Effects of HUD Presence on Cybersickness

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Abstract

Cybersickness is a problem that severely limits virtual reality. One method of understanding why virtual environments generate cybersickness is sensory conflict theory, which states that symptoms are generated from a conflict between the visual and vestibular motion frames. In order to reduce the symptoms of cybersickness under the assumption of sensory conflict theory, we propose to overlay an HUD onto a virtual environment. The though is that the HUD will provide a stationary element to the visual frame that agrees with the vestibular frame, thus reducing symptoms. Also proposed is a way to overlay an HUD without decreasing from the user's enjoyment of the virtual environment. This is via the varying of presence of the HUD in proportion to perceive motion. To test this, a study 9 participants was conducted and divided into three groups: no HUD, a minimum presence HUD, and a dynamic HUD. Results indicate that the HUD does reduce symptoms of cybersickness that elicit nausea, but does not affect oculo-motor symptoms, with the dynamic HUD reducing more than the minimum HUD. Also shown is that the dynamic HUD did distract from user enjoyment of the virtual environment.

Introduction

Virtual reality (VR) has become a recent sensation in the world of gaming in the last several years, making break into mass-market gaming products. However, a large problem with the VR games of today is that of cybersickness, a type of sickness where users develop symptoms similar to those in motion sickness. Symptoms include disorientation, headache, nausea, and even vomiting [1]. Cybersickness is a relatively common problem to those who experience virtual reality games, and due to this, the market and design of such games have been troubled.

Sensory conflict theory is the most accepted theory relating to cybersickness and motion sickness. This theory states that the symptoms of the conditions are elicited from conflicting signals received from the visual and vestibular senses. One proposed method to reduce simulator sickness under the assumption of sensory conflict theory is that of superimposing an independent visual background (IVB) to the simulation scene. In a study conducted by Duh, Parker, and Furness [1], a grid-like IVB was applied to the virtual environment in a driving simulator in an attempt to reduce simulator sickness. Their results indicate that simulator sickness was reduced due to the presence of the IVB.

In another study by Jäger, Gruber, Müri, Mosimann, and Nef [3], the superimposing of an IVB onto the virtual environment was combined with methods of scene optimization and a decrease in brightness. In their attempt to reduce simulator sickness in a driving simulator, their results indicate that the combined method did reduce the feeling simulator sickness.

Similar to this experiment, Shahal, Hemmerich, and Hecht [5] conducted a study to find whether brightness and contrast affect cybersickness in virtual environments. In their study, they differed brightness and contrast in four recorded flights of a fixed-base flight simulator. Their results report that brightness and contrast did not affect the elicitation of cybersickness. This leads us to the conclusion that the reduction in brightness by [3] had little effect on the reduction of cybersickness, bringing more credence to the use of an IVB.

In another study by Fernandes and Feiner [2], the field of view (FOV) of a virtual environment was decreased in order to reduce cybersickness. In their study, the FOV of the users was dynamically, albeit subtly, decreased in proportion to perceived motion in the virtual environment. Their results show that such a dynamic reduction did in fact reduce the reported presence of cybersickness. Moreover, subjects reported that they hardly, if at all, noticed the reduction in the FOV.

Based on the results presented in use of an IVB to reduce cybersickness and the decrease of the FOV in proportion to perceived motion, this paper introduces the question of the effect of heads-up display (HUD) presence on cybersickness in a virtual environment. Similar to the IVB, the use of an HUD could mitigate the effects of cybersickness based on sensory conflict theory. In addition to this, we propose to vary the presence of the HUD in proportion to perceived motion as in [2]. Our hypothesis is that the use of an HUD will reduce symptoms of cybersickness as compared to when one is absent. Furthermore, we expect that an HUD of varying presence will result in a stronger reduction of symptoms than in the case of a standard HUD of constant minimal presence.

Equipment and Setup

Used in this study was the HTC Vive, a head-mounted, virtual reality display. The virtual environment used was built using Unity 5.5.1 and based off of an edit of the Oculus Rift Tuscany demo by [2]. Used also was a Logitech Wireless Gamepad F710.

Study participants would don the HTC Vive and navigate through the virtual environment in a seated position as shown in Figure 1. Participants would use the gamepad's left joystick to navigate forward, backwards, left, and right in the environment. Rotation was handled using the Vive. To rotate, the user would physically rotate their body around the point of the chair. Here, forwards with the gamepad was the direction the user was facing.

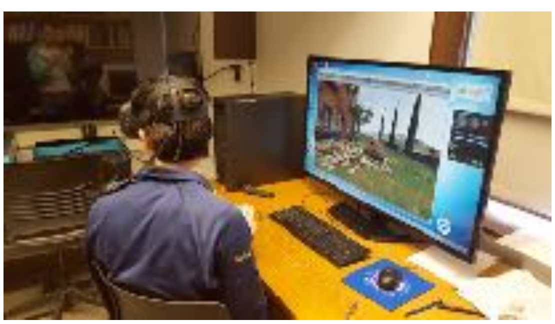


Figure 1: A study participant navigating the virtual environment

Design and Implementation of HUD

The design of the HUD was based on a study conducted by Loïc Caroux and Katherine Isbister [6] which stated that players preferred HUD elements displayed horizontally as compared to vertically. It was also shown that a compass was ranked as a very important element for users. In consideration of the user's perceived presence in the virtual environment and most movement to be done horizontally, the suggestion to place HUD elements on the top and bottom of the user's field of vision matched well with [6].

Elements chosen for the HUD could not directly impact user performance in the virtual environment. Therefore, features such as a mini-map were not used and instead other features that provided information that the user felt was useful, but did not actually aid them in performance were implemented. The final elements chosen due to these considerations were a horizontal compass shown at the top of Figure 2.b-c, a progress counter shown at the bottom left, and digital clock shown at the bottom right.

Figure 2. a: Visual with no HUD

Figure 2. b: Visual with minimum presence HUD

Figure 2. c: Visual with dynamic HUD at max presence

In showing the users the HUD, a large goal was to not reduce from the enjoyment of the virtual environment. As such, a minimum level of presence had to be determined for the HUD that would allow users to clearly see the contents while simultaneously not distracting them too much from the virtual scene. Here, the presence of the HUD was varied by changing its transparency value. The threshold for minimum presence was determined to be 0.5 or 50% transparency.

Similar to [2], a version of the HUD to be tested was one in which the presence was scaled in proportion to the amount of perceived motion by the user. For this dynamic HUD, the minimum bound was set to be the minimum determined presence value of 0.5. From there, the transparency value was then calculated via: *transparency = (angular velocity + translational velocity * 20) / 400 + 0.5,* where angular velocity was measured in degrees/second and translational velocity was measured in scene units/second.

Figure 2 shows the three variations of the HUD used in the user study: no HUD, a minimum presence HUD, and a dynamic HUD.

User Study

In order to measure the effectiveness of the HUD on the symptoms of cybersickness, participants were recruited to undergo a testing procedure. 9 participants all of an age group of 20-22 years were recruited and divided into three groups to test the effectiveness of the HUD: a group given no HUD, a group given the minimum presence HUD, and a group given the dynamic HUD. Participants were asked questions before and after navigating the virtual environment to record the effects on any symptoms present. This study was approved by the Connecticut College IRB.

The design of the study consisted of an information session where participants were told about the risks of the study and their rights as participants followed by a brief overview of the procedure. Following this, users answered a pre-procedure questionnaire (Appendix A) before navigating through the virtual environment. Following their navigation completion, the participants were then asked to fill out a Simulator Sickness Questionnaire (Appendix B). Those who were given an HUD, be it the minimal or dynamic one, were also given a post-procedure survey (Appendix C). After this, users were given access to an arrangement of refreshments that addressed any minor symptoms they felt and were allowed a small period to rest on site.

Pre-procedure Survey

The pre-procedure survey shown in Appendix A asked questions regarding any aspects that might influence their performance or presence of any symptoms in the study. These included questions about gender, age, computer usage, and their current health.

The Virtual Environment

Upon completion of the pre-procedure survey, participants then navigated through the virtual environment. Users would follow a series of 77 waypoints positioned across the environment. Upon reaching one waypoint, it would disapear and the next would become visible. In this way, participants were asked to follow each waypoint. Movement was restricted to following the path of the waypoints. However, rotational movement was left up to the user, and they were told to take as much time as they needed, turning their heads to look at the environment to their heart's content. A waypoint was a noticeable red object that floated in the environment as shown in Figure 3.a-b.

Figure 3. a: Waypoint used in and around the house

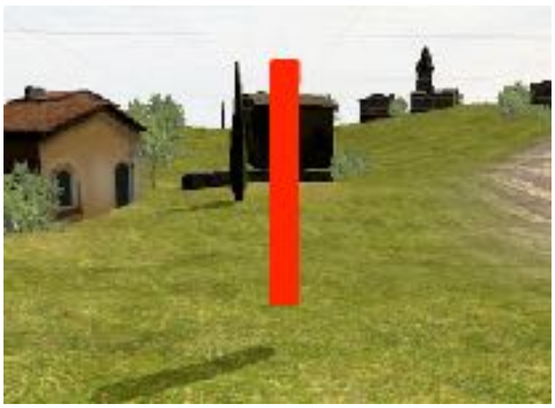


Figure 3. b: Waypoint used outside the area around the house

Shown in Figure 4.a-b is the path each participant followed through the virtual environment. The lines present connect individual waypoints throughout the environment in the order in which they were presented to the user. Starting from the yellow line in Figure 4.a, participants would move through the interior of the house, then proceed along the blue line out of and around the house and out of the courtyard. The roof in Figure 4.a was removed for the image and was present during the study. Following this, users would proceed from the house along the blue line shown in Figure 4.b into the village. Merging into the yellow line of Figure 4.b, participants would then travel up the large hill shown and back down to the house, completing the course.

Should the participant experience any extreme sense of discomfort as a result of symptoms of cybersickness, they were allowed to immediately stop their navigation of the environment as their symptoms had already reached a maximum level.

Figure 4. a: Navigation course in and around the house

Figure 4. b: Navigation course outside of the area around the house

Simulator Sickness Questionnaire

Following their navigation through the virtual environment, participants were then asked to fill out a Simulator Sickness Questionnaire (SSQ) shown in Appendix B. The SSQ is a standard method of measuring symptoms of both simulator sickness and cybersickness. The SSQ used in this study was an edit of one by Kennedy, Lan, Berbaum, and Lilienthal [7] edited by the UQO Cyberpsychology Lab [8].

In the SSQ, participants ranked the degree of any symptoms present on a scale of none, slight, moderate, or severe.

Post-procedure Survey

For those users in the minimum presence HUD group and dynamic HUD group, following the SSQ they filled out a post-procedure survey shown in Appendix C. This survey asked questions regarding the HUD in order to gauge how much it affected the user's enjoyment of the scene. Questions asked include those about how helpful/ distracting the HUD was, their opinions on how noticeable it was, whether or not they noticed any changes, and any further comments they had.

The ideal here was that users did not notice the dynamic nature of the dynamic HUD and that it did not distract from the user's enjoyment any more than the minimum presence HUD.

Results

To properly calculate the level of symptoms present in the participants after their navigation of the virtual environment. Results from the SSQ were grouped into two categories as in [8]: nausea and oculo-motor. Here, nausea represented those symptoms that elicited a feeling of nausea or stomach sickness in the user, while oculo-motor symptoms represented those symptoms that elicited a feeling of eye strain or or blurred vision. Items 1, 6, 7, 8, 12, 13, 14, 15, and 16 of the SSQ were grouped into the nausea category while items 2, 3, 4, 5, 9, 10, and 11 were grouped into the oculo-motor category. The symptoms of each category were then summed over all users in each group. The results are presented in Figure 5.

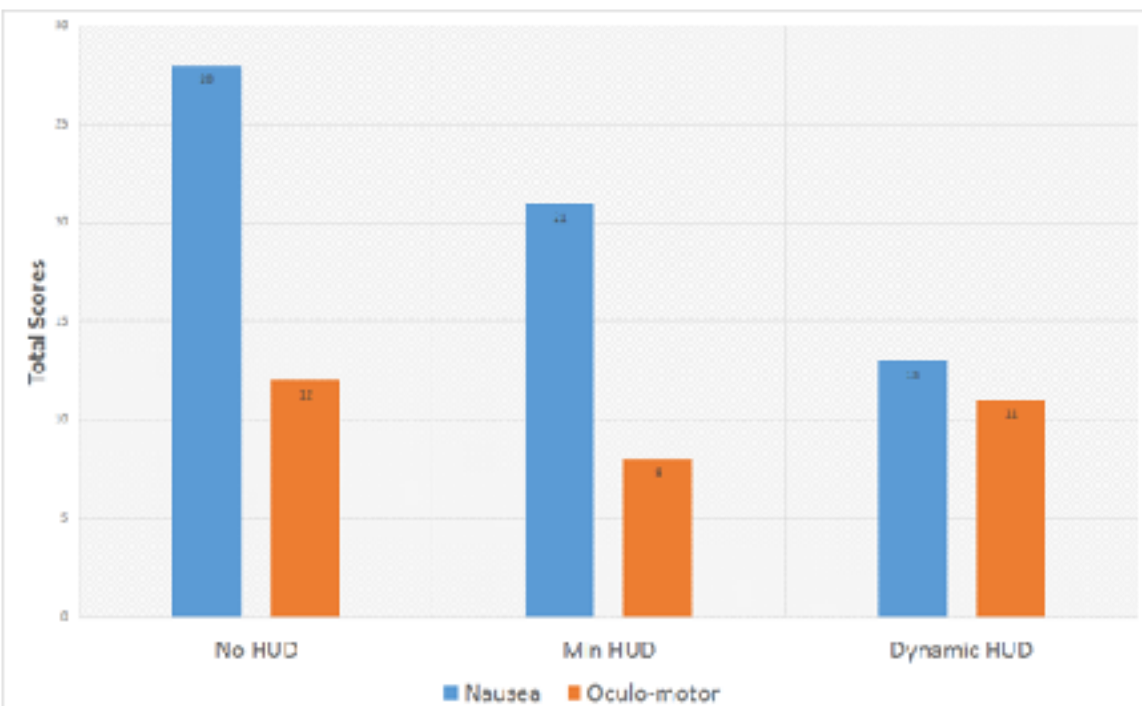
In addition, it was discovered that no trends were present between most items covered in the pre-procedure survey and the presence of any symptoms. Exceptions may be that the prior health of the user before the study did seem to slightly effect the presence of symptoms and that those with a history of motion sickness were more likely to exhibit symptoms.

Also, results from the post-procedure survey show that participants in the minimum presence HUD group found that the HUD was very helpful, although they would have preferred it be slightly less noticeable. The dynamic HUD group on the other hand found the HUD to be distracting and would have preferred there be no HUD at all. However, only one participant noticed the dynamic nature of the HUD.

Discussion and Conclusions

It can be seen in Figure 5 that the HUD was successful in reducing the nausea symptoms in participants with the dynamic HUD further reducing symptoms compared to the minimal HUD. This agrees with our hypothesis quite nicely and illustrates that an HUD can decrease symptoms of cybersickness. However, it can also be seen that the oculo-motor symptoms were nearly the same between all three groups, with the HUD having no noticeable effect. Reasons for this may include that the oculo-motor symptoms are not affected by any sensory conflicts between perceived motion frames, but rather from problems involved in the virtual environment such as resolution and frame rate which were the same for all three groups.

The results also show that the dynamic HUD did distract from the user's enjoyment of the virtual environment to a considerable degree. Despite that fact that only one participant noticed the the dynamic nature of the HUD, the HUD had



a definite impact on the user's enjoyment. Future considerations should take this into account and perhaps make the virtual environment more interesting and/or make the HUD less distracting.

Also, the subject pool used in this study was rather small. To ensure a robustness in data and to insure that individual impact on results is minimal, the study should be conducted on a larger subject pool, spanning more than the small age range of this study.

Acknowledgments

We'd like to thank Ajoy Fernandes [2] for providing us his edited copy of the Oculus Tuscany Demo. This save us quite a lot of time and insured that the environment was ready for testing.

We'd also like the thank the Connecticut College IRB for approving the study. Without this, the research could not have generated results.

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Appendix A

Pre-procedure Survey

1. What gender were you assigned at birth?

2. What gender do you identify as?

3. What is your current age?

4. How often do you use a computer in an average week? (in hours)

5. What are you main reasons for using a computer?

6. How often do you play video games in an average week? (in hours)

7. Do you have any experience with virtual reality games or virtual reality devices?

8. On a scale of 1-10 with 1 being very ill and 10 being perfectly fine, how would you rate your overall health at this moment?

9. On a scale of 1-10 with 1 being very seldom and 10 being very often, how frequently would you say you get sick?

10. Do you easily get motion sick? If so, please explain.

Appendix B

Simulator Sickness Questionnaire (SSQ)

Instructions: Circle how much each symptom below is affecting you right now.

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. *Fullness of the Head	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. **Vertigo	None	Slight	Moderate	Severe
15. ***Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

* Fullness of the head can also be described as a perceived buildup of pressure in the head making it feel "full."
** Vertigo is experienced as loss of orientation with respect to vertical upright.
*** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Appendix C

Post-procedure Survey

1. On a scale of 1-10 with 1 being very distracting and 10 being extremely helpful, how useful would you consider the heads-up display (HUD).

2. Would you have more enjoyed a less noticeable HUD, more noticeable HUD, or no HUD at all?

3. Did you notice any changes to the HUD during the experiment?

4. Do you have any further comments concerning the HUD? If so, please write them down here.