Reduce Simulator Sickness by Overwritten Symbol in Smartphone-Based VR System

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Reduce Simulator Sickness by Overwritten Symbol in Smartphone-Based VR System

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***Abstract*—The aim of this paper is to reduce simulator sickness caused by the low refresh rate of display in smartphone-based VR system. Without regard to the improvement of hardware, the method proposed in this paper reduces simulator sickness by adding static symbol on the screen of the smartphone. A series of user-participation experiments were done to validate the effectiveness of the method. Participants' responses to the symbol with different textures (cross or Minion logo) and in different positions (the center or near the corners) were assessed by Simulator Sickness Questionnaire (SSQ). The preliminary results demonstrate that the existence, the position and complexity of the symbols can be factors in relieving symptoms of simulator sickness.**

Keywords-simulator sickness; smartphone-based head-mounted display; virtual reality

I. INTRODUCTION

Because of the occlusion of peripheral vision, people wearing HMDs have to focus on the virtual contents on display, which offers high immersion. However, the screen refresh rate of smartphone is notably lower than the integrated HMD. The low screen refresh rate of smartphone may cause oscillatory images and blurring screen instantaneously as users rotate their heads rapidly. This makes people's eyes out of focus, because there is no certain object in their sight. This happens frequently and brings people eyestrain and simulator sickness.

In 2001, Henry Duh suggested that an independent visual background (IVB) may alleviate disturbance when conflicting visual and inertial cues are likely to result in simulator or VE sickness. And in Duh's research, a brighter IVB is easier to alleviate simulator sickness than a dim one [1]. In 2005, Tsubaki et al. proposed a video stabilization method for reducing visually induced motion sickness [2]. Tsubaki`s system achieved the removal of oscillatory motions in scenes. Moss et al. suggested that a degree of sensory information of the external environment in the periphery could be offered to reduce simulator sickness, which meant not all the peripheral vision of the external real-world environment should be occluded by HMDs [3]. In 2014, Llorach's experiments showed that the position estimation system did a better job in the reduction of simulator sickness than the traditional game controller for navigation [4]. In this paper, we proposed an approach to reduce simulator sickness evoked by the low refresh rate of the smartphone screen by adding an overwritten static symbol on it.

II. METHODS

It is well known that in some highly immersive FPS games, the simulator sickness is mainly caused by the conflict between visual and vestibular self-motion systems [5][6]. The game developers found out that some objects which were static on screen could reduce simulator sickness to some extent, such as a "virtual nose". Analogously, although the simulator sickness in smartphone-based VR system is mainly caused by the screen blurring evoked by low screen refresh rate rather than the reasons above, it could be assumed that a static symbol displayed on smartphone screen may attract user`s attention and decrease the simulator sickness.

A. System Design

We hypothesized that the existence, position and complexity of symbols are factors in the reduction of simulator sickness. First of all, a first-person VR game with a bright colorful scene was designed with Unity3D. It was found out that people in standing condition have a higher incidence of simulator sickness than those seated during HMD console video games and that even simply making active head movements may elicit symptoms of simulator sickness [7][8]. So in this research, the players were asked to stand in situ and turn their heads to seek coins in the virtual scenes, wearing a smartphone-based HMD, in which a smartphone was running the game. There is only one coin in the scene at any moment, which stays at a fixed position and rotates slowly (to get attention). The players need to find the coin and turn their heads to make it at the center of the screen. If so, the coin will disappear and then show up in another random place, bringing one more score for the players.

However, the refresh rate of our smartphone`s screen is 60 Hz, and it might take a long time for people to feel simulator sickness from it. So there was an additional blurring effect in this game, raising the level of blurry that a screen could be, and increasing the chance that simulator sickness can happen in a short time (we make it 3.5 minutes in our experiment). If the player stays still or just turns his head slowly, the smartphone will offer clear frames as usual.

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Only when the player turns his head in a fast speed would the additional effect be active: in this case, the screen should blur because of fast picture switching, while the additional effect would heighten it, making it much more blurry than it should be (Fig. 1).

Three static symbols are chosen in this system: one is a black ring inside white rim, one is a black cross inside white rim, and the other one is a Minion logo carrying the most abundant colors and texture among all symbols. All symbols are digital images rendered on the screen and they are immune to additional blurring effect. There are two ways the symbols can be rendered on the screen: one single symbol gets put on the center or the same four symbols get placed near the four corners. The two ways will be described in Fig. 2.

B. Participants

A total of 40 participants (13 females and 27 males) completed the experiments, all of whom are graduate students in Beijing Institute of Technology in age from 21 to 28 years old. All participants were in good conditions before experiments and clear that they got carsickness sometimes. Participants were divided into five groups and the arrangement of experiments is summarized in Table I. The vision in different groups is displayed in Fig. 2.

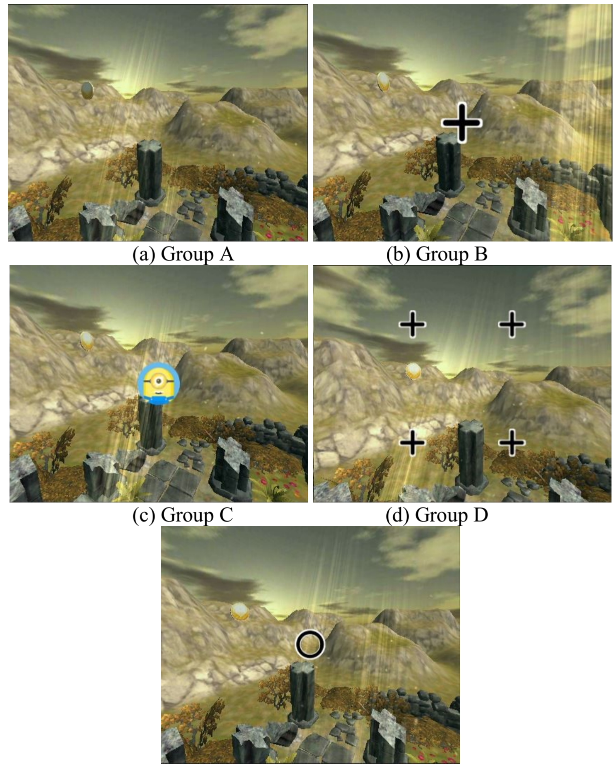
C. Procedure

As shown in Fig. 3, participants first stayed in calm for 3 minutes, looking at green trees, relieving their eyes. Then the participant was asked to fill out a Simulator Sickness Questionnaire (SSQ) regarding his or her current disposition.

TABLE I. THE ARRANGEMENT OF EXPERIMENTS

Group	Conditions			
	Symbol	*Positions*	*Males*	*Females*
A	none	_	5	3
B	cross	center	5	3
C	Minion	center	6	2
D	cross	near corners	5	3
E	ring	center	6	2

Fig. 1. The blur effect: calm (left) or active (right). When the state of blurring effect changes from one to the other, the screen will look like a low refresh-rate one.



(a) Group A (b) Group B

(c) Group C (d) Group D

(e) Group E

Fig. 2. The vision in different groups

In the experiment phase, the participant worn a smartphone-based HMD, playing the game which we designed in different groups for 3.5 minutes. Finally, after finishing the game, the participant completed a second SSQ and then got rest. Fig. 4 presents pictures of the participants in the 3.5-minutes game.

D. Procedure

In this paper, the SSQ proposed by Kennedy.R.S was used to estimate simulator sickness of participants in our system [9]. In SSQ, simulator sickness is measured by 16 items. The participants used variable score (0, 1, 2, 3) to express how strongly they felt each item. Again, 0 being Never and 3 being Extreme. The 16 items were grouped into subscales, each subscale received its own score. The three subscales used in our questionnaire are as follow: Nausea (N), Oculomotor (O) and Disorientation (D). Then the Total Scores (Ts) can be achieved by the formula:

$$Ts = 3.74 \times ([N] + [O] + [D]) \quad (1)$$

III. RESULTS

The differences between pre-game SSQ and post-game SSQ were taken to quantify the impact that the game had on participants. The mean differences in scores between pre-game and post-game SSQ among all groups are given in Fig. 5 and Fig. 6.

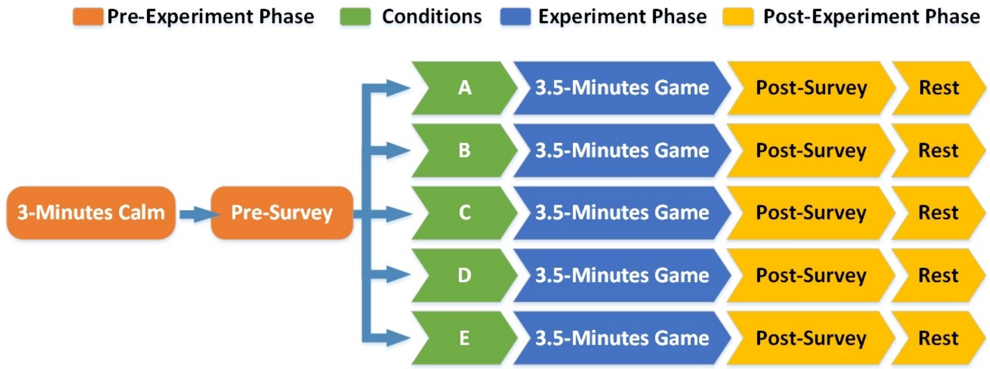


Fig. 3. The time-line of the experiment from left to right.

Fig. 4. The participants in the 3.5-Minutes Game

In general, for Fig. 5, the scores in Disorientation were the highest among the 3 subscales, then Oculomotor, then Nausea, which meant that the participants were more sensitive to Disorientation than the other two aspects and that the subscale Disorientation made the greatest contribution to Total Scores.

As shown in Fig. 6, Group A has the highest total score among all groups, Group D has the second highest of that, Group B has the third, Group E the fourth and Group C the lowest. So it can be concluded that in order of most severity of simulator sickness, it goes: A, D, B, E and C. The same situations happened in subscale Disorientation.

And it could be seen from Fig. 5 and Fig. 6 that Group C had the lowest scores in each subscale and Total Scores, which indicated that the participants in Group C felt the least severity of simulator sickness.

Through the above experiments, we can get some conclusions. First, Group B has lower Total Scores than Group A in Fig. 6, which shows that the static symbol plays a role in decreasing simulator sickness. It can catch users` attention when the screen of smartphone blurs because it becomes the target that users can focus on. Second, the Total Scores of Group B are lower than those of Group D, indicating that the symbols placed on the four corners of the screen may reduce simulator sickness but it works not as well as one of those placed in the center. In terms of human`s viewing habits, the objects placed in the central parts of the field of view are easier to notice than those around. Third, Group E has lower Total Scores than Group B, suggesting that a smooth symbol (ring) may work a little better than an angular one (cross). A more smooth shape is easier to be noticed. Fourth, the Total Scores of Group C are lower than those of Group E, which means that a symbol with abundant colors and texture is more effective in the reduction of

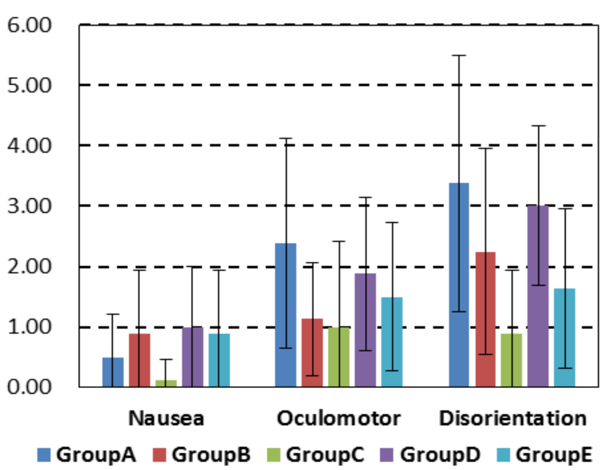


Fig. 5. The mean scores of subscales: Nausea, Oculomotor and Disorientation.

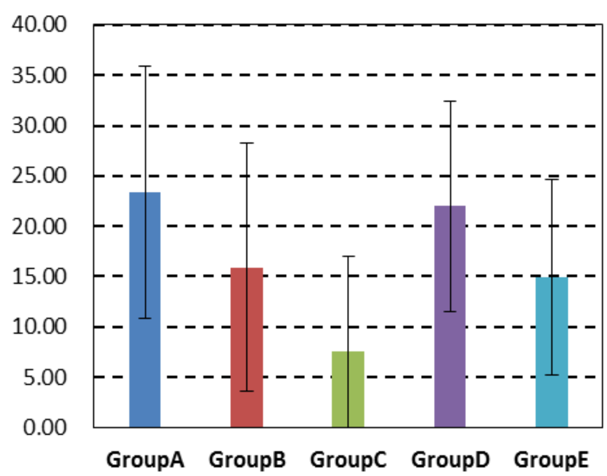


Fig. 6. The mean Total Scores in 5 groups.

simulator sickness than that with a simple texture. The abundance of color and texture catch people`s eyes, especially when there are colorless objects with less texture nearby.

And more interestingly, the male participants found more coins in the game and had lower Total Scores in SSQ than the females. The reason given by some male participants was that the experiences of first-person games, such as Counter-Strike and Call of Duty, made them more adaptive in first-person environment.

IV. Discussion

We put forward a static overwritten symbol placed on the screen to reduce simulator sickness which is mainly caused by low screen refresh rate of smartphones in smartphone-based HMDs.

We chose a ring, a cross and a Minion logo as the alternative symbols. The center and the points near the four corners in the screen are optional positions where the symbols can be put. The participants were divided into different groups, where the combination of the symbol and the position was unique. All participants were asked to spend 3.5 minutes on a VR game run by a smartphone-based HMD. SSQ acted as a tool to evaluate simulator sickness evoked by the game in all groups. Our research demonstrates that the existence, the eye-catching position and the abundant texture of static symbols can decrease simulator sickness to some extent.

However, the size of static symbols was not taken as a variable in our experiment though it should be. And our research mainly targets at simulator sickness caused by initiative rotation of participants in stationary scenes rather than the motion of scenes with participants still. Further studies are planned with an increasing number of cases.

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