VIRTUAL REALITY USER EXPERIENCE AS A DETERRENT FOR SMARTPHONE USE WHILE DRIVING

by

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DEDICATION

This thesis is dedicated to my parents, Andy and Kathy Morley, whose love and support allowed me the opportunity continue my education in pursuing my Master degree.

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ABSTRACT

This study examines the effectiveness of virtual reality technology in creating an immersive user experience in which participants experience, first hand, the extreme negative consequences of smartphone use while driving. Research suggests that distracted driving caused by smartphones is related to smartphone addiction and causes fatalities. Twenty-two individuals participated in the Virtual Reality User Experience (VRUE) in which they were asked to drive a virtual car using an Oculus Rift headset, LeapMotion hand tracking device, and a force feedback steering wheel and pedals. While driving in the simulation participants were asked to interact with a smartphone, and after a period of time trying to manage both tasks, a vehicle appears before them, involving them in a head-on collision. Results indicated a strong sense of presence was felt by participants in the VRUE and a change or re-enforcement of the participant's perception of the dangers of smartphone use while driving was observed. Participation in the VRUE positively affected the behavior of 70% the participants who reported an increase awareness of the dangers and/or using their smartphone less while driving.

CHAPTER I

INTRODUCTION

Smartphone Usage

The personal computer was once the only way an individual could connect to the Internet or communicate through email and social media. Now all of these functions and more can be accomplished with a smartphone. A smartphone is a multimedia cellular phone that has the ability to browse the Internet, send and receive email, and run applications with a wide variety of functions (Joo, 2013). Over 75% of teenagers now have a cell phone, and nearly half (47%) of those are smartphones, the number of all teenagers with smartphones increased 15% from 2011 to 2013 (Madden, Lenhart, Duggan, Cortesi, Gasser, 2013). It is estimated that by 2020, 70% of the world's population will be smartphone users (Ericsson Mobility, 2015). This rate of growth means that the smartphone is quickly becoming the primary multimedia communication device in people's lives.

Smartphones have drastically changed the way people communicate and do business, however this has led to the growing societal problem of smartphone addiction (Harwood et al., 2014). 37% of adults in a survey admitted their relationship with their smartphone was highly addictive, and 60% of teenagers being highly addicted (Ofcom, 2011) 81% of smartphone users say they keep their devices on at all times even while they are sleeping (Ofcom, 2011). The desire and perceived need to interact with one's smartphone and the anxiety felt when one is unable to do this is similar to other types of addiction (Harwood, 2014). This perceived need to interact with these devices can be very dangerous and life threatening problem if that user is also attempting to operate a motor vehicle.

Smartphone Usage and Driving History

The ability to talk on the phone while driving began in the late 1980s, when the car phones became popular. Since then, cell phones have made it easier for individuals to communicate on the phone while driving. From 1990 to 2000, the number of cell phone users rose from 4 million to 100 million (Arceneaux, 2005). As cell phone technology has advanced, such as social media applications, the ability to browse the Internet, and GPS navigation, it has been easier for individuals to have even more opportunities for distracting interactions while driving, apart from talking on the phone.

The dangers of driving while talking on a cell phone brought about the creation of “hands free” devices, which allowed users to operate their phones by voice alone, in the hopes of freeing their hands to concentrate on driving. However, according to Automobile Association of America (AAA) (2013), these devices and methods are not very effective and can still be distracting to the driver, and in some cases, raising their risk for an accident by up to 23%, compared to drivers abstaining from any phone usage.

“Texting and Driving” has become an even greater problem in society over the last 10 years, because holding a conversation over text messages, while driving, requires the user take their eyes off the road. However, the language of “Don’t Text and Drive” has become dated as smartphone features have advance to allow communication and interactions over many different mediums and features that are just as distracting to the driver as sending and receiving text messages (Harwood et al., 2014). In July 2012, insurance company, State Farm conducted an online survey to see which functions drivers were using on their smartphones; 15% of drivers used social media, 56% used their smartphone for navigation, 33% used it for music, and 21% admitted to browsing the internet while driving (State Farm, 2012).

Text messaging while driving is not the only way one can communicate through a smartphone and is also not the only feature on modern day smartphones that can distract the driver from what is happening on the road (Allen, 2014). In 2011, distraction was a contributing factor in about 10% of all driver fatalities and 17% of injuries in the U.S. (NHTSA, 2013). Every time an individual successfully interacts with their smartphone while driving this becomes a positive re-enforcement that this behavior is less dangerous. Negative re-enforcement only comes after the individual has been involved in an incident that could prove fatal. The ability to show users first hand, in a safe environment, the dangers of this behavior, has been made possible by the advancements in creating an immersive user experience through virtual reality technology.

History of Virtual Reality

For the purpose of this study, virtual reality is an attempt through technology to immerse an individual completely in a digitally fabricated environment, this is also defined as an immersive multimedia experience. This idea was something only explored by philosophers and science fiction writers until 1962 when Morton Heilig built his first Sensorama, credited as the first immersive multimedia device (Blascovich & Bailenson 2011). The technology would gradually improve but would never really become accessible to the public until the late 1980s and 1990s when video game companies like SEGA and Nintendo experimented with consoles in this virtual reality immersive multimedia format. These earlier systems were prone to cause users "simulation sickness" after prolonged exposure. Simulation sickness is caused when head and vision tracking does not react fast enough, creating a delay between body movement and the computer rendering the change in the environment, causing nausea and disorientation in the user (Bridgeman, Blaesi, Campusano, 2014).

Recent advances in the ability for VR technology to track movements in real-time have reduced simulation sickness in users, and as result, virtual reality has seen a large amount of growth in the last decade (Hale & Stanney, 2015). Although demand in the video gaming industry was the primary driving factor in the improvement of virtual reality technology, these fully immersive multimedia user experiences have introduced new opportunities for use in education, training, and clinical treatment (Eichenberg & Wolters, 2012).

Virtual Reality as Treatment and Education

Virtual reality has become a powerful tool in its ability to place a person in an environment that would otherwise be impractical or unsafe. For example, flight simulators allow pilots to train and practice dangerous safety maneuvers without endangering lives or property. Skills learned and practiced in the immersive virtual environment allow the pilot to apply them in real life situations with the calmed confidence of a veteran pilot (de Winter, Dodou, & Mulder, 2012). The more closely the simulation mimics the sensory inputs of reality, the more immersed the user will feel in the simulation; with the ultimate goal being "presence", or the user's inability to distinguish the simulation from reality (Slater, 2009). A higher level of presence means that the user perceives the virtual reality as grounded reality (Hale & Stanney, 2015).

This gives researchers and developers a powerful tool to place individuals in any possible situation imaginable.

Clinical and social researchers have been expanding this same concept to social situations, creating environments in virtual reality that reflect situations in the real world: like a crowded super market, to help someone who suffered from social anxiety, or lecture hall full of people, for someone with a strong fear of public speaking. The presence these individuals feel in these social simulations reflect the emotional and physiological experiences they have in real life giving researchers the opportunity to study reactions and treat anxieties (Eichenberg & Wolters, 2012).

One of the earliest studies in virtual reality and behavioral adjustment focused on people with a strong phobia of spiders, conducted at the University of Washington in 2001 (Garcia-Palacios, Hoffman, & Carlen, 2002). This study showed that users could be placed in a virtual reality simulation that would create the same emotional and physiological response, that those individuals felt while encountering spiders in the real world (Garcia-Palacios et al., 2002). Subjects were placed in several virtual reality sessions that exposed them to various cues to their arachnophobia, in the final control test participants were asked to go into a room with a large spider on a table underneath a clear glass jar. 80% of the individuals treated by the VR simulation were able to walk up to the spider and remove the jar, which none of the participants were able to do prior to treatment (Garcia-Palacios et al., 2002). The arachnophobia study demonstrated virtual reality's ability to reduce the irrational and debilitating fear of spiders.

VR treatment methods have also proven effective in the treatment of substance addictions. The average rate of relapse among addicts of any substance is 40% - 60%, demonstrating a considerable challenge for anyone hoping to treat those individuals (McLellan, Lewis, O'Brien, and Kelber, 2000). Cue exposure is currently one method of addiction treatment, which involves identifying cues in a individual's life that might trigger a relapse, then working to reduce the effectiveness of those cues on the individual through imagery exposure and counseling (Loeber et al., 2006). This includes a hypothetical discussion about this high-risk environment, because asking someone who is struggling with alcoholism to go to a real bar, so they can experience those biological and psychological emotions, could immediately result in a relapse. In virtual reality, however, researchers can place individuals in these environments in a controlled way and work to extinguish the desire to use highly addictive substances, like cocaine (Saladin et al., 2006), tobacco (Pericot-Valverdeet et al., 2014), and alcohol (Son et al., 2015).

VR technology has increased in its accessibility as demand has increased and costs reduced (Hale & Stanney 2015). Devices considered for this study were in two main price-points: medium cost (between $200 and $600) and low cost (between $10 and $200). Medium cost headsets, such as the Oculus Rift (Figure 1), have greatly reduced the price point of VR technology. Microsoft recently announced its HoloLens augmented reality headset, which projects real-time hologram-like images in the users' surroundings. This product is still under development and Microsoft had not released a price point for this system at time of writing. Low cost systems, such as the Google Cardboard (figure 2) and Samsung Gear (figure 3) use smartphones that are inserted into the headset to become the display, and using the smartphones accelerometer to track the user's head movements. Should this study prove effective, this increased accessibility would enable versions of this Virtual Reality User Experience to be shared with a large number of people, and easily installed and demonstrated in schools, driver education, and community centers, nationwide.

Figure 1: Oculus Rift

Figure 2: Google Cardboard

Figure 3: Samsung Gear VR

Thesis Organization

This study is organized into five main parts starting with this introduction to the development of the smartphone platform and the problems this technology offers its users. Second will be the statement of the problem and the hypothesis. Third will be preliminary research examining the relationship between smartphone addiction and distracted driving, as well as virtual reality technologies current usage as a form of treatment. Following the preliminary research will be the statement of development, measurement, and research methods used in creating the Virtual Reality User Experience and testing that experience on volunteer subjects and results recorded. Lastly will be the conclusion where the hypothesis will be supported or rejected based on the analysis of the data from the research method, as well as a discussion on limitations and future research.

CHAPTER II

STATEMENT OF THE PROBLEM

Motor Vehicle Accidents in the US

Last year 32,719 Americans were killed in motor vehicle accidents. (nhtsa.gov/NCSA). Statistically, driving is one of the most dangerous activities the average person will do in their lifetime, and it is something that most of us do every day (Rogers, 2015). Overconfidence and desensitization of roadway dangers can lead to errors, as drivers feel comfortable performing other tasks while behind the wheel (Overton et al., 2013). Human error accounts for 93% of motor vehicle accidents (nhtsa.gov/NCSA).

While car safety technology (e.g., seat belts, air bags, ABS) has drastically improved over the last 40 years, the amount of distractions for the driver has also increased. Driver impairment and distraction are large factors in the number of motor vehicle accidents a year (NHTSA, 2012). In 2013, 10,076 Americans were killed in drunk driving accidents (MADD, 2016). Driver impairment and drunk driving has long been an issue in America, and efforts from many different organizations have resulted in an improvement in the number of accidents per year (MADD, 2016). By comparison, From 2012 to 2013 the number of people injured as a result of distracted driving rose from 421,000 to 424,000 (distraction.gov, 2016), and equal to, if not greater than drunk driving (Williams, 2015).

Driver distraction has become a fairly new issue: Before cell phones, few studies were written on how dangerous other distractions in the car are to the driver, such as adjusting A/C, changing a CD, smoking, or talking to a passenger (Overton et al., 2013).

Recently however, with cell phone use while driving becoming a standard occurrence, "Texting and Driving" has become a serious issue in American culture. Each year since 2010, texting and driving was the cause of 100,000 car accidents in the US (National Safety Council, 2013).

Smartphone Related Accidents

In the span of 5 years from 2007 to 2012 the number of text messages transmitted in the United States increased from 362 billion to two trillion messages (Williams, 2015). 34% of drivers in an online survey admitted to sending and receiving text messages while driving (State Farm, 2012). This is especially concerning, as sending a text message while driving makes the driver 23 times more likely to be involved in an accident (NTSHA, 2013).

While fatal motor vehicle crashes have declined as a total over the last 10 years (NHTSA, 2013), the percentage of driver distraction related crashes has increased and the number of fatalities due to driver distraction rose from 10% to 16% between 2005 and 2009 (Williams, 2015). Texting and driving has become such a dangerous and common occurrence that 35 states have passed ordinances to make this behavior illegal (NTSB, 2016).

Impact on Society

In 2011, 1.3 million crashes in the US involved cell phones (State Farm, 2011). 3,154 people were killed as a result of driver distraction, accounting for 10% of fatal crashes in 2013 (NTHSA, 2015). In 2008, a California Metrolink commuter train failed to stop at a red light and was involved in a head on collision with a freight train (Flaccus, 2008). Post-incident records from the operator's cell phone showed that he was text-messaging seconds before the crash, and as a result, 135 people were injured and 25 were killed (NTSB.gov, 2010). In response to this tragic incident, Congress passed measures to insure all trains had Positive Train Control systems in order to stop the train in an event of operator error, costing freight and commuter rail companies $10 billion to implement (Shine, 2015).

Aaron Deveau, an 18 year old from Massachusetts, was sentenced to a year in jail after a head-on collision with another vehicle resulted in the death of 55 year old Donald Bowley (Mlot, 2012). Deveau's phone records show he had sent 193 messages that day, including a number of texts moments before the crash, breaking a Massachusetts Highway Safety Division ban on handheld cellphone use while driving. Deveau was found guilty of vehicular homicide, texting while driving, and negligent operation of a motor vehicle. His license was suspended for 15 years and was sentenced to two and half years in prison. In both of these cases, personal behavior and lack of perceived risk resulted in the loss of life, destruction of property, and a high cost for the taxpayer.

While there has never been any case of an individual being convicted for negligent operation of a motor vehicle because the driver was distracted by another feature of their smartphone, this study will explore how interactions with a smartphone that cause the driver to look away from the road are dangerous, life threating distractions and create a virtual experience, where the user will experience the dangers first hand.

Current Solutions to the Problem

Efforts to reduce distracted driving, in many ways, have been modeled after drunk driving prevention methods (Williams, 2015). The current solutions to this problem fall into three categories: Educational, Engineering, and Enforcement (Overton et al., 2013).

Educational

The educational approach to the problem is designed to inform people on the dangers of texting and driving and distracted driving. This is accomplished through advertising and community out-reach events. Major cell phone service providers have joined forces behind AT&T's *It Can Wait* campaign. Although initially, cellphone companies were resistant to any communication or legislation that would tell people not to use their products, the main providers have put millions of dollars towards texting and driving education advertising (Svennson, 2013).

It Can Wait is a online social media campaign that asks drivers to make a pledge to not use their smartphones or text message while driving. Their slogan, "no text is worth a life", tries to draw a connection between a seemingly harmless text message and traffic fatalities (AT&T, 2016). The campaign also produces videos that attempt to put the problem in a real world and personal context. The latest video, shows the lives of six people in a seemingly normal day that ends tragically, because of a glance at a smartphone while behind the wheel (YouTube, 2016). The included website also provides personal stories and celebrity endorsements through social media and the hash tag, "#ItCanWait" (AT&T, 2016).

The campaign has received over 7 million pledges (AT&T, 2016) and received the award for best campaign in 2014 by the Public Relations Society of Americas. Preliminary reports from 3 states, suggest a reduction in texting and driving related accidents due to people sharing and participating in the campaign (ENPnewswire, 2014). The pledge, however, requires only that the user click a button on the website so it is impossible to tell if someone has taken the pledge, is later involved in a smartphone related accident or receive a citation for the behavior, where it is prohibited by law, or simply continuing the behavior and not getting caught. This, and the lack of third party analysis, makes it difficult to judge the overall effectiveness of the campaign in terms of behavioral change.

A similar campaign by insurance company Allstate, *X the TXT,* combines web and social media presence with in-person texting and driving simulators (Allstate, 2015). These driving simulators have been set up at locations like the University of Texas in Austin and use an actual car, fitted with monitors in front of the windshield (KXAN, 2014). Drivers are asked to drive around a virtual environment and attempt to use their smartphone. The user is presented with a number of obstacles, which they can crash into, receiving a grade at the end of simulation based on performance.

The problem with this solution is that the technology behind it is physically large, requiring a great deal of set up and space. The simulation itself is very rudimentary in its graphics and the crash event is merely a combination of sound and visual effect of the screen cracking. There have been no studies into the lasting effects of the simulation or in its ability to change an individual's behaviors.

This educational method has raised the awareness of the dangers of smartphone use while driving and the possible negative consequences. Over 70% of people surveyed admitted texting and driving was a dangerous activity, however, 34% will admit they are guilty of the behavior (State Farm, 2015). The language of texting and driving is also only part of the issue, as 27% of drivers in AT&T *It Can Wait* admitted to accessing Facebook and 17% to taking a photo of themselves while driving (AT&T, 2015). All of these activities distract the driver and increase the risk of an accident (Richtel, 2015). The

AT&T *It Can Wait* campaign now defines the issue as distracted driving.

Engineering

Another solution to the problem involves engineering technology to make it incapable of using one's smartphone while driving or attempt to make it safer to use a smartphone through hands free voice commands.

Hands-free systems enable drivers of newer model cars to sync their smartphones to their vehicle's dashboard sound systems, allowing the driver to receive messages through and digital reader and send messages through voice command without ever looking at their smartphones. However, an AAA Foundation for Traffic Safety study shows these systems could actually increase mental distraction and risk of accident compared to abstaining from smartphone use while driving (AAA, 2015).

Through the use of smartphone GPS tracking, it is possible to develop smartphone applications that can limit or restrict activities when the phone reaches a certain speed. Kentucky became the first state in the US to sponsor such and application for its residents, the sponsored application, *Textlimit*, completely locks the screen of the smartphone when the GPS information determines the user reaches a predetermined speed (PR Newswire, 2014). The problem with this solution is that it is ultimately self-policing, because the applications can be uninstalled or turned off by the user. There has yet to be a case were a court mandated the use of an application like *Textlimit* on an individual found guilty of texting and driving or distracted driving.

Enforcement

There is currently no Federal standard on the enforcement of texting and driving or distracted driving. Legislation and enforcement differs from state to state, some states and cities require the use of hands free devices, and some have regulations that only apply to new drivers (Overton et al., 2013). The ALERT Driving Act, which failed to pass in Congress, would have given the Federal government the right to enforce texting and driving laws on a national level. In addition, there is currently no law in existence that relates to distracted driving (Williams, 2015).

This inconsistency can best be seen in an incident in California where Deputy Anthony Wood struck and killed a cyclist with his patrol car, while taking his eyes of the road to use his dashboard laptop. The internal investigation on the incident ruled the Deputy was not at fault because the email he was typing while driving was work related and faced no charges (Farberov, 2014).

While these efforts have seen some success in combating distracted driving, they fall short because they target the symptoms but not the root cause: smartphone addiction. Current attempts deter smartphone use while driving focus around creating awareness of the dangers of this behavior, but fail to address why the behavior occurs in the first place, even though most people understand some level of danger to themselves and others.

Smartphone Addiction

Overdependence on smartphones, and the anxiety felt when one cannot access them, is the growing problem of smartphone addiction (Harwood et al., 2014). The addictive nature of these devices comes from the information, entertainment, and personal connections it allows for the user (Emanuel et al., 2015)

The desire and perceived need to interact with one’s smartphone, and resulting anxiety when the individual is unable to do so, is similar to other forms of addiction (Harwood et al., 2014). This can become a very dangerous and life threatening behavior when these devices become a distraction while driving a motor vehicle.

Hypothesis

It is the hypothesis of this study that the construction and testing of a VRUE in which the user will experience first-hand, the dangerous consequences of using a smartphone while driving, will change or reinforce the users perception of the danger in the real world. Testing this experience by surveying participants before and after a VRUE session will indicate if the experience immersed the individual in the virtual environment, created an emotional response, and/or changed in their perception of risk.

CHAPTER III

PRELIMINARY RESEARCH

Smartphone Addiction

The way Americans have communicated over the last 20 years has changed drastically through the use of the Internet, with 87% of Americans are now Internet users (nldstats.com, 2016). Additionally, with the raise of social media sites like Twitter and Facebook, the amount of time one spends on the Internet can become a problem. In some cases an individual's relationship with the Internet has represented a dysfunctional addiction (Burnay et al., 2014), and over the last 10 years smartphone technology has given individuals the ability to access all the functions of the Internet and social media, anywhere at any time (Islam & Want, 2014). Internet addiction is closely related to smartphone addiction (Hadlington, 2015), because with smartphones it is not that they are addicted to the device itself, but rather, the connectivity it allows to other people through various smartphone features (Emanuel, 2015).

In a Rice University study (2015), 34 students who did not own a smartphone were given instrumented iPhones to use for one year (Tossell et al., 2015). Participants were given no instruction on how they should use the phone, only that it needed to be their primary cellular device. At the end of the study, participants were surveyed and the data usage was collected from the phone. 62% of participants agreed or strongly agreed that they were addicted to the device (Tossell et al., 2015). Data collected from the smartphone reflected the participant's self-assessment, and those who reported an addiction to the device had more frequent interactions than those who did not. One participant even reported a debilitating addiction to the smartphone, "checking the smartphone was an uncontrollable urge and yielded an average of 122 application launches per day" (Tossell et al., 2015, pg. 40).

Smartphone Use and Driving

If smartphone users report anxiety when they are unable to check an application (Tossell et al., 2015), what would be their likely action if they receive a message or notification while they are driving? As stated before, most American's perceive texting and driving as a dangerous activity that should be made illegal, but a portion will admit to sending messages, browsing the internet, or checking social media (State Farm, 2015).

In an initial online survey for this study, 40% of participants admitted that they "will take calls and glance at messages but refrain from sending messages or using social media while driving." The perceived risk does not out weight many drivers desire to stay connected (Atchley et al., 2011). Some drivers seem to justify a level of distraction from their smartphones while driving, but may be unaware that looking away from the road for just 2 seconds makes the driver 2.2 times more likely to be involved in a crash/near crash (Klauer et al., 2006). In 2011, distraction was a contributing factor in approximately 10% of all driver fatalities and 17% of injuries in the U.S. (NHTSA, 2013).

Feeling confident in one's ability to safely use a smartphone while driving or feeling obligated to use a smartphone while driving because it pertains to work, or the feeling that a notification might be extremely important, pose a great threat to public safety and should be a main concern for intervention (Engelberg et al., 2015). It is the goal of this study to create a user experience that will give individuals a first hand perception of the dangers of smartphone use while driving.

Virtual Reality as Valid Treatment

Virtual reality technology's current use in the treatment of substance addiction gives us a hint at how this technology could be applied to solving the problem of smartphone use while driving.

VR technology is a viable media for cue exposure (Giroux at al., 2013), and not only offers the ability to create immersive real world situations, but also gives researchers the ability to finitely track the user's experience in the simulation. In studies done with alcoholics in VR simulations, researchers were able to track how long the user looked at a virtual bottle of beer that was placed on the bar (Lee et al., 2007). This is a powerful tool in creating quantitative data that can better prove the effectiveness of the treatment over time. It the case of addiction treatment, it also gives researchers insight into what situations cause the greatest increase in substance craving (Ryan et al., 2010). Using these methods in a study of nicotine craving and cue exposure therapy, researchers were able to decrease the smoking count of participants in a VR program by the end of treatment (Lee et al., 2004).

VR technology has been used in the past to educate drivers on the dangers of drinking and driving. In one study participants would complete two different driving simulations. The first of which would be the control, driving simulation with no added visual effects and the second would have altered steering controls and distorted visual effects (delayed response time, blurred display, fish eye effects, etc.). Participants would make more mistakes when trying to complete the "drunk" driving simulation than in the control simulation (Montgomery, Montgomery, & Sirdeshmukh, 2006). However, these studies often fail in creating a connection between mistakes made in a game-like program and real world car accidents resulting in injury and death, participants see the simulation as a game that they try and beat rather than educate them on the dangers of the behavior (Jewell, Hupp, & Luttress, 2004). The simulation created in this study intends to show participants consequences of their behavior on the road rather than score them in a game style model.

VR's ability to create a personal experience that reflects reality has been used to alter an individual's behavior by placing them in environments that would be otherwise dangerous. Individuals are able to understand and manage urges so that in the future when found in the same scenario the individual will feel empowered by already having overcome the same scenario in a simulation. This study will examine how the same technology may be used to show someone the dangers of a behavior they might already do in order to change their behavior before they experience that danger in real life and risk the lives of themselves and others.

CHAPTER IV

METHODS

Development of the Virtual Reality User Experience

The Virtual Reality User Experience (VRUE) created in this study was developed by evaluating the current virtual reality technologies, and determining a combination of software and hardware that could best test the hypothesis. Development of the virtual

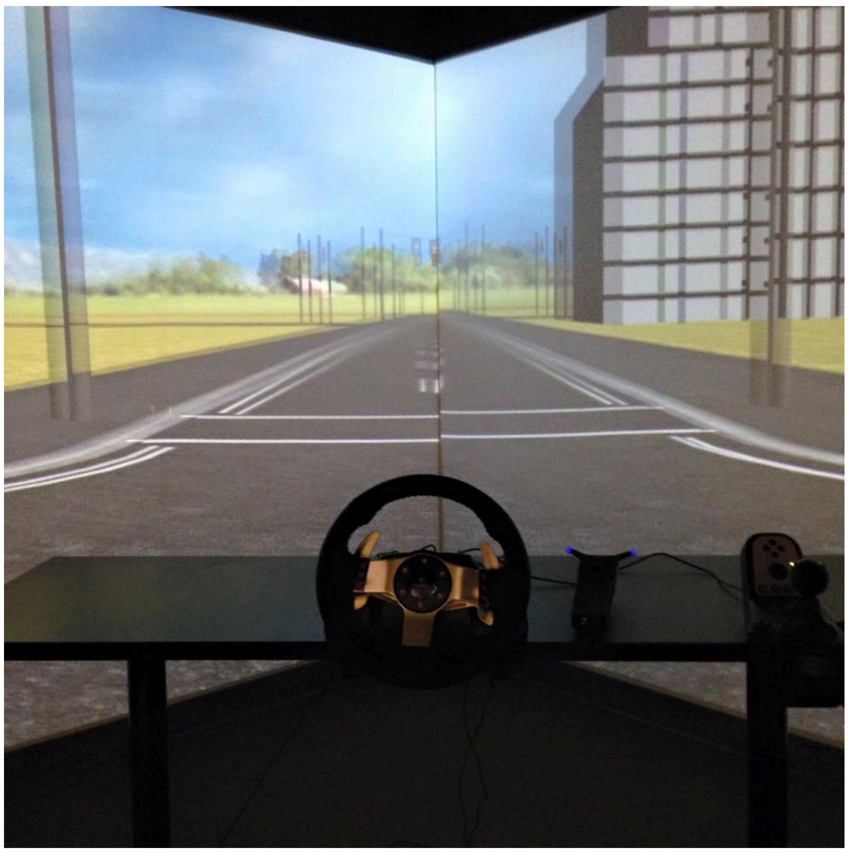

Figure 4: Initial VRUE set up

environment focused on a simple driving course with little traffic or hazards and one that would be easily navigated in order to limit the user's focus to simple driving and attempted smartphone interaction.

The user's interaction with the smartphone was a vital part of testing the hypothesis, and would require a way to have the user's hands be apart of the simulation. The initial VRUE prototype used two perpendicular projectors and 3D glasses with a steering wheel and pedals placed in the center of the room (Figure 4). While this VR system was less immersive than traditional head mounted displays, it allowed for the user to interact with their own smartphone while in the VRUE. However after testing this system, it was discovered that the polarized 3D glasses made it difficult to read the smartphone screen. Additionally, it was determined that the experience would be more immersive using a head mounted display creating a higher level of presence in the simulation.

Switching to a head mounted display allowed for tracking the user's hands and displaying them in the simulation. Hand tracking is traditionally accomplished by having the user hold a wand or controller that has infrared nodes; however having the user hold such a device and still be able to operate the steering wheel normally was not practical. It was determined that the best method for interacting with the smartphone and still being able to operate the steering wheel was through gestural tracking of the user's hands, using an infrared LeapMotion hand tracking device. This device was placed on the front of the head mounted display, thus allowing the user to simply make the hand gesture they normally would while holding a smartphone. The software would display a virtual smartphone in the user's virtual hands. The best available hardware set up in terms of price and availability was determined to be an Oculus Rift DK2 head mounted display, a LeapMotion hand tracking device, surround sound speakers, and a Logitech force-feedback steering wheel and pedals (Figure 5).

Figure 5: Final VRUE set up

As discussed previously, texting was not the only distracting feature on a current smartphone, the ability to have the smartphone screen in the digital environment change was out of the scope of our available development capabilities. Forced with having a static smartphone screen it was decided a new received text message screen would be the best choice for the user to attempt to interact with while driving.

The virtual environment was developed and programmed in the Unity game development engine, an open source platform that was most familiar to the computer science student who assisted in the development of the VRUE. The Unity platform also provided a large library and easy importing of digital assets such as cars, buildings, roads, road features, and scenery in order to make the VRUE as realistic as possible.

Measurements

In order to determine any effect on the user's perception of the risk of smartphone use while driving, a survey was designed to evaluate the users Perception of Risk Score (PoRS) before and after the VRUE. These multiple-choice surveys scored the user based on their responses to questions about their perception and behavior of using a smartphone while driving. A high PoRS score indicated a lower perception of the risks of using a smartphone while driving and higher danger of smartphone use while driving. By establishing a baseline before the VRUE it can then be determined if the there was any change in the PoRS in the follow up survey after the VRUE.

A decompression survey was designed to be administered immediately following the VRUE. The purpose of this survey was to assess the level of immersion the user felt in the VRUE and any emotional or physiological response it generated in the individual. Questions in this survey included short answer responses to allow the user to elaborate on their experience and give as much feedback as possible.

Statistical analysis between the baseline and the follow up surveys would determine if there relevant change in the PoRS, supporting or rejecting the hypothesis. Analysis and review of the short answer responses will be used to determine the effectiveness of the VRUE in terms of immersion and response.

Research Methods

This study was conducted at the Texas State University Virtual Reality and Technology Lab. Research was approved by the Texas State University IRB and supervised by Dr. Kenneth Scott Smith, and Mr. Grayson Lawrence.

Individuals were recruited by disseminating flyers in three classrooms during the Spring

2016 semester. From this, 20 volunteer participants took part in the study. Although demographics were not selected for or used in the results, 8 participants were male and 14 were female, and ages ranged from 20 to 40. Participants signed an IRB approved consent form (Texas State University IRB #2015E3393) prior to taking part in the study. Participation in the study was discouraged if the participant had a history of seizures, neurological issues, or had experienced nausea or discomfort with a head mounted VR display before. Participants were instructed that participation was voluntary and if they chose not to participate or remove themselves from the study at anytime if would not impart their standing with university or administrators. Participants were informed that if anytime during the VRUE they should feel nausea or motion sickness to inform the administrator and the test would be stopped immediately.

During the intake process, participants were screened for any potential risk in participating and, if cleared, signed the IRB consent form. Participants then completed the intake survey to evaluate their current perception and behaviors as it related to smartphone use while driving. Participants were not told or warned what would happen in the VRUE, only that they were testing a VR driving simulator. The participants then began the VRUE. First, insuring the participant was comfortably seated and could reach the steering wheels and pedals, the head mounted display was placed on the participant and adjusted for comfort. The program was then started and calibrated for their height. The user could now see they were seated in the passenger seat of sports sedan.

The participant was instructed to look around, in order to familiarize themselves with the digital environment, and were instructed to hold their hands up to see how their gestures were being tracked and displayed as two virtual hands. They were then instructed to start driving. The track was a small rectangular circuit that looped in two, wide 180 degree left turns. The participant was instructed to drive two laps to familiarize themselves with the simulations driving mechanics. This familiarization, allowed the researcher to make sure the participant could successfully navigate the small track, unaided.

On a third lap, participants were prompted to attempt to look at the smartphone in their virtual right hand while still driving the vehicle. The participants making the same gesture they would in the real world and the LeapMotion device tracking their hand movements and gestures would display the smartphone in their hands, allowing them to

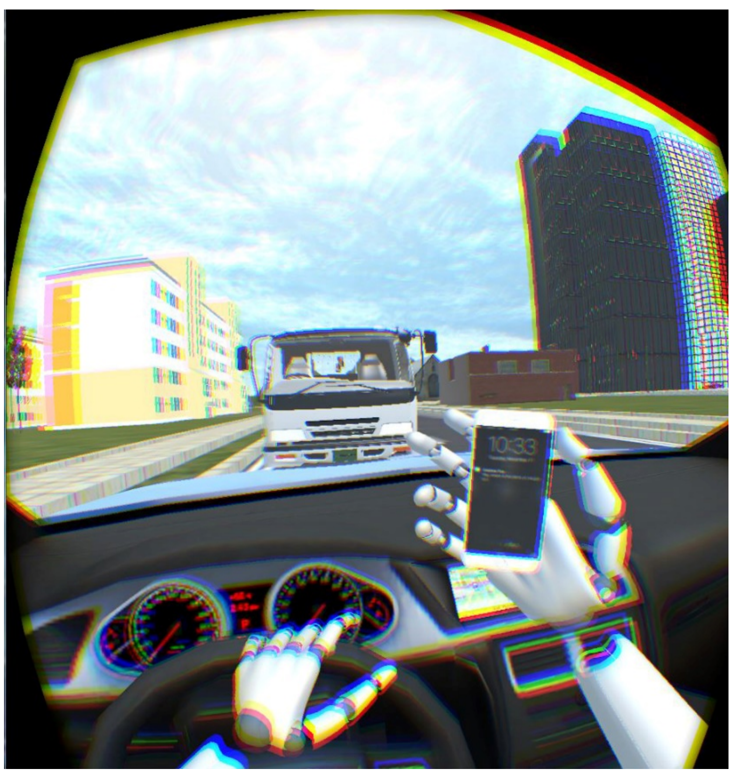

Figure 6: Crash Event from user’s perspective

read a text message.

While the user was attempting to read the message displayed on the virtual smartphone screen, a crash event would be triggered (Figure 6). The crash event involved a large truck approaching head on with a truck horn sound effect playing through the surround sound system, the user then may make any attempt to avoid the truck but ultimately unable to do so by design. The truck crashes head on into the user, causing loud crash sound effects and violent movement from the force feedback steering wheel. The entire event happens in less than a second. Immediately afterwards, the participant completed a decompression interview to gain initial reactions and level of immersion felt. One week after the VRUE, a follow-up survey with the same questions as the intake survey was given to evaluate any lasting effects on their perception of the risks of smartphone use and driving.

Results

Intake

In the intake survey, 68% of participants reported they checked their smartphones “many times every hour” or more frequently over the course of the day. 40% commuted by car for 15 minutes or less while the rest (60%) commuted 15 minutes to 1 hour by car every day. All participants agreed that a risk of smartphone use while driving included causing serious or fatal injuries to themselves or others; but still 70% of participants admitted to using their smartphone while driving. 20% said they used a hand free device, and used their smartphone for navigation while driving. 10% indicated that missing out on information was a concern for them if they abstained from using their smartphone while driving.

The minimum and maximum possible PoRS range was 4 to 19, the range of PoRS in the intake survey were 4 to 10 and the average was 7.5. The mode PoRS was 9, and only 10% of participants received the lowest PoRS of 4. This indicated an average level of perception of the risk of smartphone use while driving among participants at the intake. However, with more than half participants admitting to using their smartphone while driving in some capacity, this perception of risk might not have been high enough to deter behavior.

Decompression

No participants had to end the VRUE due to nausea or simulation sickness. In the decompression survey, when asked to rate the realism of the simulation from 1 to 10, (10 indicating most realistic), 55% of participants rated the VRUE 7 or higher. 72% of participants reported feeling scared, surprised, or anxious by the crash event. Three participants reported feeling an elevated heart rate, though no biometric equipment was used and cannot be confirmed. 80% answered that smartphone use while driving, even with a hands free device, distracts the driver and greatly increases the risk of an accident, and 86% of participants expressed that the VRUE either changed or re-enforced their existing perceptions of the dangers of smartphone use while driving.

Follow Up

In the follow up survey, the amount of participants stating they used a hands free device while driving rose from 20% to 45%. Additionally, the amount of participants that admitted to "glancing at their smartphone to read messages" decreased from 50% to 30%. The follow-up survey responses showed that 70% of participants reported a change in the perception of the dangers of smartphone use while driving, and those that agreed that smartphone use while driving, even with a hands free device, greatly increased the risk of accident rose from 70% to 90%.

The Follow Up survey PoRS was 6.2 with a range of 4 to 9. The mode PoRS was 4 with 30% of participants receiving the lowest possible PoRS. PoRS scores at the Follow Up survey indicated a below average PoRS among participants, this indicated that participants had a higher sense of the dangers of smartphone use while driving, which might have a deterring effect on that behavior.

CHAPTER V

CONCLUSION

Discussion

The VRUE indicated to be effective in creating a realistic experience that showed users, first hand, the negative consequences of smartphone use while driving. In most cases, the effects altered or re-enforced their perception about the dangers of this behavior.

Analysis of PoRS from intake to follow up, indicated that the VRUE was effective in lowering the PoRS of individuals by increasing their perception of the dangers of smartphone use while driving. The responses to the VRUE also indicated that it was very effective in reinforcing and strengthening existing perceptions with the number of participants with the lowest PoRS increasing from 10% to 30%.

Responses from the decompression survey indicated that the VRUE was effective in immersing the user in the digital environment as well as producing an emotional response from the user during the crash event. This further validates VR technology’s potential for research and treatment. It also indicates that a VRUE could prove to be an effective tool in solving the problem in society of drivers distracted by smartphones.

The VRUE’s potential for effecting perception of this dangerous behavior on the nation’s road ways could result in a lowered number of accidents and fatalities, and provide education and awareness for new and experienced drivers alike. The success of this study should encourage further research and development in the use of virtual reality technology as tool to benefit society rather than just an immersive entertainment system.

Limitations

The limitations of this study included a small sample size, and lack of demographic diversity and data. The request for personal information like ethnicity, income, and age was not a part of the IRB so was not included in the Intake. This data will be included in future research in order to examine the VRUE effectiveness over different demographics. Additionally, this study would have greatly benefited from the inclusion of biometric data, as a heart rate monitor would have provided a level of quantitative data to the experiment, further validating the effectives of the VRUE and the crash event. In addition, this study relied on self-assessment and self-reporting which can be prone to inconsistencies. The addition of smartphone and driving tracking software for participants before and after the VRUE would have provided valuable data as well, as well as indicate whether the change of perception resulted in a change in behavior. Lack of compensation for participants was also a problem because 2 participants failed to complete all the surveys and their data had to be removed.

Future Research

The response to the VRUE indicated to be an effective tool in creating an emotional and physiological response in the users who participated. Absent from these results is a longitudinal evaluation of the simulation and how it impacts their personal use of a smartphone while driving over time. Future research will use smartphone-tracking applications to identify specific trends in distracted driving behaviors people have prior to the experiment and after, in order to see if their smartphone and driving behavior truly did shift over extended amount of time. Further development will be required to make the VRUE more accessible and customizable, allowing for more and varied interactions with virtual smartphones, different crash scenarios, and a range of environments to interact with. Adding elements like virtual avatar passengers and pedestrians could increase the level of immersion as well as give the opportunity for the user to see the negative consequences on others rather than just themselves, i.e. having the crash result in an injured passenger or the crash event involving hitting a pedestrian. Introducing different types of smartphone interaction would allow for testing of how different features and apps are more or less distracting for the driver.

The addition of biometric data such as heart rate will further validate the effectives of the simulation and will be included in future research. Automation of the crash event and the addition of a user interface will allow the VRUE to be run without a monitor and serve as an excellent platform to deliver additional communication and facts about the dangers of smartphone use while driving following the experience.

Future Implementations

As far as addressing the global problem of smartphone addiction in society much more research is needed but this study indicates the validity of VR technology as a strong tool treating this form of addiction as well. While this VRUE focused on a very specific symptom of smartphone addiction, it could be combined with a smartphone application that tracked daily smartphone use while not driving could help identify and treat individuals that have an unhealthy relationship with their smartphone device.

The identification and treatment of individuals with a serious problem could prove very useful in terms of law enforcement. This study could provide the foundation for a court-mandated VRUE course for people cited for texting and driving much like current defensive driving courses. Data gathered from a course like this would be extremely valuable in understanding and treating the problem in society in the future.

After further development and research, a simulation like this one should be implemented at relatively low cost, in new driver education programs, defensive driving curriculum, and community centers across the nation. It also should be delivered in anti-texting and driving campaigns, as well as provided to middle school, high school, and college students as a prevention mechanism. If proven to be efficacious in altering behavior over time, a wide-spread implementation could reduce the number of distracted driving instances every year, saving states and taxpayers money, and more importantly saving lives.

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