Virtual Eye Exercise to reduce VR Sickness

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ABSTRACT
This paper discusses how Virtual Eye Exercises introduced between a Virtual Reality (VR) Simulation can act as one of the potential solutions to the problem of Virtual Reality Sickness. Our technique is based on a study that proved that physical eye exercises can reduce fatigue and eye strain. The simulator sickness (SS) or the VR sickness was measured using the Simulator Sickness Questionnaire (SSQ). The experiment was performed with 20 participants, aged between 20-27 years. Each participant was made to play a VR game with and without the virtual eye exercise, with a 15-20-minute break between the two sessions. The data gathered at the end showed that, the virtual eye exercises reduced the level of VR sickness for almost 66.67% of the subjects.

Author Keywords
Virtual Reality Sickness; Virtual Reality; Virtual Reality Rehabilitation; Simulator Sickness; Reach of Virtual Reality; Prolonged VR Use; Human Factors.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers. This section is required.

INTRODUCTION
With the advent of technological advancements, Virtual Reality HMDs (Head-mounted displays) are getting widely popular in a number of fields such as medicine, engineering, education, design, training, and entertainment and other industries, holding a promising future for all. However, the VR experience still is long way behind to gimmick real-life experience due to a major issue that it poses: Virtual Reality Sickness.

Virtual Reality Sickness or Simulator sickness in VR has been one of the major problems that dents the application of VR in medicine, engineering, education, design, training, and entertainment and other industries. If virtual systems are to be effective and well received by their users, considerable human factors and research needs to be accomplished to eliminate sickness. VR Sickness is majorly attributed by symptoms that are

- Oculomotor (ex. eye strain, difficulty focusing, blurred vision, and headache)
- Disorientation (ex. dizziness, vertigo)
- Nausea (ex. stomach awareness, increased salivation, and burping).

Various research has been done to counter the effect of VR sickness. One of the prominent ones has been regarding changing the FOV of a VR scene dynamically in a way that the user is unaware of it [1]. However, this might not be a good solution for some applications like simulator training where the immersiveness is a key factor in adding realism and decreasing field of view can prevent that. Moreover, this study was conducted with very few participants which were not enough to prove the proposed theory. Similarly adding a static reference frame inside the VR scene can also induce stability and hence reduce the visually induced motion sickness. In this regard, Whittinghill [9] suggested having a fixed nose in the view of the user inside the VR scene. This not only reduced simulator sickness but also increased immersion.

The most successful way up till now to deal with simulator/VR sickness is to make the user adapt to the VR environment by repeated or frequent use of HMDs, a technique called habituation. Though this increases tolerance towards the negative effects of the VR experienced in the initial stages, an initial unpleasant experience can also prevent users from using the VR headset again.

In light of all these possible yet not completely applicable solutions, we came up with the idea of introducing virtual eye exercises in between normal VR scenes to minimize the degree of visually induced motion sickness(VIMS) experienced by users. We began with studying the effect of

physical eye exercises used in various applications. Eye exercises have been used in the past and present to treat a wide range of conditions such as vergence problems, ocular motility disorders, accommodative dysfunction, amblyopia, dyslexia, asthenopia, myopia and many more. Though their use has been controversial in some cases, there are studies that prove their efficacy in terms of improving vision and reducing eye strain and general fatigue experienced in different situations. Usually these exercises are carried out independent of the situation that caused them i.e. once the unpleasant situation has ended. However, in our case we want the user to overcome the unpleasant feeling(VIMS) during the situation that causes it (VR simulation) not only to prolong the usage time of the VR headset but also make the user fully enjoy the VR experience. Thus, we decided to introduce virtual eye exercises in between the VR scenes in a way that does not interrupt the VR simulation. One way to do this is to introduce eye exercises on the loading screen that comes before the beginning of the next level of a game. This way no additional time needs to be assigned to the exercises and the game process can run smoothly as it was running before the eye exercise. Moreover, since the eye exercises are virtual the user would not have to remove the headset, thus causing no interruption in the VR experience.

Some of the major theories contributing to Motion Sickness include sensory conflict theory, evolutionary or poison theory, postural instability theory, rest frame hypothesis theory, the eye movement theory and the vergence accommodation conflict theory. Based on these theories, we believe that a virtual eye movement activity (virtual eye exercise), adhering to the major findings of these theories will help in reducing virtual reality sickness.

Definitions

- Motion sickness - adverse symptoms and readily observable signs that are associated with exposure to real (physical or visual) and/or apparent motion [2]
- Cyber sickness - visually induced motion sickness resulting from immersion in a computer-generated virtual world simulator sickness - results from shortcomings of the simulation, but not from the actual situation that is being simulated [3]
- VR sickness - Combination of both Motion sickness and Cyber sickness

Previous Work

The main use of eye exercises can be seen in vision therapy used to treat a number of eye related problems, one of them being convergence insufficiency. A study conducted by Paul Adler [4] employed simple convergence exercises, like simple pencil to nose exercises while Arnoldi [5] proposed the idea of performing orthoptist exercises that would need to be carried out on a daily basis to have a lasting effect. Both studies revealed at the end that convergence exercises are an effective way for treating convergence insufficiency.

Another major use of eye exercises has been seen to treat eye strain and fatigue generally. Sain [10] proposes computer implemented type of eye exercise in which a single focus object is displayed, moved and resized in various patterns on a computer screen. A similar yet unique approach was employed by Sina [11] in his research where "a viewer focuses on a central focal point interposed between the viewer's eyes and the associated images, the viewer perceives, in addition to the associated images, a merged image (also possibly having a plurality of objects) derived from the associated images. Then, by performing one of a number of suitable movements with the associated objects, the viewer's eyes are exercised. For example, by increasing the separation between the associated images along a horizontal axis while the viewer attempts to maintain the perception of the merged image, the viewer's eyes are exercised in such a manner that eye fatigue and eye strain may be relieved."

Making the user observe computer generated scenes with varying brightness and color has also proved to be an effective way of exercising eyes and relieving stress. Wagner [12] performed an experiment in which the brightness of a computer display was automatically adjusted. This made the observer's eye muscles to re-adjust and refocus, thereby reducing the fatigue by a great level. Liberman [13] taking a slightly different approach made the observer's eyes refocus by exposing them to a sequence of images with varying wavelengths, with each image being displayed for a short amount of time.

The most relevant study to our case is the use of oculomotor exercises prior to watching a Virtual Reality scene on a head mounted display (HMD) [6] .The analysis of the results was done with regards to 3 notable symptoms of VIMS: nausea, oculomotor, disorientation, while the evaluation of the results was done using a Simulator Sickness Questionnaire (SSQ) [7] test. The results showed significant reduction in cyber sickness experienced by VR users.

Technology Analysis

As a technology, virtual reality already has decades of experimentation and hype behind it, even if it is still early days for this latest generation of devices. That means that we can expect the technology to improve rapidly. There's a good argument for waiting until the technology, and the content created for it, is more established, more compelling, cheaper and most importantly usable with less health issues.

Though being age old technology that has been there for decades, the current version of VR evolved after the first prototype of the headset created by Palmer Luckey, which is now the Oculus Rift. Some of the major competitors

include HTC Vive, Sony's PlayStation VR, Google Cardboard etc.

The VR headset of today consists of a device like a thick pair of goggles that covers the eyes. The more expensive, higher quality headsets need to be connected to a computer to run apps and games, while some cheaper ones use a smartphone clipped to the front of the headset.

All headsets need to be used alongside a good quality pair of headphones, and there are other optional accessories from hand controllers to treadmills that are all designed to enhance the simulated experience of being in another world. Hand controllers translate the real-world gestures into whatever game or application the user is using, although standard gaming joypads can also be used.

Hypothesis

Motion sickness in VR is triggered by a number of factors: 'Small lags between simulator visuals and motion remain a problem, mismatch between what is perceived by the inner ear and the visual perception given by the VR headset. In the recent years, various solutions have been suggested/invented to minimize the effect of motion sickness, if not completely getting rid of it. While most address the technological aspects of the problem, few address the therapeutic side. While most focus on preventing the issue, few focus on reducing the effects of it. Our solution relates to the latter. We propose that virtual eye exercises if introduced at various intervals of a VR activity can minimize the effect of virtual reality sickness experienced by the user and thus prolong the use of VR. The main rationale behind using eye exercise is their effectiveness in the physical world in countering motion sickness and other fatigue related issues.

METHOD

Participants

The participants were recruited from the Computer Graphics Technology course. There were 20 participants in total. Out of which 10 were male and 10 were female aged between 20-27. They were all from different geographical backgrounds temporarily put up in the United States. The subjects were from the United States, China, India, South Korea, Taiwan and UK. Most of the participants had limited exposure to VR applications prior to the experiment having exposed less than 20 number of occasions. The participants did not have high susceptibility to motion sickness or VR sickness except a few of them.

Resources

The experiment was performed with the Oculus Rift VR Headset with the controllers that tracked the users head movement. It had 110 degrees default field of view with 2160 x 1200 image resolution. Unity3D - 2017.2.1 the cross-platform game engine was used to develop the VR game.

Experiment Design

The players head position was tracked using the sensors which had a tracking area capacity of 5X5 feet. In order to avoid unnecessary collision with the ambience, the participants were asked to sit in a rotating wheel chair in the center of the tracking space as shown in the figure 1.

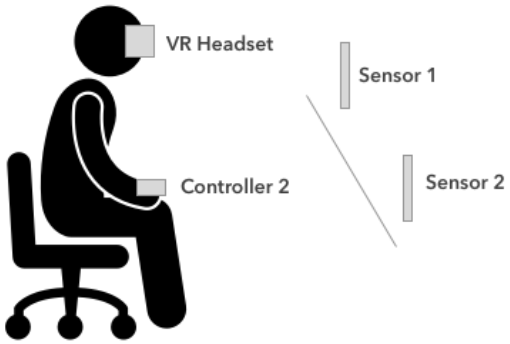

Figure 1: The figure depicts the experimental setup where the subject is made to sit in a rotating chair wearing the VR headset within the range of the VR sensors.

The experiment had a shooting VR game in which the player has to shoot the floating targets in three-dimensional space spawning in 360 degrees. The participants were exposed to pre-and post SSQ for both the sessions that had the virtual eye exercise and that did not have the virtual eye exercise as illustrated in the figure q.

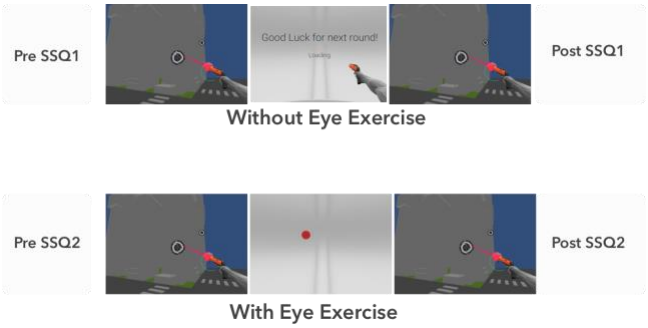

Figure 2: The figure depicts the VR sessions without the eye exercise and with the eye exercise.

For the session without the eye exercise, a Loading Scene of same duration of that of the eye exercise was used as a filler. Each session lasted for 6 minutes with a 20-minute break before the next session so that the participant completely recovers from the VR sickness caused by the first session. The virtual eye exercise and the Loading Scene was designed for a minute.

The Virtual Eye Exercise

The Virtual Eye Exercise that lasted for a minute is based on the Dynamic Adaptive Vision Therapy [8] that is used to treat motion sickness. Of all the exercises, simple zooming in and out, sideways translation and pendulum oscillatory exercises were chosen to last for the entire minute of the exercise which was simulated inside the virtual environment as shown in the figure 3.

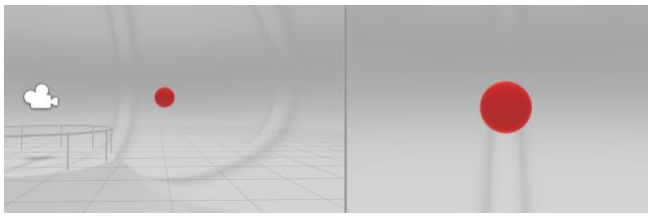

Figure 3: The figure depicts the virtual eye exercise in the virtual environment using a red ball for drawing the user's focus.

Due to the technical inability to track the participants eye movement, the participants were asked to focus on the moving red ball with their heads in still position.

The Virtual Environment

The Virtual Environment of the game simulates an urban street with tall buildings all around with a rotating chair in the center where the participant is virtually seated. Being in first person character mode, only the player's arm is visible to the player which is shown in figure r. Floating targets were randomly generated. The subjects can use the VR controllers to shoot these targets. The calibration for the simulator sickness was done by the level of circular motion intensity and the height of the buildings in the player's field of view. The default loading scene instructed the participants to wait for the next round. The instructions were designed to stay in the user's field of view.

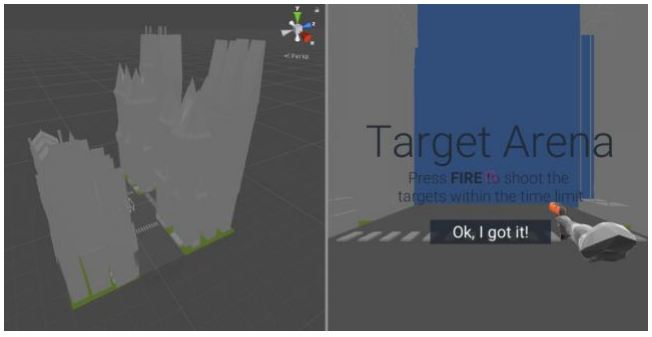

Figure r: The figure depicts the urban street view on the left and the player's relative position and field of view on the right inside the virtual environment.

DISCUSSION

Notably, the VR game did not cause any effect for 3 participants which was evident from their SS scores whereas a couple of participants gave up while performing the experiment. The results of our experiment are hence limited to 15 participants.

The scores were normalized as per the standard SSQ norms[7]. Analyzing the data showed us a trend that for most of the participants (66.67%), the introduction of a virtual eye exercise that gimmicked the Dynamic Adaptive Vision Therapy in a virtual environment decreased the level of simulator sickness caused by the VR game. For some (6.7%) of the participants the virtual eye exercise did not have any effect. Contrary to the initial belief, for a considerable (26.7%) of the participants, the virtual eye exercise had a negative impact which increased the simulator sickness caused by the VR game. This is depicted in the figure x and y.

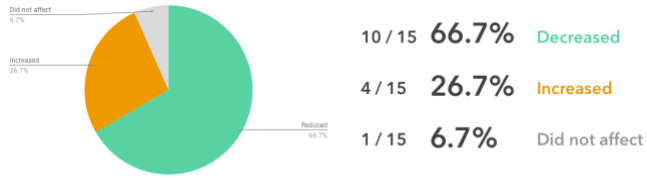

Figure x. The figure depicts the corresponding percentage of the participants with whom the simulator sickness decreased, increased or did not have any effect by the introduction of the virtual eye exercise.

Figure y: The figure depicts the simulator sickness score caused by the VR game measured for each participant with and without the Virtual Eye Exercise.

From the figure y, it is notable that for few participants, the SS score increased by the introduction of the virtual eye exercise. Probing those participants specifically after the experiment revealed that the eye exercise smoothened their discomfort to a great extent which in turn made it difficult for them in the last round of the VR game after the virtual eye exercise. Though qualitative in nature, this observation

could be a plausible aspect to explore in the future. One participant reported that the effect of virtual eye exercise almost got nullified by the last round of the VR game which was recorded in the Post SSQ2.

Another inference is that a few participants had some discomfort before performing the second session as the time required for their recovery wasn't sufficient. Hence the difference of the SS scores is in the negative scale.

RESULTS AND FUTURE WORK

We came up with the idea of using virtual eye exercises in between VR scenes to reduce VIMS. From our results, it is clear that eye exercises can reduce VIMS to a great degree. Since we performed the experiment on just 20 people, with ages limited in the range of 21-27, it is hard to predict the results for a larger group that also includes older and younger people. Therefore, one of our future work would be to include people from a wider age group. Another improvement would be to vary the circular motion intensity for each participant. This is essential as some of the participants did not feel sick from the rotation speed that we kept constant for all participants and thus the results they generated had to be neglected. Tracking the user's eye movement to make sure that they followed the eye exercises correctly is also very important. However, currently we were unable to do that since the present model of oculus does not have an eye tracker nor did it aid in attaching one to it. We are hoping that the next model would have this functionality, thus helping us assure if the eye exercises have been performed the way they should be. We also plan to experiment with more different kinds of eye exercises to help us determine the most effective ones, such as figure drawing with eyes, making the eyes follow a rotational, diagonal or vertical pattern.

This study suggested a positive correlation between virtual eye exercise adapted from DAVT and the reduction of VR sickness. Complete understanding of the underlying model and possible causal relationships among SS and Virtual Eye Exercise requires further research.

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