Towards an Immersive Driving Simulator to Study Factors Related to Cybersickness

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Abstract

The commercialization of Virtual Reality (VR) devices has made it easier for everyday users to experience VR from the comfort of their living rooms. This recent uptake in VR has also increased reported incidents of cybersickness. Cybersickness refers to the discomfort experienced by an individual while experiencing virtual environments. The symptoms are similar to those of motion sickness but are more disorienting in nature resulting in dizziness, blurred vision, etc. Cybersickness is currently one of the biggest hurdles to the widespread adoption of VR, and it is therefore critical to explore the factors that influence its onset. Towards this end, we present a proof of concept simulation to study cybersickness in highly realistic immersive virtual environments.

Index Terms: Human-centered computing—Empirical studies in HCI——Human-centered computing—User Studies

1 Introduction

Rapid technological advancements and lowering prices of commercial Head-Mounted Displays (HMD) have led to an increased demand for modern VR applications, many of which, involve the travel and exploration of large virtual environments. Of multiple VR travel metaphors studied in the past, steering is one that is relatively intuitive and straightforward, giving users continuous control over their movement in immersive virtual environment (IVE) using physical devices like steering wheels, joysticks, etc. [10]. Despite the growing popularity of VR and its potential as a technology, it has yet to become widely adopted. Apart from the costs associated with the technology, a major hurdle hindering its widespread adoption is cybersickness. Cybersickness is the discomfort felt by users while experiencing virtual environments marked by symptoms such as nausea, eye strain, sweating, disorientation, dizziness, etc. [5], and it usually occurs when users are exposed to visual motion stimulus while remaining stationary in the real world. With modern VR applications increasingly incorporating travel, it is critical to investigate factors influencing cybersickness. Therefore, in this work, we present a proof of concept immersive driving simulation platform to extensively study cybersickness in virtual reality.

2 Related Work

Visually Induced Motion Sickness (VIMS) is a subset of motion sickness that is most commonly experienced when people perceive motion through visual stimuli when in fact they remain stationary, resulting in symptoms similar to those produced by motion sickness [3]. This perception of self motion, referred to as vection, is caused due to the optic flow experienced, and is often correlated with, if not a prerequisite to, VIMS [4]. VIMS usually manifests as simulator sickness in contexts involving simulators, and as cybersickness in contexts involving IVEs. Several theories like the Sensory conflict theory and the postural instability theory have been used to address the issue of cybersickness [2]. Several factors affecting cybersickness have been investigated in the past like latency [7,9], rest frames [1], etc. Travel techniques in immersive VR have constantly evolved and improved with an intention to produce lower levels of cybersickness. Recent work on this front has shown that jumping induces lesser sickness, justifying its use as an alternative to steering where applicable [10]. Other factors such as users' VR experience, duration of the simulation, field of view, speed of travel, etc. have been revealed to strongly influence cybersickness levels associated with immersive virtual reality experiences [8].

In this work, we develop a realistic immersive virtual reality driving simulator to study factors affecting cybersickness. The simulator's feasibility was evaluated by conducting a preliminary study that looks at the onset of and the susceptibility to cybersickness.

3 System Description

A large scale virtual cityscape environment was created for this study. The IVE was rendered onto an HTC Vive HMD connected to a desktop computer with an Intel Xeon processor, 64 GB of RAM, and a dedicated NVIDIA GTX 1080 Ti graphics card. To provide a realistic experience, participants are seated on a car seat mounted on a wooden platform and use a Logitech Driving Force GT[1] steering wheel and pedals to control the vehicle, see Figure 1. The seating apparatus is constructed such that the height and positioning of the steering wheel, pedals and the car seat match that of an SUV. The simulation runs at an average of 70 frames per second. The average HMD latency is 60.6 milliseconds, measured based on methods described in [6], is 60.6 milliseconds.

The cityscape is realistically scaled with skyscrapers, apartment complexes, etc. along with 16 distinguishable landmarks distributed evenly across 120 city blocks. The environment is created in Unity using downloadable assets from the Unity[2] Asset Store and custom 3D objects modeled in Maya and Blender. We followed a concentric square pattern alternating between small and tall buildings to provide uniform optic flow across the city, see Figure 2. The landmarks are simple structures like monuments, statues, tennis courts, etc. that can easily be distinguished from other buildings in the scene. The

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[1]https://support.logitech.com/en_us/product/driving-force-gt

[2]https://unity3d.com/

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Figure 1: (a) Real world car seat and HMD setup. (b) First person view of the participant sitting in the virtual car.

landmarks were placed strategically in the city with each quadrant having no more than four landmarks.

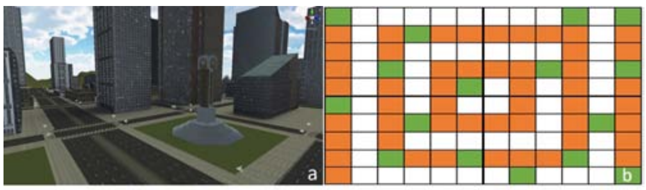

Figure 2: (a) A screenshot of the city environment where the participant looked for landmarks.(b) City layout. Orange blocks represent tall buildings like skyscrapers, white block represent short buildings like apartments, complexes, etc., green block represent landmarks.

In the IVE, participants are seated in a 3D modelled, scaled replica of a Subaru Forester SUV. The Logitech steering wheel's movements in the real world are mapped to the virtual steering wheel of the car. The virtual car's speed and driving mode (Drive or Reverse) are accurately represented in the speedometer using text and a 3D needle respectively. The physical gear knob provided with the Logitech wheel allows users to switch driving modes. The dynamic properties of the virtual car like the suspension, traction control, acceleration time, braking time, torque, etc. have been adjusted to act like a real life Subaru SUV. The simulation is equipped with sounds corresponding to acceleration, deceleration, braking and gear shifts.

Users are given a self-avatar whose hand movements are mapped to those of the participant's. This is achieved by strapping HTC Vive controllers onto the participant's wrist along with a Unity plugin[3]. A custom automated script is used to scale the avatar to match users' arm-length and accurately position them in the virtual car. The script also ensures that male and female participants are assigned avatars of the appropriate gender and size.

4 Pilot Study

A pilot study was conducted where participants used the Logitech steering wheel to freely drive around the city. Participants were given a search task where they had to look for landmarks presented on a virtual screen in the car. This task was added as we wanted participants to stay engaged in the simulation for as long as possible while experiencing as much optic flow as they could. Participants were instructed to explore the city and look for landmarks for a maximum of 30 minutes and were allowed to stop at anytime if they felt any discomfort. Since the purpose of the study was to investigate cybersickness, participants were not scored on their performance of how many landmarks they located or how long it took them to find specific landmarks. They were asked to fill out the Simulator Sickness Questionnaire (SSQ), Motion Sickness Susceptibility Questionnaire (MSSQ) and a presence questionnaire. We also collected qualitative feedback in the form of comments.

5 Results

A paired samples t-test revealed significant differences in pretest (M = 5.24, SD = 7.45) and posttest (M = 65.33, SD = 31.67) SSQ total scores ($t(14) = 6.82$, $p < 0.001$). The pre and post SSQ scores differed significantly indicating that participants were getting sick after experiencing the virtual simulator.

The general feedback we received from participants suggests that our simulation is realistic and engaging. Several participants commented on the city environment calling it 'realistic', 'life like', 'detailed', and were excited to have virtual avatars that matched the size of their of their bodies. Many participants felt that driving the virtual car closely resembled their real world driving experiences, expressing that the car's driving behavior met their expectations. They also found the search task engaging and were motivated to continue looking for the landmarks they hadn't found. This feedback is indicative of our simulation's potential to be used as a highly realistic, immersive and reliable test bed to study cybersickness in fully immersive virtual environments.

6 Conclusion and Future Work

In this work, we developed a highly immersive proof of concept virtual driving simulator that can be used as a reliable test bed to examine cybersickness in users. Subjects that experienced the simulation exhibited significant levels of cybersickness and provided feedback suggestive of the simulation's realism, accurate driving behavior and immersive qualities. Given these results, we believe that our simulator can be used as a reliable platform to study cybersickness. With this in mind, we aim to study how cybersickness is affected by factors like the locus of control, cognitive load, field of view, resolution of displays, etc. in immersive virtual environments.

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