Effect	The data in the first round is not used for experimental analysis.

Hypothesis

Fernandes et al. [1] showed that dynamic FOV had effect on reducing the motion sickness, the experiment was carried out to change the mask area when moving. We propose several variables in terms of FOV as well as display. The reduction of motion sickness will depend on the shape and size of the mask, the way it moves, and how it is applied. The hypothesis is that, first, the shape of the mask will have a different rate of reduction of motion sickness. Second, it is effective to apply a mask to not only translational moving but also rotation conditions. Third, applying a mask to HMD display reduces the amount of visual data the user perceives, it is assumed that the level of presence will be decreased.

Participants

The number of participants in the Main Experimental were 19 for Stage 1 and 18 for Stage 2 and 3. Each participant had 25 trials in stage 1, and 30 trials in stage 2 and 3. There were 1,015 trials for a total of 37 subjects.

Task Procedure

Each participant performs the experiment for 5 days. The participants should be familiar with the experimental procedure before performing experiment. On the first day of the experiment, the same experiment as the preliminary experiment was conducted to collect the subject's CQ and MSSQ. Depending on the type of mask and application method, Stage 1 was performed 5 times a day, Stage 2 and 3 were performed 6 times a day. The experiment time was 3 minutes for each trial, and after each trial, participants were asked to take 5 minutes rest. During the rest, the subject were asked to complete the SSQ[3]. PQ was proceeded after each 'No Mask' experiment and after the last experiment.

Main Experiment Results

Correlation between SSQ and MSSQ

In the experiment, subjects' sensitivity was the most difficult variable. In the previous work [1], the subjects' sensitivity was measured by MSSQ. In this study, we also used MSSQ, a validated questionnaire for the subjects' sensitivity, as a criterion for dividing the subjects' sensitivity group. In order to confirm the correlations between SSQ and MSSQ, we calculated the RMSE on the mean SSQ and MSSQ of the subjects before dividing the sensitivity group. As the result, it is interpreted that there was no relation between MSSQ and SSQ. According to the result, the MSSQ was not used as a measure of the sensitivity of the subjects. RMSE results are presented in Table 2.

Table 2: Analysis of the correlation between SSQ and MSSQ using RMSE.

Stage	SSQ – MSSQ(Child)	SSQ – MSSQ(Adult)	SSQ – MSSQ(Total)
Stage 1	4.316	4.952	4.425
Stage 2	6.368	7.153	6.758
Stage 3	6.128	7.083	6.625

Change of Presence

As the immersion and presence are important to user experience in virtual environments, applying a mask to reduce motion sickness should not affect the sense of presence. We used the PQ which was created by BG Witmer et al in 1998 to confirm the presence score[4]. In this experiment, the PQ (19 questions, 7

points scale) was used to confirm the reduction of presence when mask was applied. The result is illustrated at Fig. 8 (PQ1: No Mask, PQ2: Mask data recording). The PQ average of "applying mask" and "not applying mask" is 83, 88 for coin map and 83, 86 for cinema map. However, in the case of "not applying mask", the standard deviation was 1.8 for coin maps and 0.6 for cinema maps. This indicates that applying a mask to the HMD display reduces the amount of data per frame and then reduces nausea, but does not negatively affect the presence. The values for Figure 8 are shown in Table 3.

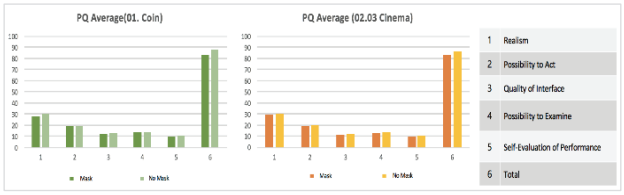

Figure 7. 3 before and after mask application

Analysis of the SSQ

The use of MSSQ is to divide the subject sensitivity group, but in our experiments, MSSQ does not show any consistency with SSQ levels of each user. To divide the subject group, we directly used SSQ values. The SSQ value of the subject is sensitive to the SSQ total average of trials for that user. In our experiment, SSQ value for each user is normalized. In the normalization, we have used two criteria, min/max value of the SSQ for each user and the amount of the rotation per frame for each user. With the high rotation speed, it is expected that SSQ value would get higher. The rotation value data was recorded for each frame of trial (60 frames per second).

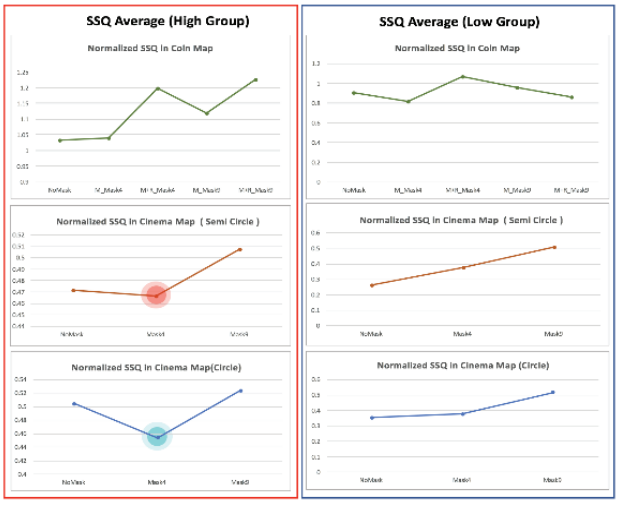

Figure 8. SSQ normalization comparative graph by group

With the result, t-Test showed that Mask 4 and Mask 9 had a significant effect in Stage 2 group with low sensitivity, while Mask 4 had the similar effect in Stage 3 group with high sensitivity ($p < 0.05$). The results of the t-Test are shown in Table 4. The data analysis showed that the sensitivity was lower in Stage 2, and the motion sickness became worse. In Stage 3, Mask4 reduced the nausea by 10.01%. Stage 3 was experimentally designed to require more motion of the user than Stage 2. According to the result, the more susceptible subjects are, the more effective the mask is to reduce motion sickness. The results of SSQ analysis are shown in Table 5.

Conclusion

Compared with the previous work [1], we studied various confounds that affect motion sickness on the display side. In the coin map experiment, most of 20 years old participants did not feel motion sickness in that experiment. Probably due to most of the 20 years old subjects had sufficient video game experiences, and the interaction methods used in the coin map experiment were a mouse and a keyboard along with the HMD. The effects of mask on reducing motion sickness did not found in the group of subjects with low sensitivity. In addition, there was disadvantage that the mask caused motion sickness, for example, Mask 9 induced motion sickness. A group of subjects with a high sensitivity to motion sickness have an effect on a specific mask. However, the changes in the mask motions will be carried out in future work. If a fixed mask was employed, participants can expect that the reduction in motion is maximized. However, it reduces the amount of visual data the user acquires. There was no significant difference in presence, when the mask was applied (see Fig 8 and Table 3). In addition, motion sickness in HMD can be reduced through learning effects based on the subjects' interviews.

Several problems were found in this experiment. First, there is no relationship between MSSQ and SSQ. Therefore, new measures are needed to distinguish the sensitivities of each subject. Second, it is difficult to obtain accurate data because SSQ is a questionnaire with 4 points scale. It is therefore necessary to increase the number of scales. Third, in the case of subjects with low sensitivity, the experiment time per set is not enough to induce the nausea. Therefore, the experiment time should be prolonged. Fourth, repeated experiments for five days cause subjects to feel bored and tired. It needs to encourage the participants to get more interested. This is expected to be more effective when there is compensation for competition. In future work, we will investigate the experimental environment design more closely together with the mentioned problems above.

Acknowledge

This research was supported by Samsung Display.

Table 3: Measuring presence with or without masks

Dimension	Stage 1				Stage 2, 3			
	Apply Mask		Don't apply Mask		Apply Mask		Don't apply Mask	
	Average	SD	Average	SD	Average	SD	Average	SD
Realism	28.096	5.377	30.750	5.882	29.905	6.831	30.821	6.783
Possibility of Act	19.346	2.501	19.750	3.396	19.474	3.515	19.857	3.990
Quality of Interface	12.066	4.176	13.313	2.960	11.517	3.639	11.964	3.305
Possibility to Examine	13.757	2.552	18.875	3.403	12.853	2.801	13.750	2.744
Self-Evaluation of Performance	9.971	1.829	10.563	1.825	9.767	1.829	10.571	1.731
Total	83.235	12.559	88.250	14.383	83.517	16.774	86.964	17.319

SD : Standard Deviation

Table 4: t-test result of normalized SSQ compared with rotation angle per frame ($p < 0.05$)

Stage 1 (Coin Map)

SSQ Average (High Group)				SSQ Average (Low Group)			
Mask 4		Mask 9		Mask 4		Mask 9	
M	M + R	M	M + R	M	M + R	M	M + R
0.961	0.186	0.265	0.093	0.641	0.808	0.613	0.799

M : Movement, R : Rotation

Stage 2, 3 (Cinema Map)

SSQ Average (High Group)				SSQ Average (Low Group)			
Semi Circle		Circle		Semi Circle		Circle	
Mask 4	Mask 9	Mask 4	Mask 9	Mask 4	Mask 9	Mask 4	Mask 9
0.971	0.210	**0.042**	0.997	**0.038**	**0.001**	0.091	0.186

Table 5: SSQ normalization comparative graph by group

Stage 1 (Coin Map)

Group	No Mask	Mask 4		Mask 9	
		M	M + R	M	M + R
SSQ Average (High Group)	0.488	0.509	0.514	0.488	0.500
SSQ Average (Low Group)	0.459	0.456	0.605	0.516	0.466

M : Movement, R : Rotation

Stage 2, 3 (Cinema Map)

Group	Stage 2 (Semi Circle)			Stage 3 (Circle)		
	No Mask	Mask 4	Mask 9	No Mask	Mask 4	Mask 9
SSQ Average (High Group)	0.485	0.474	0.522	0.518	**0.449**	0.553
SSQ Average (Low Group)	0.337	**0.479**	**0.654**	0.443	0.539	0.547

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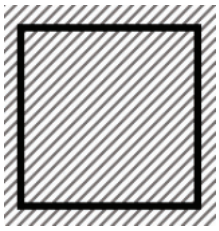
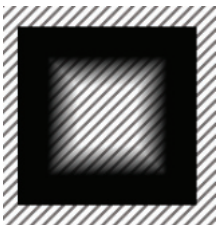
Classification Questionnaire

Please '✔' or 'O' the item.

No.	Questions	Items
1	Gender	(Male) (Female)
2	Age	(20 – 25) (26 – 30) (31 – 36)
3	HMD usage experiences before this experiment	(0) (1 – 2) (3 – 5) (5 times or more)
4	Do you play FPS game often?	[Never : 0 | A few times : 1 | Frequently : 2 | Every day : 3] (0) (1) (2) (3)
	If you selected one of [A few times (1), Frequently (2), Every day (3)], please answer.	
	How much do you play games per week?	(1 hour or less) (3 hours or less) (5 hours or more)

Please answer only in pre-experiment.				
5	List the mask in the order of lowest motion sickness. Ex) Mask with the least motion sickness : 1, Mask with the more motion sickness : 9	No Mask (1)	Black circular (2)	Black square (3)
				
		Black gradation circular (4)	Black gradation circular (5)	Gray gradation circular (6)
				
		White gradation circular_100 (7)	White gradation circular_50 (8)	Gaussian blur (9)