Mitigating Visually-Induced Motion Sickness in Virtual Reality ⋆

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Abstract: Visually-induced motion sickness (VIMS) remains a major impediment to the growth of virtual reality technologies. Symptoms of nausea prevent users from staying in virtual environments, especially in experiences that emphasize movement. Our research concerns techniques to mitigate this problem; previous research has shown that techniques used to reduce VIMS in the physical world can also be successful in virtual ones, suggesting that exploring different techniques of VIMS-reduction could be worthwhile. We chose to study a concept we denote "anchoring": the idea of having a point of reference (typically a stationary object) to focus on as motion occurs. Ultimately, we found that in a majority of test subjects adding an anchor to virtual environments was successful in decreasing symptoms VIMS, as measured through responses to the Simulator Sickness Questionnaire (SSQ). Future research would aim to remove possible confounding variables such as our non-wireless setup, which required users to periodically stop their movement, since this could have also reduced VIMS symptoms; additionally, to ensure our results are generalizable a study on a larger and more diverse sample of subjects would be necessary.

Keywords: Virtual reality, motion sickness, visual anchors, vestibular systems

1. INTRODUCTION

A central problem in virtual reality is user discomfort, with particular regards to motion sickness. One complication of this is that the exact causes of motion sickness are not yet known: one of the more popular explanations for this phenomenon is the sensory conflict theory, a theory postulated in a 1975 paper by Brand and Reason. This theory posits that motion sickness is the result of sensory rearrangement in which the motion signals received and transmitted by the eyes, the vestibular system and the nonvestibular proprioceptors are different not only with one another, but also with past experiences and those expectations (Reason). For the sake of our research, we accepted this definition as a basis by which to explain motion sickness, an effect which is commonly characterized by symptoms of nausea and disorientation (Rine et al., 1999). Given this definition, it follows that motion sickness as experienced when the environment is at odds with ones perceptual experience (such as being stationary in a moving car) is only aggravated when virtual reality is the environment in which the conflicting stimuli are being experienced; after all, in VR the entire vision field is obscured, and therefore the entire visual system can be at odds with the vestibular. With our research, we aim to explore ways to reduce motion sickness in VR. This is critical as consumer products will be limited by consumer discomfort; if the symptoms of motion sickness can be decreased, then this will make VR a more viable option for long-term use.

In order to reduce motion sickness in VR, we must first identify what is causing the sensory mismatch in VR. A 1992 paper published by MIT gave two main causes for vestibular and nonvestibular disconnect: first, the conflict between being physically stationary while perceiving self motion; and second, the detectable lags between head movement and recomputation and presentation of the virtual display (Hettinger et. al.). In other words, this paper posited that the key problems that induced motion sickness in VR were the actual experience of motion, and the lag of the virtual display itself. Both of these problems pose interesting challengesfor the sake of our research, we chose to focus on the former. That is, our research explored how to bridge the perceptual gap between engaging in active behaviors (e.g. travel) within virtual reality while maintaining a stationary position in the physical world.

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For those experiencing motion sickness in the real world, such as while traveling in a car, relief can be provided by utilizing a concept which we will denote anchors. Anchors are stationary objects in the real world that individuals can focus on to provide some sense of external consistency: think of watching trees pass as you are being driven, or how ballerinas choose focus points as they pirouette. The general idea behind anchors is that focusing on stationary objects allows the mind to rationalize movement, reducing vestibular and perceptual conflict. This idea introduces a novel concept: could this idea of anchors be incorporated somehow into a virtual environment, and therefore reduce motion sickness therefore much like anchors did in the real world? The following sections will discuss past work on motion sickness in VR, the development of our project, and the results of our research.

2. RELATED WORK

In 2014, Michael Keneke Curtis of Iowa University published a paper researching VIMS mitigation techniques within virtual environments. This paper proved invaluable to the development of our study. In this paper, Curtis explores various techniques of mitigating motion sickness within virtual reality and compares them with techniques used in the physical world. Curtis and his team tested responses chiefly through use of the Simulator Sickness Questionnaire (SSQ), which they derived from the Pensacola Motion Sickness Questionnaire (Kellogg et al., 1965). Prior to Curtis research, some work had been done to discover the correlates of VIMS: for instance, a paper published in 2005 found a negative correlation between presence (the feeling of being in a virtual environment) and simulator sickness (Jerome et al.), suggesting that as an environment feels more real, VIMS becomes less potent. Also critical to the development of Curtis research was a 2007 paper which found that physical readaptation strategies, such as hand-eye coordination activities, are effective in accelerating relief from VIMS (Champney et al., 2007). Finally, a paper published in the journal Experimental Brain Research ruled out postural instability as a cause for VIMS by testing whether VIMS could be induced in a subject that was wholly restrained (Faugloire et al., 2007). Given this research, Curtis team decided to ask whether techniques such as those described in Champneys work could be used to mitigate VIMS from within a virtual environment as well as in the physical world.

In his study, Curtis tested four conditions. The first two used tasks in the physical world to mitigate motion sickness after exposure to virtual reality; the latter two conditions used these same tasks but placed those tasks within a virtual environment as well. One of these tasks was a hand-eye coordination activity where users placed pegs into a board, and the other was natural decay (where users simply sat in the respective environments until the motion sickness faded).

Ultimately, what was found was that the eye-hand coordination task was far less effective in the virtual environment; the natural decay task, however, was just as effective. This suggested that some VIMS-mitigating techniques used in the physical world could be effective while the subject was still within the virtual environment (although others lost effectiveness). This result thus implied that future research on more time-effective methods of motion sickness relief would be worth exploring, a fact critical to our choice of project.

3. IMPLEMENTATION DETAILS

For our experiment we needed to simulate movement and be able to easily add and remove an anchor to our subjects view. To simulate movement we decided on a live video feed from two webcams that were calibrated to produce a stereoscopic effect. The webcams were then mounted on an toy RC car that could be moved around by us using a controller.

To allow us to easily add and remove an anchor we opted to put the video streams from the two webcams into Unity. With Unity we were able to add in a car interior model from the Unity Asset Store.

3.1 Live Webcam Feed in Unity

To produce a stereoscopic effect we first needed a way to simultaneously get the live stream from two webcams. To do this we got two Logitech webcams that what we connected to the computer with two USB extension cables. The extension cables were so that the RC car would be able to move around more freely. In order to get the the webcam feeds in Unity, we utilized Unitys WebCamTexture. Using WebCamTextures meant we were able to texture two planes with the webcams live video feeds. One plane would get the left webcam video feed and the other would get the right webcam video feed. The planes we used in Unity were UI components called RawImage.

3.2 Calibrating Webcams for Stereoscopic Effect

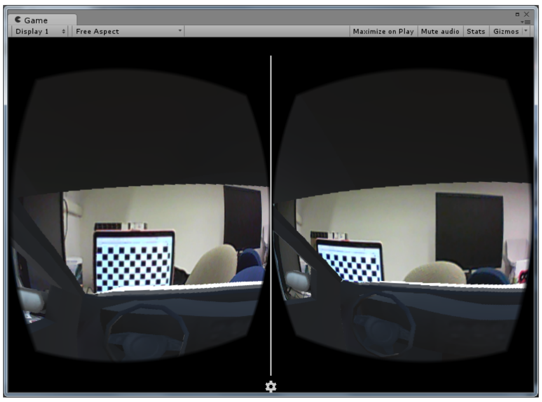
To produce a stereoscopic effect we first had to get the correct distortions for the headset and render the video feeds side by side. We did that by using the Google VR SDK for Unity. We imported the SDK and utilized the GvrMain Prefab which split the screen and produced the appropriate distortion for the View-Master VR HMD. The

GvrMain PreFab itself is two game cameras that have an overlay and a distortion applied. The two planes with WebCamTextures were put in front of the cameras. To calibrate the webcams for the stereoscopic effect we started by taping one of the webcams onto a mount made of cardboard, making it stationary. This mount was then placed onto the RC car. The second webcam was then placed onto the same mount but not taped down. We then placed a laptop with a checkerboard image at a set distance from the two webcams. From there we took the RawImage plane corresponding with the video feed of the webcam not taped down and put it on top of the RawImage plane of the webcam that was stationary. We then adjusted the position of the webcam that was not taped down until the video feeds of the two webcams overlapped to produce one checkerboard image. Once that was achieved we secured that webcam to the mount as well.

3.3 Adding the Anchor

The anchor we used in our experiment was a model of the interior of a car we got from the Unity Assets Store. We added two car interior models so that each camera (left camera and right camera) from the GvrMain PreFab could go in each one. The car interior model was either disabled or enabled while the experience was running. The anchor would be stationary while the video footage would run in the background.

Fig. 1. The stereoscopic webcam feed with an anchor in the form of a car dashboard added.



4. **EXPERIMENT**

4.1 Method

Our experiment involved two videos. Both videos were stereoscopic footage of us driving the RC car on the same course in Bytes Cafe in the Packard building. One video was with car interior anchor and the other was without it. We ran the experiment on 6 subjects, with 3 seeing the video with the anchor and 3 seeing the video without.

For the experiment we had each subject answer the Pre-Questionnaire and Post-Questionnaire from the Simulator Sickness Questionnaire. Each subject would answer the Pre-Questionnaire, watch a video, and then answer the Post-Questionnaire. We would then compare the Simulator-Sickness Questionnaire scores of the Pre-Questionnaire and Post-Questionnaire for each subject.

4.2 Simulator Sickness Questionnaire

The Simulator Sickness Questionnaire involves users rating the degree to which they felt certain sensations such as discomfort, nausea, sweating, and burping. The ratings are none, slight, moderate, and severe, each respectively taking on a value of 0 to 3. There are three subscores: the Nausea-related subscore, the Oculomotor-subscore, and the Disorientation-subscore. Each of these subscores are calculated by applying weights to the ratings of relevant sensations The overall Simulator Sickness Questionnaire (SSQ) score is calculated by taking the sum of all subscores and multiplying by 3.74.

5. **RESULTS**

Despite the small sample size, the results of the experiment were interesting. For the group of 3 subjects that saw the video with the anchor, 2 of them had an SSQ Score increase of 1 and 1 had a decrease in SSQ Score of 1. For the group of 3 subjects that saw the video without the anchor, with all having increases of > 2.

Fig. 2. SSQ Scores with no anchor added.

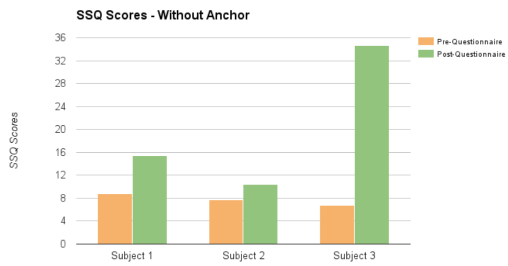
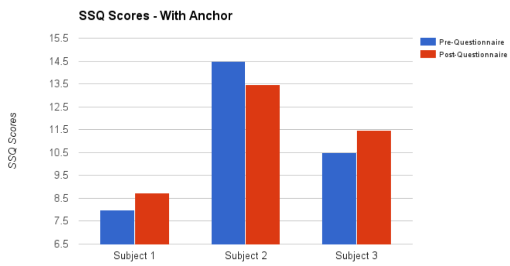


Fig. 3. SSQ Scores with an added anchor.



6. DISCUSSION

6.1 Results

The results from the small sample size were promising. However, it was still a very small sample size so the results are in no way significant.

It is worthwhile to note one particular subject who viewed the video with an anchor. This subject was the only subject whose SSQ Score decreased: the subject rated their headache as Moderate in the Pre-Questionnaire and None in the Post-Questionnaire. Although it is difficult to determine why this may have been the case, we do not believe it is likely that this could be a generalizable result.

In terms of general confounding variables, one could have been the anchor limiting the field of vision of the viewer. The car dashboard model that we utilized as an anchor could have obstructed the footage in a way that prevented viewers from seeing the majority of the footage. Seeing less of the footage may have resulted in subjects not feeling as motion sick. In other words, the reduction in motion sickness could have been more due to lower field of view as opposed to the presence of an anchor.

Another confounding variable is that our setup was wired. This wired setup limited the distance and freedom that we had when getting the footage of the RC car moving, which meant we were required to make stops while filming. The multiple stops in this footage could have reduced potential VIMS symptoms.

6.2 Future Work

In order to make our results more generalizable, it will be necessary to do additional studies in the future that use more diverse subjects, as all of ours were students at Stanford University. It will also be necessary to control for some additional variables such as prior exposure to virtual reality, gaming experience, and other factors that may have affected subjects' experiences. One particularly important improvement to the study would be conducting this experiment with a wireless setup, as the forced pauses as a result of having a wired setup (with participants having to readjust themselves whenever the reached the end of the cord) could have created some sort of natural decay effect that in itself lessened the development of VIMS symptoms.

If this work proves valid, some additional avenues that might prove worthwhile to explore would be finding whether the experience we generated with an RC car could be replicated with better equipment. There could be some interesting applications for drone travel through virtual reality, but the question remains of whether adding a flying component (such as if the device was rigged up to a quadcopter) would aggravate VIMS symptoms.

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