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Classic Driver VR

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Classic Driver VR

A VR car-driving simulator for evaluating the user experience of new drivers by helping them to learn driving rules and regulations.

by

Prateek Chatterjee

A Master's Thesis

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Abstract

The Classic VR Driver helps new drivers to learn driving rules and regulations using various audio and visual feedback. The simulator helps them to get acquainted with the risks and mistakes associated with real life driving. In addition, the users have to play the game in an immersive environment using a Virtual Reality system.

This project attempts to fulfill two important goals. The major goal is to evaluate whether the user can learn driving rules and regulations of the road. The game allows the users to take a road test. The road test determines the type of mistakes the user makes and it also determines if they passed or failed in it. I have conducted A/B testing and let the testers participate in user-interviews and user-survey. The testing procedure allowed me to analyze the effectiveness of learning driving rules from the simulator as compared to learning rules from the RMV (Registry of Motor Vehicles) manual.

Secondly, the user experience was evaluated by allowing users to participate in user-interviews and user-surveys. It helped me to understand the positives and drawbacks of the game. These feedback are taken into consideration for future improvement.

All these factors were considered to make the game as enjoyable and useful in terms of skill training.

Acknowledgement

I would like to express my special appreciation and thanks to my advisor Professor Dean O'Donnell for his constant support and invaluable guidance throughout this thesis study. His encouragement, support and advice on game design allowed my ideas to turn into a thesis level project. I would also like to thank my committee members Professor Joshua Rosenstock and Professor Jeffrey P Kesselman for their guidance, advice and their valuable time to assess my work and provide invaluable feedback.

Additional thanks to the IMGD community and participants for giving genuine suggestions and advice during the course of the user testing of the game.

Finally, I would like to express my deep gratitude to my grandmother Meera Roy, my parents Pradeep Chatterjee, Rekha Chatterjee and my sister Priyam Chatterjee for their continuous support in everything I attempted. They encourage me to never give up and always strive towards my goals. Thank you.

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Chapter 1: Introduction

Car accidents leading to injuries or deaths are one of the most important safety concerns among drivers. Global statistics say that nearly 13 million people die in road crashes each year and on average of 3,287 deaths occur per day. An addition of twenty to fifty million people get injured or disabled annually. The important thing is to note that more than half of all traffic deaths occur among young adult's ages from 15 to 44. Road traffic deaths is ranked as ninth among the leading cause to death. The causes of car accidents are due to speeding, reckless driving, running red lights, running stop signs, night driving, unsafe lane changes, wrong way driving, improper turns, fogs and many more. While lectures and manuals can be effective in mitigating the risk, studies have shown that people retain much better information if they use simulators for practicing driving techniques.[1]

The goal of my game is to reduce or remove such tragedies from happening. To reduce these accidents it is very important for the users to experience the situation in a simulation before they actually start driving in reality. My project determines whether the game satisfies the goals, answers all solutions for these problems, and is aimed to improve the mentality of the driver.

The main intention is to allow them to drive and get actual feedback while they undergo many situations like driving in roadwork zones, wrong ways, traffic dividers and many more. With these feedback, they can get acquainted with the mistakes they are performing. The feedback is in the form of visuals, audio and through a provided user interface as discussed in the gameplay section.

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[1] "The Association for Safe International Road Travel (ASIRT)", Accessed November 19, 2018. https://www.asirt.org/safe-travel/road-safety-facts/.

Chapter 2: Background

1. Introduction to Virtual Reality

Virtual reality (VR) is an artificial environment created with computer software and hardware and presented to the user in such a way that it appears like a real environment. To enter the virtual reality environment, a user uses a head mounted display, controllers/special gloves and earphones, which receive their input from the computer system. The virtual reality environment is experienced through two of the five senses such as sight and sound.[2] The head mounted displays are used with earphones and a controller to provide a fully immersive experience. There are many elements in Virtual reality, which make it essential. They are as follows:

Virtual World: It is a three-dimensional environment, where one can interact or create with other objects as a part of the interaction.[3]

Immersion: Virtual reality immersion is a perception of being physically present in a non-physical world.[4]

Sensory Feedback: This technology requires as many senses as possible to simulate brain. These senses include our vision, hearing, touch and more.[5]

Interactivity: The element of interaction is very crucial for the experience provided to the users. If the virtual environment responds to a user's action in a natural manner, excitement and senses of immersion will remain. If the virtual environment cannot respond quickly enough, the human brain will quickly notice and the sense of immersion will diminish.[6]

A Simple Explanation of Virtual Reality is best understood by first defining what it aims to achieve which is total immersion. Total immersion means that the environment experience feels so real, that we forget it is a virtual-artificial environment and we begin to interact with it as if we are in real world. In a virtual reality environment, a particular world may or may not mimic the properties of a real-world environment. This means that the virtual reality environment may simulate a

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[2] Webopedeia, "virtual reality", Accessed November 19, 2018. https://www.webopedia.com/TERM/V/virtual_reality.html
[3] Reality, "Reality Technologies". Accessed November 19, 2018. https://www.realitytechnologies.com/virtual-reality/.
[4] Ibid.
[5] Ibid.
[6] Ibid.

regular everyday environment or may exceed the bounds of physical reality by creating a world, which does not exist in reality for e.g. shooting space aliens on a foreign gravity-less planet.[7]

2. Background of Virtual Reality

The Virtual reality technology was emerged in the 1980s, with the development, the marketed systems consisted of head mounted displays and data suits attached to a computer. These technologies simulated three-dimensional environments displayed in surround stereoscopic vision on the head mounted display. The user could interact and navigate through the initiated environments through the head mounted displays and data suits (Items that track the positions and motions of the person). This original technology helped define what is meant by "virtual reality": an immersive, interactive three-dimensional computer-generated environment in which interaction takes place over multiple environments that includes tactile and positioning feedback. [8]

It is important to know how Virtual Reality really works. In order for the human brain to accept the virtual environment to be as reality, it has to look real. Making the environment look real can be achieved by wearing a head-mounted display, which displays a recreated life size 3D virtual environment right in front of your eyes. While feeling real can be achieved through handheld input devices such as motion trackers and body suits that create interactivity on user's movements and actions.[9] Below, we explore some of the key devices behind this system:

[7] Ibid, p. 2.

[8] P, Brey, "*Virtual Reality and Computer Simulation*." Handbook of Information and Computer Ethics, John Wiley & Sons, 2008.
https://ethicsandtechnology.eu/wp-content/uploads/downloadable-content/Brey_2008_VR-CS.pdf

[9] Ibid, p. 2.

- *PC, Console & Smartphone systems:*

(Image 1: PC/Console)[10]

Virtual reality environment, which is what users view inside of a virtual reality headset. In order to power these interactive three-dimensional environments, significant powerful computing power is required. At present, there are three type of systems that power these VR environments. They are discussed below:

PC Virtual reality systems:

Desktop-based VR systems are the most powerful when compared to the rest of the systems. They are powered using high end CPUs and GPUs. They require cameras as well. These cameras are responsible for tracking the user with in particular area for their movements. In addition, these type of systems need big area for setting up. Some examples are Vive VR, Oculus VR.

Console VR Systems:

These systems are similar to the desktop VR systems and have similar setups. However, these systems are less powerful than the PC virtual reality systems due the hardware difference, since consoles are very cheap in comparison to high end PCs, e.g. PlayStation 4 VR.

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[10] Vitillo, Antony, "*Why do most VR games have poor graphics while normal games are being played in VR by YouTubers.*" Quora, Jan   30, 2018.
https://www.quora.com/Why-do-most-VR-games-have-poor-graphics-while-normal-games-are-being-played-in-VR-by-YouTubers-Whats-the-difference

Smartphone VR systems:

These systems are powered using an android or an iOS based smartphone. Hence, they are the least powerful when compared to the rest.

However, these systems do not require any cameras. Hence, they are easy to setup and use. The least amount of hardware required to setup a smartphone VR is a mobile phone and head mounted display. They are also cheap in comparison to the other systems.

- *Head-Mounted Display:*

(Image 2: Head-Mounted Display)[11]

A head-mounted display, which is also called HMD, Headset, or Goggles, is a type of device that contains a screen display mounted in front of a user's eyes. This display usually covers the user's full field of view to display virtual reality content. In addition, these head mounted displays have an audio jack for connecting headsets or earphones for providing the sound. Some virtual reality head mounted displays use computers such as Vive and Oculus while others utilize smartphone displays, including the Google Cardboard and Samsung Gear VR.[12]

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[11] Ibid, p. 2.
[12] Ibid, p. 2.

- *Input Devices:*

(Image 3: Input Devices)[13]

Input devices are one of the two categories of hardware that provide the users with a sense of immersion with the environment. These provide users with a more natural way to interact within a virtual reality environment.

Some of the more common forms of virtual reality input devices include Joysticks , Force Balls/Tracking Balls, Controller Wands, Data Gloves, Trackpads, On-Device Control Buttons, Motion Trackers/Bodysuits, Treadmills and Motion Platforms.[14]

3. Games as educational tools

Over the past few decades, video games have emerged to become an important part of children's play and adult's leisure time. There are a number of video games, which are classified as educational games, for instance, Math Blaster, Learn lot, and Simulator games. Users can use these type of games for skill training, for instance, aviation training, car diving simulators and many more.[15]

Apart from these games, there are a number of video games, which are classified as educational games, for instance, Math Blaster, Learn lot, and Simulator games. Users can use these type of games for skill training, for instance, aviation training, car diving simulators and many more.[16]

Video games can be called as patient teachers, if they are specifically designed for educational purposes. They have positive effect on children's motivation, attention, and concentration and has shown to be an improvement in their academic achievements as well. Video games are generally

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[13] Ibid, p. 2.
[14] Ibid, p. 2.
[15] Sakic, Mateja, Varga, Vanesa, "*Video games as educational tools.*" University of Zagreb, Faculty of humanities and social sciences, 2015. http://econference.metropolitan.ac.rs/files/pdf/2015/36-Mateja-Sakic-Vanesa-Varga-video-games-as-an-education-tool.pdf.
[16] Ibid.

connected with a storyline and evoke various emotions of gamers. They immediately provide feedback, which is very important for learning process because it encourages re-attempts until success. Rapid and the frequent changes of the scenes, music volume and tonality of voice helps to trigger formation of new connections between our brain cells. Video games also helps to enhance our coordination and activate all senses, for instance, watching the monitor is followed by handling a mouse and keyboard simultaneously. Video games also develop hypothetical thinking and intuition. If the gamers want to learn and follow new rules, understand the plot and become heroes, they must be imaginative, good observers and adapt to the situation.[17]

There are several commercial and non-commercial web sites that offer lists of popular video games, including educational games. For instance, Wikipedia's list includes Bot Colony, Genomics Digital Lab Big Brain Academy: Wii Degree, Immune Attack, Urban Jungle, Democracy, and Global Conflict: Palestine, Gizmos & Gadgets and many more. In addition, several video games are not marked as educational ones but have great potential for teaching and developing skills. Strategy video game such as Sid Meier's Civilization is set to be in 4000 years BC, and the gamers have a task to grow their empires through different historical periods and up to the modern times and near future. The game includes gathering resources, accumulation of wealth and power, conflicts with different civilizations, political system and construction and expansion of towns. This game helps people with planning, self-awareness, flexibility and to think intellectually. For instance, when players start the game, they have to begin developing strategies of how they are going to explore and expand their colony.[18]

Games provide a learning curve for young children and even corporate level instructors have recognized the importance of simulators and tabletop games in skill training. Video games have been used for children to teach them how to protect them from various critical things, which are important for their safety. Currently, researchers are studying the impact of using different virtual environments to help children think about Science in new ways. The main impact for learning lies in the fact that simulations are fun and they provide immediate feedback and allow users to experience a realistic environment without any real world consequences. For instance, children between the ages of 7 to 11 are being taught how to cross roads through simulations. Apart from developing these games as general computer games, developers have started to use new

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[17] Ibid, p. 6.
[18] Ibid, p. 6.

technologies like Virtual Reality and Augmented Reality to develop these games, which brings a new dimension to play the games.[19]

Pedestrian injuries are a leading cause of death with children around the world. In order to raise awareness to this problem, a University of Alabama at Birmingham psychology Professor named David Schwalbe has decided to create something that will help children learn how to cross the street in an accessible and safe environment. His latest project is an immersive virtual reality mobile game that recreates virtual street crossing scenarios on a google cardboard Virtual reality. According to the professor, Safe pedestrian behavior requires sophisticated cognitive-perceptual skills, these skills are still developing in children, and they are very much vulnerable in pedestrian situations.[20]

(Image 4: Skill Development with children regarding crossing roads)[21]

Schwebel's first iteration of the game was available in a non-mobile desktop computer format. From there, he decided to change the technology into a larger, mobile simulator. He is using Google cardboard platform for a complete mobile and immersive virtual reality experience, and is using it to evaluate 7 to 11 year olds safe street-crossing skills in a study funded by the National Institutes of Health. This game helps children to learn whether they are safe or not while crossing the road, and learn those difficult skills of figuring out how fast the car is moving, how far away it is from

[19] R. Ericson, Emily, "*Development of an immersive game-based virtual reality-training program to teach fire safety skills to children.*" Iowa State University, 2007.
https://lib.dr.iastate.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=15540&context=rtd.

[20] Ergurel, Deniz, "*Professor develops VR game to help children cross the street safely.*" Haptic.al, Apr 4, 2017.
https://haptic.al/professor-develops-vr-game-to-help-children-cross-the-street-safely-f84fbe0c2d63.

[21] Ibid, p. 6.

them and how fast will it get to where they are located. All this can be achieved by not letting the child actually being at risk of being hit by a car. He created the environment, which recreates the street, and crosswalk in front of a local school and it gives the user to access various traffic patterns to monitor from both directions. When the child decides it is safe to cross the road and traffic is clear, he or she clicks the button on top of the Cardboard viewer and immediately triggers their virtual self to walk across the street. The user can see themselves crossing the street, so they can evaluate whether they were safe or not. Though the study is not yet complete, the results are showing that the children are able to cross streets with success similar to that of adults. Once this study is complete, Schwebel plans to continue to broaden access and make it globally available.[22]

(Image 5: Professor David Schwalbe with student)[23]

Due to decreasing equipment cost and increasing processor speeds, computer simulations have become very common over the last decade. As their complexity grows and the uses of such technologies for educational purposes have become broader. A new area of simulations is rapidly growing in virtual reality. Virtual Reality games are being used by researchers to visualize data or natural phenomenon and for entertainment purposes. Recently there are many developments of

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[22] Ergurel, *Professor develops VR game to help children cross street safely,* Haptic.al, 8.
[23] Ibid.

VR systems for training skills. It allows learners to finish an activity at very little cost, without risking themselves.[24]

A well-established example would be the use of VR in the field of aviation training. From flying a commercial plane at a crowded airport to training for the risky night flights using night vision. It provides significant benefits.[25]

Aviation simulators are most valuable training tool pilots have to have to get things right. The different things like the instrument panel, the wind and the rain and the responses of the aircraft when you flip a switch must be as high fidelity and true to life as possible. Otherwise, the pilots will risk their uncertainty or disorientation when transferring their skills and learnt experience to the real world.[26]

(Image 6: Aviation Training)[27]

Piloting commercial flights require the pilots to take on tremendous responsibility, since there are several hundreds of passengers on any flight. Taking such huge responsibility requires both conceptual and hands on training for the pilot. The initial hands on training can be evaluate by use of a simulator. These simulators employ sophisticated computer models and use virtual reality systems to recreate the environment for the pilot. These simulators even use hydraulics to recreate

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[24] Ergurel, *Professor develops VR game to help children cross street safely,* Haptic.al, 8.
[25] Ibid, p. 2.
[26] Ibid, p. 2.
[27] Ibid, p. 2.

the feeling of takeoff and landing. The benefits of using a virtual reality flight simulator is that it is forgiving to the users mistakes and pose virtually no risk.[28]

Other than commercial plane pilots, military pilots can be on a life-threatening mission. Training for a military pilot requires unique skillsets and knowledge of how to react in uncertain situations. Almost all branches of them military, including the Army, Air Force and Navy now use virtual reality systems to train their pilots. By using this technology, soldiers are learning to fly in battle scenario and understand how to coordinate air support with ground operations. As I have mentioned above, the benefit for using a virtual reality flight simulator is that it takes place in a controlled environment and poses virtually no risk of injury or death.[29]

4. Reference games

Currently, several car games have been developed for Virtual Reality Systems. However, most of the games are racing and exploring games. There are very limited car games or simulators created for google cardboard VR and vive VR, which are solely focused on educational purposes.

The car game available on cardboard VR is the "VR Car Driving Simulator". It is available for both iOS and android devices.

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[28] Ibid, p. 2.
[29] Ibid, p. 2.

(Image 7: VR Car Driving Simulator for iOS and Android device)[30]

This game allows the user to scout the desert location. It has no gameplay or any goals. The car can be controlled by tilting your head left and right, which makes it difficult to look around. To reverse the car you need to turn your head all the way around, which makes it very uncomfortable to drive. It does not have any support for external controller or gamepad. The game is a regular exploring game and has few bug issues as well.[31]

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[30] Kropov, Denis, "*VR Car Driving Simulator for Google Cardboard*." Apple, 2016. https://itunes.apple.com/us/app/vr-car-driving-simulator-for-google%20cardboard/id1065376321?mt=8.

[31] Ibid, p. 12.

Goodyear Tyres UK developed a drive test simulator for both android and iOS devices. The game's main intention is to inform young people of the dangerous distractions that can arise during driving such as text messages, billboards etc. The game focuses more on the distractions rather than making the user learn any rules. It has only one environment rather than multiple environments. However, the main takeaway from the simulator are the distractions, which I have incorporated in my simulator as well.[32]

(Image 8: Goodyear Tyres UK Simulator)[33]

The above image is a preview of the car-driving simulator developed by the Goodyear UK team. Apart from these games, there are various other simulators built for other systems. For example, Teen Drive is a VR simulator, which helps the youth and citizens with disabilities on safe driving. The VR is setup in Children's hospital of Philadelphia. The goal of this simulator is to allow the participants to understand what it means to get distracted while driving. They also learn about the increased risks of crashing while not paying attention to the road.[34]

Similarly, there are various other simulators like these such as the City Car Driving, which is developed for users to master the basics of driving in different conditions. The game offers large variations of driving in many different areas such as the autodrome training, weather conditions and much more. It was released in early 2007 with a 3D simulation of streets in Moscow. The first English version of the game

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[32] McCarthy, John, "*Goodyear Tyres leverages virtual reality to inform young people of dangerous driving distractions*." The Drum, 06 June 2016. https://www.thedrum.com/news/2016/06/06/goodyear-tyres-leverages-virtual-reality-inform-young-people-dangerous-driving.

[33] Ibid.

[34] "Using Virtual Reality to Create Safer Driver." Smartcitiesdive.com. Accessed November 11, 2018. https://www.smartcitiesdive.com/ex/sustainablecitiescollective/friday-fun-using-virtual-reality-create-safer-drivers/1090332/.

was released in 2010 and is now available worldwide. Currently it supports twelve different languages and supports US and European traffic rules. In addition, it can be used with HMDs.[35]

(Image 9: City Car Driving with autodrome training, driving in crossing and with different weather condition)[36]

However, most of these simulators do not teach rules and regulations of the road. Since every state have their own rule, it is important for them to understand the specific rules of each place. Thus, I developed a game, which is more designed towards learning the driving rules of the road rather than focusing on the driving part.

Non-VR driving simulator games like Forza Horizon 7, Grand Turismo are very popular and realistic looking games in the current market. However, games like these are not being developed for the current VR systems. It is because; the current technology and hardware are not powerful enough to render these types of quality and graphics.

However, saying that most of the Virtual reality games have bad graphics is a bit exaggerated. However, it is generally true that the graphics of VR games are inferior when compared to desktop games and the reasons are:

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[35] Buhrman, Joel, Akesson, Ludvig, "*DriVR"*. Department of Design Sciences Lund University, 2018.

http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8944255&fileOId=8944256.

[36] "Car Driving Simulator, Pc Game."Citycardriving.com. Last modified 2018. https://citycardriving.com.

Standard games have to render one frame at 25 frames per second while VR games have to render two frames per eye at 90 frames per second. Hence, there's surely a much higher requirement and it is impossible to reach the same level of graphical fidelity for now.

Also, frame drops in standard desktop games is not a big issue when compared to frame drop in VR games, because low frames in a VR game can cause motion sickness for the players. Hence, the game developers have to optimize for performance instead of quality.

The major reasons can be broken down into four reasons:

- Hardware Limitations
- Market Size
- Waiting Time for Development
- AAA Games are Risky

However, with time, the VR market will start producing high quality games when hardware gets better and better. For instance, Assetto Corsa Competizione is a recently developed VR simulator game, which has great graphics and is a realistic looking game. However it cannot be compared to the quality and gameplay of top-level non-VR games as of yet.[37]

5. Demographics

Target Audience is of the age group from 15 year to 40 year old. The simulator targets towards users who are starting to learn driving. The main audience are the non-drivers who are yet to appear for the Learners Test, and the drivers who are starting to learn the rules and regulations of the road. However it mainly targets towards young drivers because they are more likely to take serious risks while driving such as over taking, speeding, drink driving etc. It will help them specifically to control the impulses that are not developed until their mid-twenties to thirties.

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[37] Vitillo, Antony, "*Why do most VR games have poor graphics while normal games are being played in VR by YouTubers.*" Quora, Jan 30, 2018.
https://www.quora.com/Why-do-most-VR-games-have-poor-graphics-while-normal-games-are-being-played-in-VR-by-YouTubers-Whats-the-difference

Chapter 3: System Design of VR Game

1. Introduction

Driving Simulators are used for training and entertainment purposes. They are also used for research purposes to monitor driver's behavior, attention and performance. It has been proven that driving simulators are outstanding practical and education tools to improve driving techniques for all types of drivers.[38]
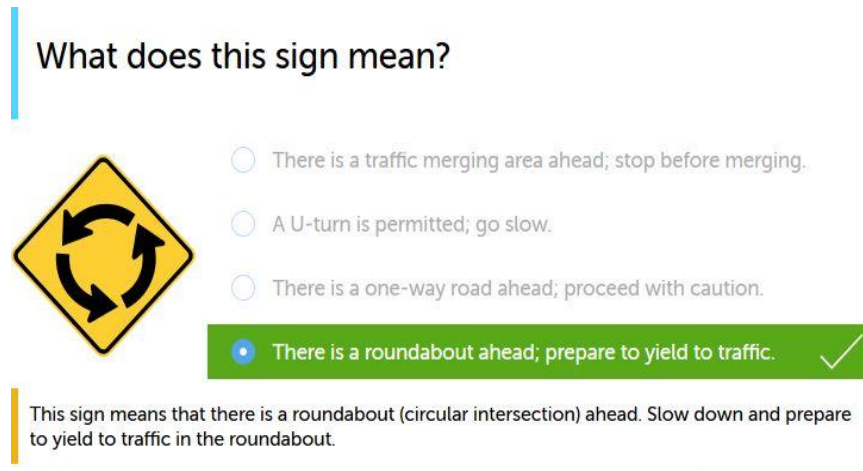
There are various types of car simulators; however, I have developed the driving test simulator for Vive and Google virtual reality systems. This virtual reality simulator incorporates an immersive and realistic environment in front of the user's eyes. For example, the effect of fog and dark environment helps to immerse the player in a realistic way and makes him more cautious while driving due to low visibility. It is a car driving simulation game, which allows the users to get accustomed to driving rules and helps them to prepare for learner's drive test exam. It not only helps the user to learn the driving rules but also helps them to remain more alert and safe during real world driving. This simulator is explicitly a game about driving rules and adapting to the environment. It is not about racing or setting new records, which is a nice break from the usual in-your-face attitude most of the games in the genre adopt. This type of simulator ensures safe environment for learning the driving rules.

2. Approach

I decided to develop a game, which will help users to evaluate their own performance by completing the test. Many things influenced me to develop this game. First being that most of my friends had appeared for the Leaner's driving test exam. They complained about how the test was tedious and boring. The reason being that they had to read the manual and give a boring multiple choice type exam. In addition, a few of them failed the test complaining that they had to memorize so many things from the manual just to answer a couple of questions. They had to pay two to three times the amount to repeat and pass the test. My idea was to not only make it fair and straight

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[38] Stevens, Jay. *"How can a driving simulator prepare you for a real driving."* Lemoptix.com, January 23, 2017. http://www.lemoptix.com/how-can-a-driving-simulator-prepare-you-for-the-real-driving/.

forward but an interactive way for them to learn and prepare for the exam, which would generate interest and the chances of failing the exam will decrease. Below is an example of the type of questions asked in the Learner's test.

What does this sign mean?

- There is a traffic merging area ahead; stop before merging.
- A U-turn is permitted; go slow.
- There is a one-way road ahead; proceed with caution.
- ● There is a roundabout ahead; prepare to yield to traffic. ✓

This sign means that there is a roundabout (circular intersection) ahead. Slow down and prepare to yield to traffic in the roundabout.

(Image 10: Learner's Test Question)[39]

3. Ideas and Inspiration

The main idea for creating the simulator came from a previous project that I had done. My teammates and I had developed a virtual reality drive simulator in an Immersive Human Computer Interaction class taught by Professor Jeffery Kesselman. The simulator was developed for Oculus Rift Virtual Reality systems and used a force feedback wheel to drive the car. The main idea of the project was to allow the users to learn to drive using a force feedback wheel. The objective was to allow users to experience active feedback through steering wheel. It was geared towards learning to drive in an open area rather than learning the driving rules and regulation of the road.

It was a great project but was limited to just driving the car in an open environment. I wanted to expand this idea, make it to great use, and help users to not only experience realistic environment but also help them to learn actual driving rules of the road.

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[39] "Driving practice test Massachusetts." Last modified November 11, 2018. https://driving-tests.org/massachusetts/massachusetts-dmv-practice-test/

I started to brainstorm ideas and wanted to remove some of the drawbacks of my previous project. I decided to make it a totally night based environment where the player can see only the area ahead of the car. This will make the users more cautious during the gameplay.

One of the most important aspects about Virtual reality is that it provides extremely engaging and immersive experience that could present real opportunities for learning and development. I wanted to include this aspect into my project. The main advantages are that the hardware now works well and the competitiveness among the vendors will drive down the prices and increase the innovation potential. Through virtual reality, actual learning and performance metrics can be captured during the gameplay session.[40]

Virtual reality offers risk free training. One of the biggest issues faced with practical training is the large amount of risk involved by putting the trainees in a new and uncontrolled environment.[8] For example, in my previous project, people could actually learn driving sitting on a seat and using a force feedback wheel. This removes the risk of driving outside in open world and by avoiding accidents. Virtual reality keeps the same training features by creating the same environment virtually. The next big advantage is the realistic scenarios. The scenarios are build up on real life operations and manipulations needed in after training situations.[41]

Virtual reality improves retention and recall. VR training enables trainees to use their hands to manipulate anything inside the simulation. This can be done either by controllers or by VR gloves. It is very innovative and enjoyable. This is a very important advantage, since training is easier if the experience is pleasant or enjoyable which means higher level of engagement and understanding.[42]

4. Gameplay of Virtual Reality Simulator

The game is available online and users who are interested to play the game can download it from here: http://prateekchatterjee.com/ClassicDriverVR/

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[40] "8 Advantages Of Virtual Reality Trainings." SimLab IT. Last modified April 22, 2017. http://www.simlabit.com/blog/virtual-reality/vr-training/advantages-of-virtual-reality-trainings/.
[41] Ibid.
[42] Ibid.

There are three versions of the game available to download on the website. The first version of the game can be downloaded for the Vive VR systems. Users must own a Vive VR system, powerful pc, keyboard and mouse to play this version of the game. The second version is for android phones. Users can download the file directly from their android phone and it will automatically get installed on it. This version of the game requires the user to have a wireless keyboard, google based head mounted display and an android phone to play it. The third version is for non-virtual reality windows systems, where users can play without any VR headset or VR equipment. This version of the game requires a Windows PC, keyboard and a mouse.

Users are able to play the game in first person view, which gives them a sense of realism. They have to complete the game in a night based environment setting and drive from location A to location B by learning and noticing the speed limit signs, road signs, pedestrians, warning alerts and hazards through audio and visual feedback.

(Image 11: First Person view of the player)

The directions to the destination is provided to the user in the form of direction boards and direction pointers as shown in the images below. Regardless of the directions, the simulator is straightforward and users won't have to worry about where to go.
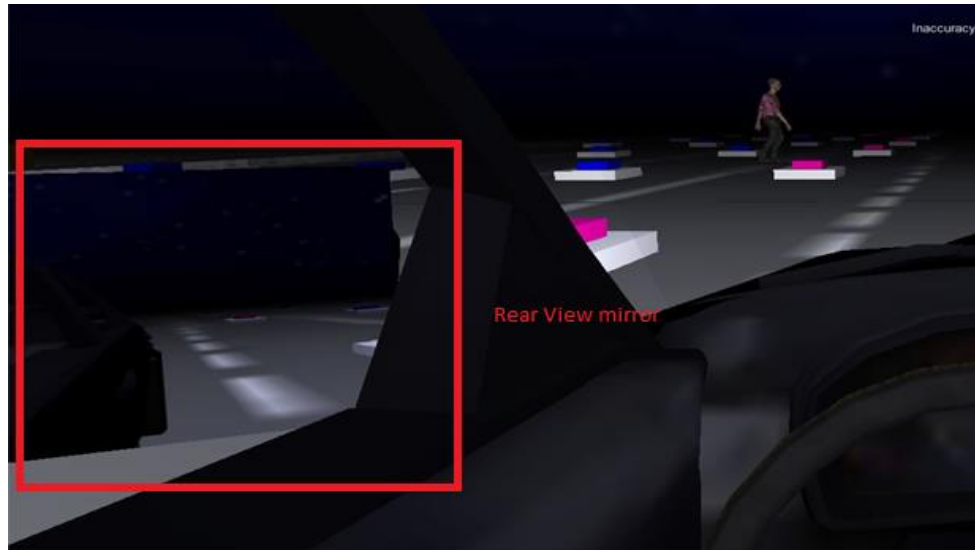
(Image 12: Direction boards showing the direction of the road)

(Image 13: Sign boards showing the direction of the road)

Firstly, users can take advantage of the rear view and side mirrors to cross lanes or park the car as shown in the image below.

(Image 14: Rear view mirrors)

(Image 15: User Interface)

As shown in the image 15, the user interface consists of a speedometer. This speedometer notifies your current speed. Thus, the user has to pay attention to the speedometer to drive in desired speed limit.

Users are able to see the entire User Interface scoreboard when they start the simulator. The first thing the user sees in the UI is the Time counter. This depicts the current time of the player. Underneath the time counter, there is checkpoint counter. The checkpoint counter lets the user know if they are progressing smoothly. There are about eleven checkpoints in the game.

Below the checkpoint counter, there are several instances. Each of these instances are denoted with a 0 input. There are ten instances in the game and user have to get at least seven instance correct out of the ten to pass the test.

The ten instances consists of Road Work Crew, Wrong way, Pedestrians crossing, HOV lane, Lane Dividers, Stay closest lane while turning left, double yellow Line, round about speed limits, one way roads, and over speeding. The user interface is transparent, which allows the user to clearly see the road ahead while driving. A screenshot of the user interface is shown below:
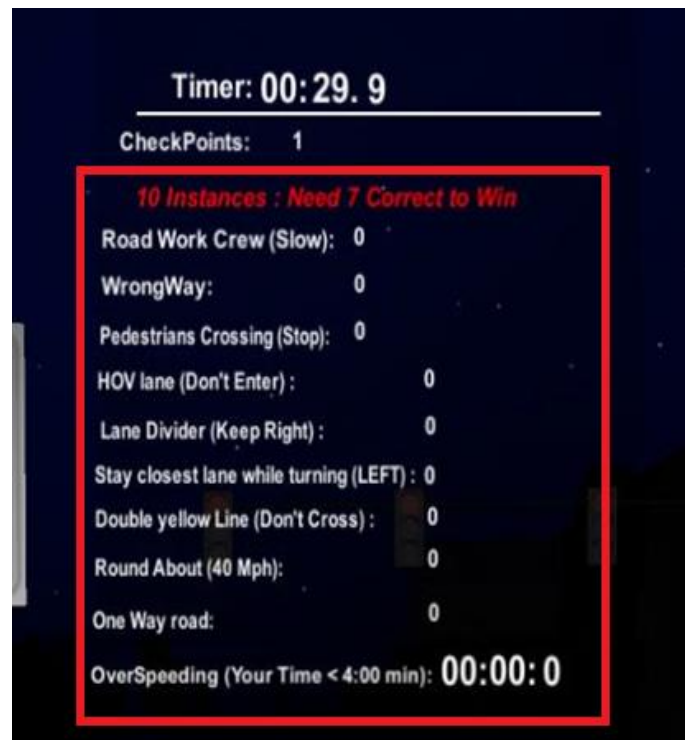
(Image 16: Ten instances)

The user interface as show in the image above is presented directly in front of user's eyes and in center of the VR screen. This is because the field of view of the head mounted display is very small when compared to a regular screen. Hence, it was important for me to adjust and include the UI to preserve the games functionality. However, I designed the UI background as transparent to avoid any interference for the user and so that the user can see the road clearly. As you can see in the image 16, the "Timer" shows the current time of the simulator. Each instance is set to 0. Whenever the user makes a mistake, a sound effect is generated and the 0 input turns into 1 for the specific instance. As shown in the image 17, the user made a mistake by driving over the road crew and the 0 input changes into 1 by letting the user know about their mistake.

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(Image 17: Mistake Displayed as 1 "marked as yellow")

The 10 instances are discussed below:

- **Roadwork crew zone:** This is the first instance of the game and the user is supposed to go slow since there is a road crew working ahead zone. The user is supposed to drive slow, use caution, and if possible, change lanes to keep your distance from the workers.
- **Wrong Way:** In this instance, the user is supposed to stay in the correct lane and try not drive into the opposite direction of road.

`   (Image 18: Wrong Way Feedback)

- **Pedestrians ahead:** Users have to look out for pedestrians crossing the road. They will have to stop the car and let them cross the road without running over them.

(Image 19: Pedestrians crossing)

- **HOV lane:** This lane is called high occupancy vehicle lane. Users are not supposed to pass through this lane since it is reserved for car pools and vehicles with more than one occupant.
- **Lane Divider:** In this instance, the user has to see the upcoming traffic island or divider and avoid collision.
- **Stay closest lane while turning:** Here the user has to stay to the closest lane for turning into the desired direction. For example, if the user has to turn left, then they have to plan before and keep to the left most lane before turning left.
- **Double yellow line:** In this instance, the user cannot cross the double yellow line regardless of any turns or crossing.
- **Roundabout (40 mph):** The user has to turn about the roundabout and with a speed limit of 40mph.
- **One-way road:** Here the user has to stay in the given direction of the road and cannot turn or take a U-turn.
- **Over Speeding:** Lastly, users are expected to complete the test without over speeding and drive as if they are giving a real driving test by learning the rules, which appear through the given feedback. They are not expected to drive the car like a racing game. In every lane, there is a speed limit board, which the user has to follow. The user is supposed to be over speeding if he completes the game within 4 minutes of time.

If they do not obey these conditions, then they lose the particular instance. These rules and conditions are related to the Massachusetts's RMV driving manual.

Throughout the game users are going to receive various types of feedback. They will receive feedback in forms of audio and visuals. If the users crash with pedestrians or other objects, the simulator creates sound effects and let them know about their mistakes. The game also provides visual feedback through images. For instance, if the user goes in a wrong way, then the simulator displays an image in front of them, which says, "Wrong way Go back" as shown in image below.

(Image 20: Instant visual feedback)

This type of feedback helps them to realize their mistake and gets them accustomed to the rules and regulations of road. In addition, whenever the user is approaching an upcoming instance, there is a visual and audio feedback, which will alert the user about it. This helps them to understand the type of instance he/she is going to approach and make them more cautious. The image below is an alert for the Pedestrians ahead zone, which notifies them to slow down:

(Image 21: Pedestrians Feedback)

When the user makes a mistake, a siren sound effect is produced; alerting the user about the mistake. The user also gets visual feedback to correct themselves. The image below shows that the user makes a mistake by driving in HOV lane and instantly gets a feedback to keep left and drive away from the HOV lane:


(Image 22: Keep Left feedback after mistake)

There are speed limits on each lane. The user has to follow these speed limits to avoid overspending. The speed limit boards are clearly visible to user as shown in image 23:

(Image 23: Over speeding when speed limit 30MPH)

The rules and the road signs are obtained from the Massachusetts RMV driver's Manual.[41] The simulator is based on the Massachusetts's driving policies. Few of the road sighs are shown in image 24:
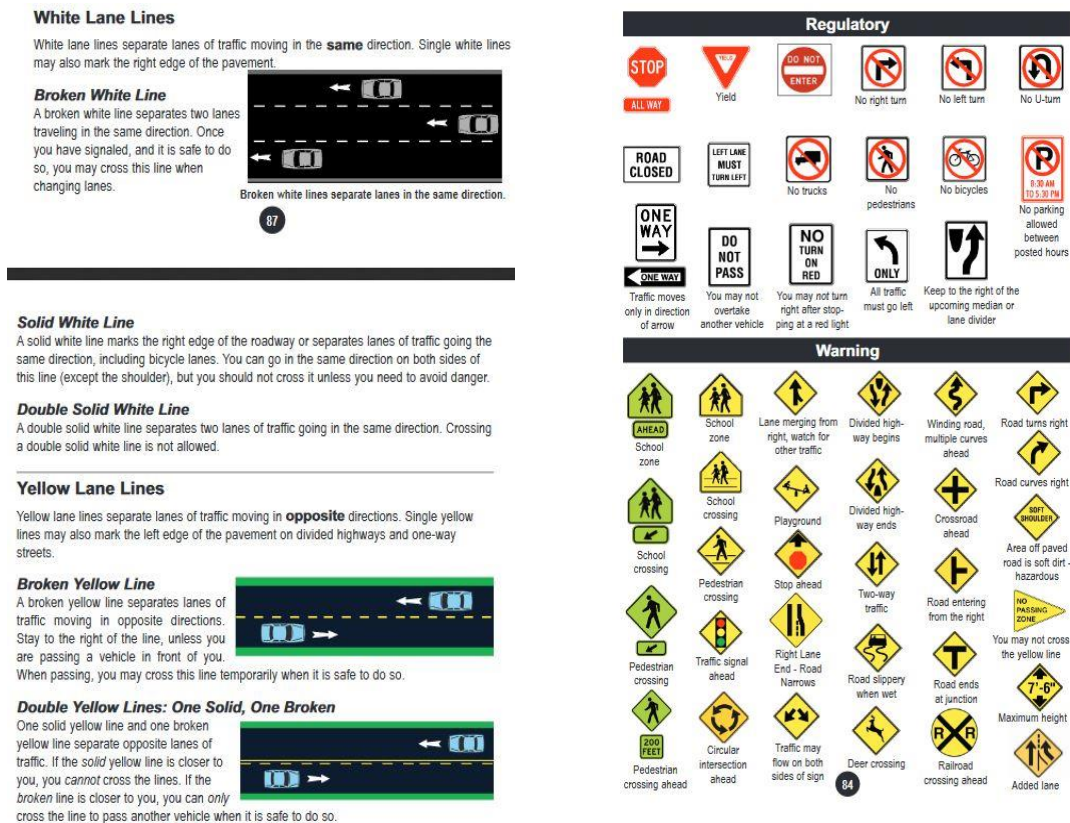
(Image 24: Road signs from RMV manual)[42]

In the end of the game, the user has to park the car in a parking lot. It will alert them that the game has ended. Also it shows the types of mistakes they have made. Below is an image of the end game:

[41] "Driving rules and regulations." Commonwealth of Massachusetts Driver's Manual. Last modified February 2018. https://www.mass.gov/lists/drivers-manuals#massachusetts-driver's-manual-.

[42] Ibid.

(Image 25: End Game Screen with mistakes displayed)

There are two screens, which are the main menu screen and the controls screen. The main menu screen allows the user to start, quit or go the Controls screen as show below:

(Image 26: Main Menu Screen)

The Controls screen shows the keyboard controls and rules or the game as shown below:

Controls: W A S D for car controls

Rules:

1. To Pass This Test - You Need To Get 7 Out Of 10 Instances Correct

2. Follow Speed Limit - Speed Sign Boards

3. Clues Will Pop Up To Alert You About The Upcoming Instance. Be Alert!

4. In The End, When You Park in the Parking Lot The Simulator Will End

5. It Will Show The Types Of Mistakes You Have Made

6. If Number Is "1" = Fail
   If Number Is "0" = Pass

7. Pass Or Fail: Count Your Mistakes By Counting Number "1"

                    If You Make More Than 3 Mistakes You Lose

8. Good Luck Driver!

Back To Main Menu

(Image 27: Options and Rules Screen)

5. Controls of Virtual Reality Simulator

The game is played in a first person view using a keyboard and VR headset. The player can move the camera by looking around and moving their head in the VR headset. The acceleration, brakes and the direction of the car is controlled using the keyboard or Joystick.

One of my future goal is to investigate more controls for this game such as providing buttons for cruise control, automated parallel parking, gearshifts, hand breaks and many more. During the study, I found that few of the users were lost and could not figure out the directions to the destination. Hence, I have decided to add features like GPS in future.

Chapter 4: Development of VR Game

1. Resources used for Developing the Game

The project required me to use several software packages to build it. The whole process introduced me to new software technologies, which helped me to get, familiarize and learn it. I also had to figure out the hardware for this game. For instance, I had to try out several types of VR systems such Oculus rift, Vive and Google VR. After testing out the VR systems, I finally decided to move forward with the Google and Vive VR. Hence, the simulator will be available for the Vive and Google cardboard Virtual reality systems. This will make the simulator very accessible to wide variety of audience. Both of these systems have their pros and cons and they are as follow:

- **Mobile Headsets (Google Cardboard VR):**

The absolute simplest form of virtual reality system is made out of nothing but a pair of plastic magnifying lenses and a box of cardboard, while using a standard android smartphone as a screen. This idea was around for years and google branded it and referred it as the Google Cardboard. Not all low-end headset manufacturers follow them, but these are the most easily available headsets and are Cardboard-compatible, which means they are guaranteed to work well with certified Android and iOS virtual reality based phones.[43]

Many companies collaborate with Google or other manufacturers to make branded headsets for their own mobile phones. People can also order some cardboard and plastic lenses, print a pattern from Google's site, and build their own headset out of it. Google started to sell basic Cardboards headsets for $15 apiece. Customizations and special materials like durable plastic can be used, which increase the price, but still they can be bought for $20 to $30 range.[44]

However, because phones are not designed specifically for virtual reality and they cannot offer the best visual experiences since they are not as powerful as compared to a PC hardware. In addition, there is currently no positional tracking with mobile VR. The only thing a user can do is to look around the

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[43] Barnard, Dom, "*The Complete Guide to Virtual Reality and the VR Industry*." Virtualspeech, June 25, 2018. https://virtualspeech.com/blog/complete-guide-to-virtual-reality.
[44] Ibid.

environment from a single point. Recently, Google and other companies have announced they are going to introduce mobile tracking in the near future.[45]

- **Desktop Headsets (Vive VR):**

The absolute best-quality VR experiences cannot be powered through a mobile device; hence, devices like the Oculus Rift, Valve and HTC's Vive, and Sony PlayStation VR are developed. These high-end headsets run with external powerful computers. They provide sophisticated features like motion tracking, high-resolution screens, and the best graphics possible. They are generally more comfortable and have better at blocking the outside light. They are also less prone to inducing motion sickness. With all these added features, the costs of these high-end headsets goes substantially high. The HTC Vive costs around $799. Along with the Vive, the user has to buy a high-end computer, which may again cost around a $1000. Hence, it is up to the user on selecting the type of VR system they want to buy.[46]

So as you can see, both these have their pros and cons. People who want better graphics, better frame rate, and want to spend large amount of cash can choose the Vive, while the others can choose google cardboard virtual reality for its simplicity, accessibility and usability, since it does not require any costly hardware other than a cheap android device to run it.

The following are a list of software and hardware resources that I have used throughout the period of the project.

Software:
- Unity Game Engine
- Adobe Creative Suite
- Maya3D

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[45] Ibid, p. 30.
[46] Ibid, p. 30.

Hardware:

- Computer running Windows
- Android Smartphone
- Cardboard Virtual Reality headset
- Wireless android supported keyboard
- Headphones
- Vive Virtual Reality System
- Windows computer with VR supported graphics card (NVidia 1080)

Training:

- Unity tutorials

2. Game Engine

Before starting the project, I had no knowledge of game engines and how they work. It was because, I was coming from a UX design background, and thus it was a good opportunity for me to learn new software such as Unity game engine and programming language like C# for Unity.

To develop the game, I had few engine options such as Unreal Engine and Unity. However, I decided to build the game on the Unity engine since it is robust and easy to learn. The development of the driving simulator was done using Unity 2017.1.1f1 engine.

Firstly, it has a robust asset store, which has plenty of useful add-ons and contents and helps developers since it is their potential revenue stream. Its workflow support 2D and 3D games effortlessly. Also, the built in animation system is very useful.

One of main reason was that its performance scales extremely well from low-end mobiles games to high-end consoles games. It has an out of the box VR support, which was a very important feature for me. I was able to develop the VR game with a lot of ease. Finally yet importantly, it has a huge, active, engaged community facilitates finding help, answers, and teammates.

3. 3D Assets and Development

Some of the 3D models used in the game are free assets while others models were created by me using Maya 3D. Some models like the car, signboards, terrain, parking lot, chairs etc. were designed and developed by me using Maya 3d. Rest of the 3D models such as the houses, apartments, bridges etc. are free and can be obtained from Unity store. The assets and animation for pedestrian and traffic lights were obtained from unity store as well.

The game was developed using C# in unity. I programmed the game's user interface and Visual/audio feedback. The audio and visuals alerts popped up in terms of images and sounds whenever the user collided with various object colliders in the game. Apart from this, the speedometer was also programmed by me.

Finally yet importantly, I deigned the whole level. The level is split into 10 tasks that the user has to undergo to complete the game. Before each task, the users are alerted with the audio and visual feedback letting them know about their upcoming task. In addition, the users are alerted whenever they make any mistake. The levels are discussed in more detail in the gameplay section.

Chapter 5: User Experience Research

1. Introduction

As we know that the objectives of the game is to allow users to learn driving rules and regulations of the road, it was important for me to evaluate the user experience of the game. I got to learn about the users and how they interacted with the game.

I held user testing, user interviews and user surveys to analyze, rectify and improve the problems of the game. I conducted A/B testing to evaluate whether the simulator is effective compared to the manual for learning rules and regulations of the road.

Twenty-two users participated in the study. All these users were non-drivers. There were two groups such as the control group and the experimental group. Eleven users were in the control group, while the rest eleven users participated in the experimental group.

The whole evaluation process of the game included user testing followed by user surveys and user interviews. The whole procedure was successfully completed. During the user-testing period, users from both groups were asked to appear for a learner's driving quiz test. The quiz format was according to the actual learner's driving test format and similar type of questions were asked. There were total of ten questions asked. For instance, below is one of the questions asked from the quiz test:

- HOV (high-occupancy vehicle) lanes are designated as ?

1. Option 1   **2.** Option 2
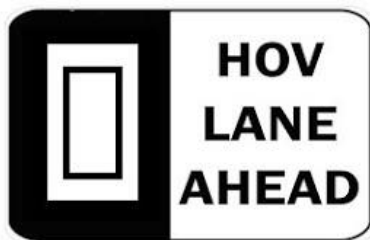
(Image 28: HOV option 1)   (Image 29: HOV option 2)

3. Option 3   **4.** Option 4

(Image 30: HOV option 3)

(Image 31: HOV option 4)

The question above is related to HOV lane and users have to select the correct answer. Similarly, within the game, the user is alerted about HOV zone and they are not allowed to drive in that particular zone. Likewise, rest of the questions are included in the appendix A (p. 52).

(Image 32: HOV Keep Left)

In the image above, the user drives into the HOV lane and is prompted to keep left since he is making a mistake on being on the HOV lane.

2. User Testing with Experimental group and Control Group

A total of eleven people from the experimental group gave the quiz test mentioned above. After taking the test, they were asked to play the VR game. After completing the game, the users were again asked to take the same quiz.

Just like the experimental group, eleven people from the control group appeared for the quiz test as well. After appearing for the test, they were asked to read the RMV manual, which consisted of all the answers to the questions mentioned in the quiz. After reading the manual, they were asked to appear for the Quiz test again. It was found that, they were able to evaluate the correct answers to the given questions in the test.

However, it was not possible for me to include all the questions from the manual in the game and so I had to reduce the scope of the project. Therefore, I presented them with only few pages of RMV manual to keep the scope small and this allowed the users to focus on the answers in short period of time.

3. User Experience Research

I had conducted user experience research two times. During the first round of testing, I tried to analyze the user goals and requirements for the project. I conducted the research in the form of user surveys and user interviews. Around 30 users participated in the first research. I received constructive feedback, which I then used to improve the game. Below are the drawbacks from my first iteration of the game.

The first drawback was that the frame rate of the game was around 14-25 fps on a low budget android phone. This made it very difficult to maneuver the car.

The second and the most important issue was that the lack of feedback through visuals. The testers wanted more visuals than sound. Although the game alerted when they drove in a wrong way, but it did not correct them for their personalized mistakes.

I had to get rid of these issues, so I started developing it for high-end VR devices such as Vive and high end android phones. This resolved the issue of low frames and lag. Secondly, I incorporated personalized feedback through many visuals and alerts. This improvement also overcame the main challenges the simulator was facing during its first iteration.

During my second user-experience research, all the testers were non-driver students only. They were anonymous to me, and thus no biased answers were recorded. During this period of testing, several users were very excited to use the technology, as it is a new and upcoming technology and were satisfied with the whole procedure. People within the age group from 15 to 40 participated in the test. All these testers were non-drivers and did not have a driving license. Each one of them were given instructions and rules through a consent form agreement for appearing for the study.

After users completed the simulator, they were given a post survey questionnaire. This questionnaire determined the user experience of the simulator and determined if the simulator satisfies the given objective or not. The following is one of the question, which was asked in the post-test survey:


Post-Test Survey:	Disagree				Agree
• You played the game without any help	1	2	3	4	5

The question above indicates if the user required any help to start, understand and play the game. If they agreed to this question, then it means that the user interface was robust and clear instructions were provided to play the game without any external support. Similarly, the rest of the post-test survey questionnaire is included in the appendix B section (p. 55).

4. Experiment Results

Users from both the groups appeared for the first quiz test. It was seen that four users failed the test from the experimental group, while only three users failed from control group. Then I conducted user testing by letting the users from both the groups to perform their respective task, for instance, the users from experimental group were told to play the simulator, while the other

group were told to read the RMV manual. After letting them to do their respective tasks, users from both the groups took the quiz test for the second time. It was seen that users performed better and passed in the test after learning from the game and manual.
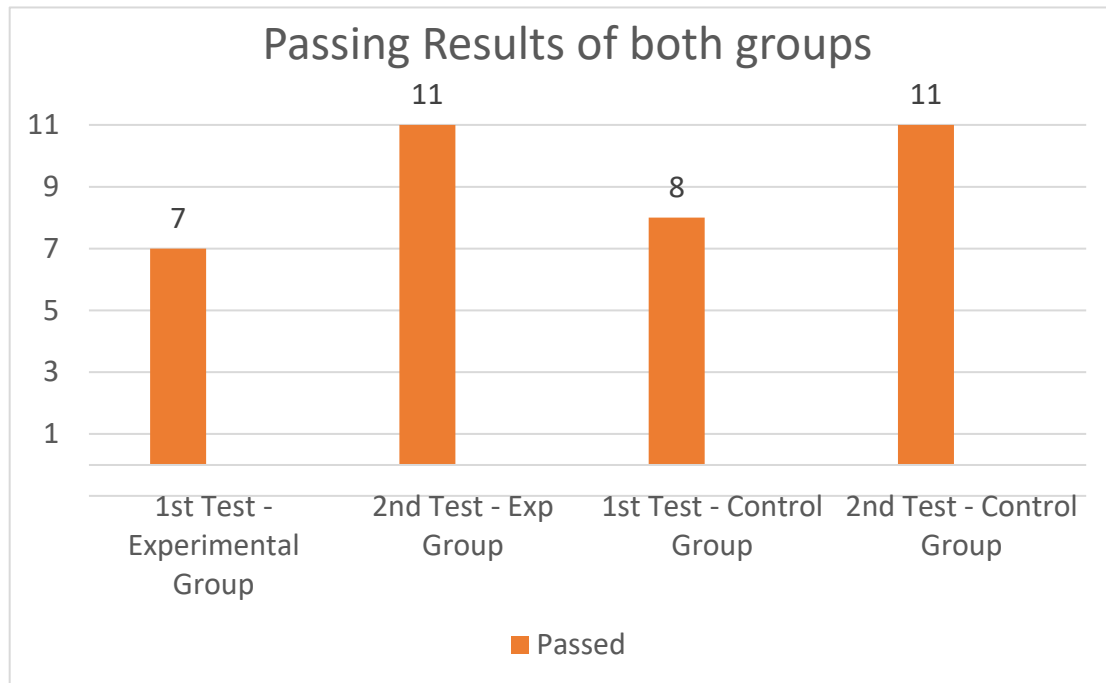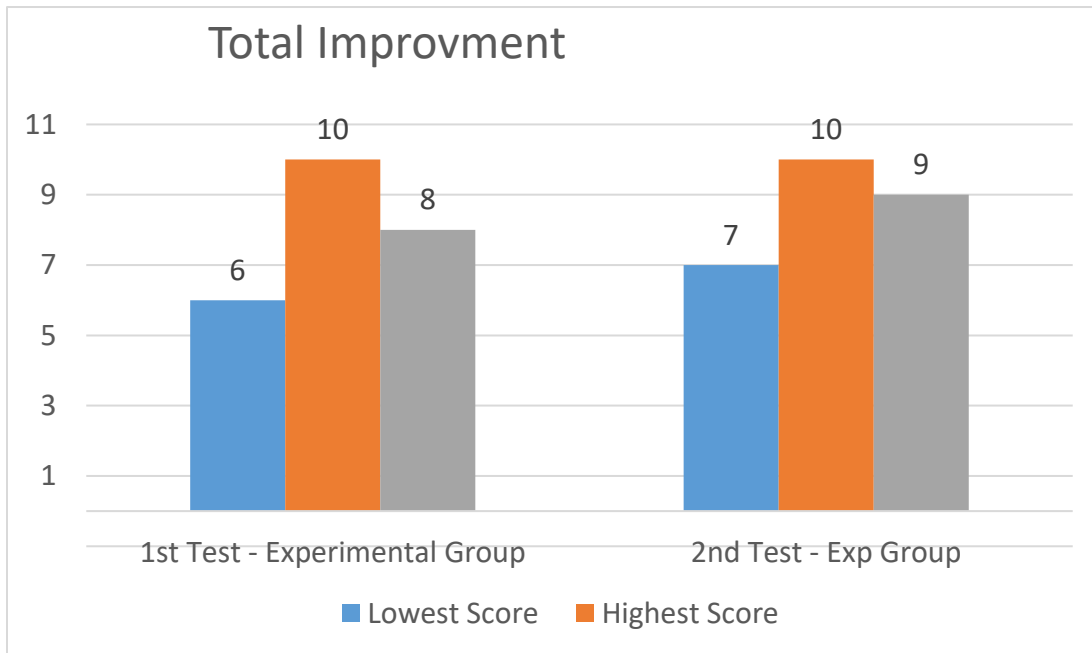

(Image 33: Passing Results of both groups)

The results of participants taking the test for the first time in experimental group:

- Lowest score: 6/11
- Highest score: 10/11
- Average score: 8/11

The results of participants taking the test for the second time in experimental group:

- Lowest score: 7/11
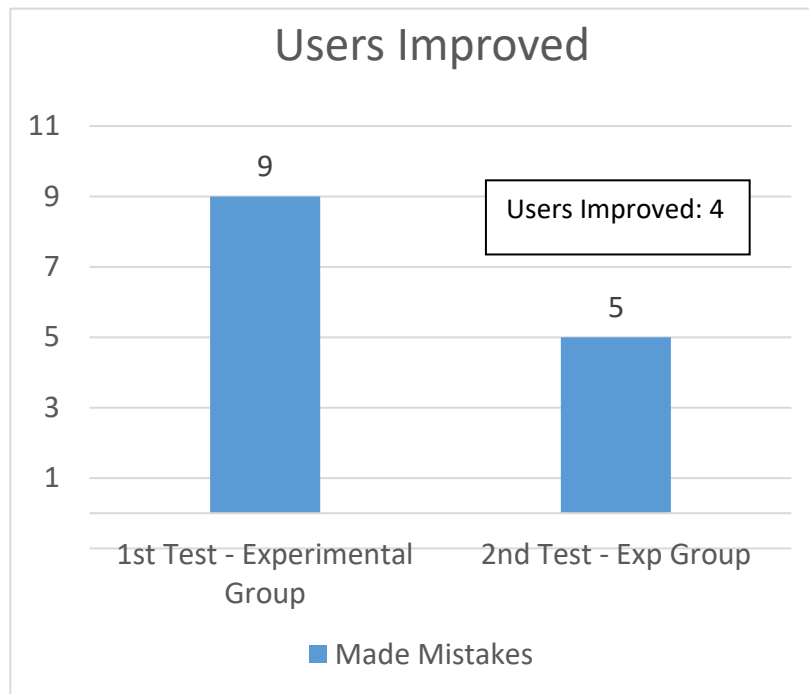- Highest score was 10/11
- Average score: 9/11

(Image 34: Total Improvement Exp group)

The lowest score is depicted as blue, highest score is depicted as orange and average score is depicted as grey.

The results and overall improvement of experimental group:

In the experimental group, nine out of eleven users made mistakes while taking the test for the first time. Five users made mistake, while taking the test for the second time. Thus, we can see that four users improved. From the results, we can say that playing the game did help them to improve from their mistakes.
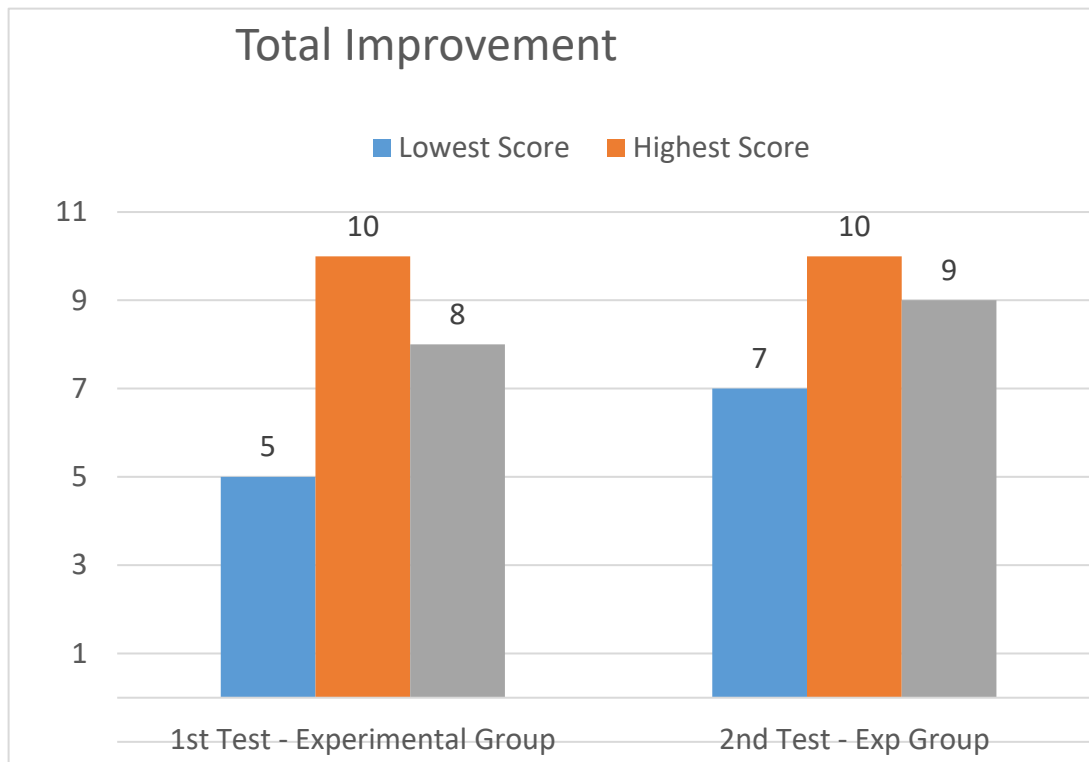
(Image 35: User Improvement Exp Group)

The results of participants taking the test for the first time in control group:

- Lowest score: 5/11
- Highest score was 10/11
- Average score: 8/11

The results of participants taking the test for the second time in control group:

- Lowest score: 7/11
- Highest score was 10/11
- Average score: 9/11

(Image 36: Total Improvement Control Group)

The lowest score is depicted as blue, highest score is depicted as orange and average score is depicted as grey.

The results and overall improvement of control group:

In the control group, 8 out of 11 users made mistakes while taking the test for first time. Just like the experimental group, only 5 of users made mistake, while taking the test for the second time and 3 users improved. Thus, we can also say that the reading the driver's manual did help them to improve from their mistakes.
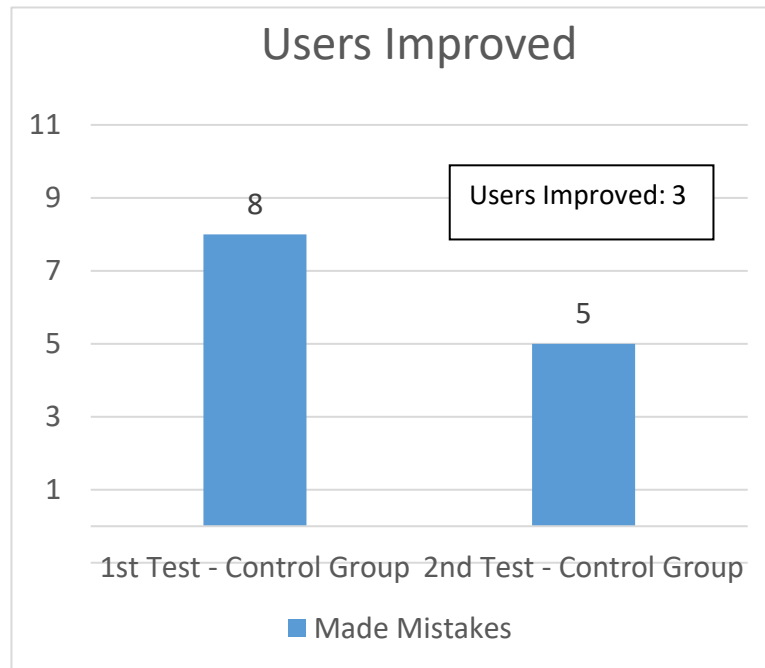
(Image 37: User Improvement Control Group)

The most failed questions by the users were the HOV lane, turnpike speed and crossing two yellow solid line. There was an average improvement of two correct answers by each individual while taking the test for second time.

As we can see, users from both the group have similar results and we can say that both the techniques are equally viable for learning driving rules and regulations of road.

5. User Experience Results:

After successfully conducting the user testing, I wanted to evaluate the user-experience based on the user-surveys and user-interviews. The survey did suffice the expectations of the simulator. Majority of the users thought that this could be used as a medium for learning driving rules and regulations of the road, which satisfies the requirement of the simulator. Majority of them also though that the environment was realistic.

User Experience- The Positives
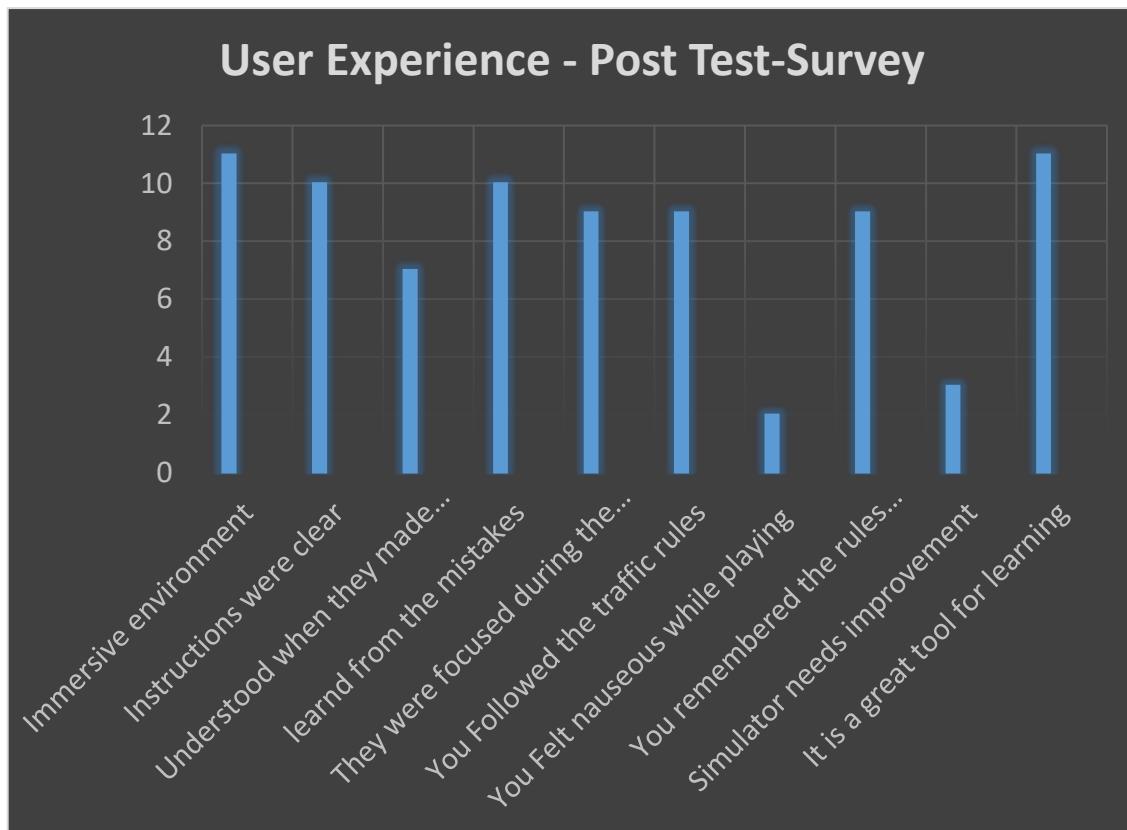

(Image 38: User Experience- The Positives)

Users had a positive feedback for the following asked:

● Users felt that the environment was immersive: 11/12 users

● Users felt that the instructions were clear: 10/12 users

● Users knew when they mistakes (Feedback was good): 7/12 users

● Users learned from the mistakes they made: 10/12 users

● Users felt that they focused in the game to win: 9/12 users

● Users who remembered rules through the feedback: 9/12 users

● Users who followed the traffic rules 9/12 users

● Users who felt Nauseous while playing: 2/12 users

● Users who felt that the simulator needs improvement: 3/12 users

- Users who felt that it is a great tool for learning rules and regulations: 11/12 users

However, there were few things, which the user did not appreciate or wanted to see improvement.

User Experience: The takeaways:
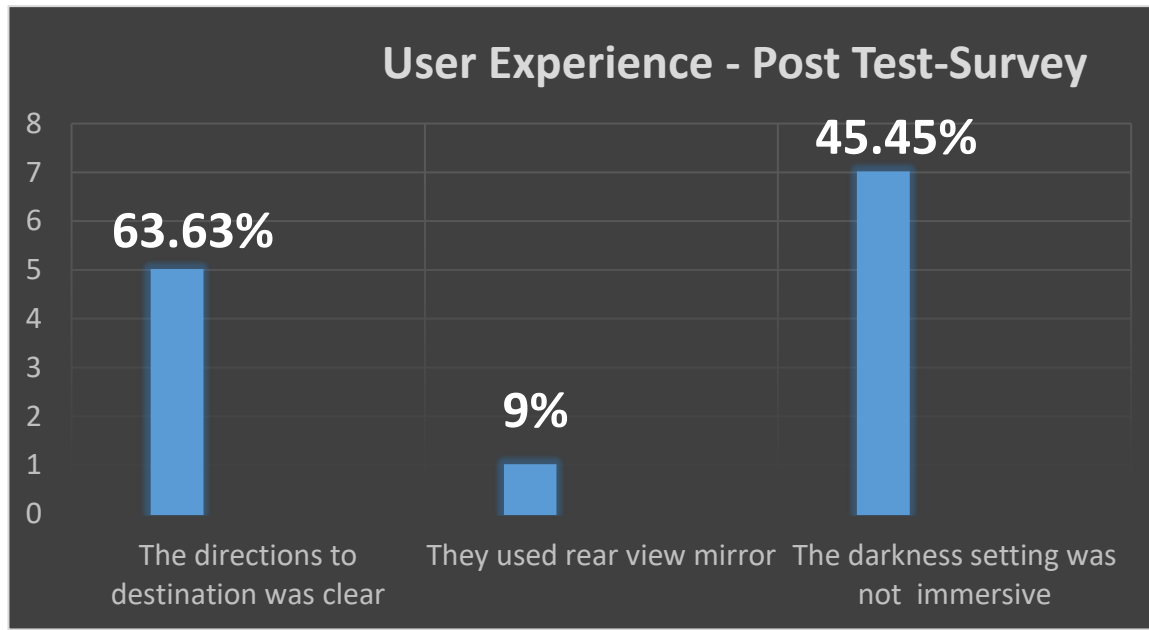
(Image 39: User Experience- The Takeaways)

Users who though that the simulator should get rid of them or needs improvement:

- Users felt that some road signs were not clear and were confusing to understand the directions to the destination: 7/12 Users

- Users who used rear view mirrors: 1/30 Users

- The dark environment was not immersive: 7/12 Users

From these results, we can say that simulator was definitely affective and its main goals were accomplished. However, there were very few things, which the users pointed out and that needed improvement such as providing clear direction to destination, removing things, which are distracting or unnecessary such as the rear view mirrors or moving cars, since they did not have any effect in the game. In addition, the environment needs to be more immersive in terms of the fog or darkness to make the user more alert while driving. While interviewing the users, they felt that the car controls were not fluid and were not able to maneuver the car properly.

The user experience research definitely helped me to realize the importance to improve the simulator. However, the simulator satisfied the main objectives and was considered effective in terms of learning rules and regulations when compared to the RMV manual.

In the future, I will be making various improvements. Firstly, I will improve the environment by making it more immersive. This will be achieved by introducing new environments such as rain, fog, daylight and anymore. I will try to make the game compatible with most of the virtual reality systems such as Oculus rift and PlayStation systems. Also, I will be increasing the scope of the simulator and its effectiveness by adding several other rules into the gameplay such as fines for making mistake, obeying traffic lights and anymore.

Chapter 6: Conclusion

This project is an attempt to make users acquainted with the rules and regulations of road. It also helps users to understand the consequences of reckless and unsafe driving.

The initial goal was to include several instances in the game. However, the initial scope turned out to be too ambitious for a one-year/one-person project and thus the scope was narrowed down with only 10 instances. In addition, few things did not go as planned. For example, developing for low budget android phone was not viable, because the game had performance issues even when the graphic quality was on low setting. Hardware of the low-end phone was not good enough and hence, I had to develop it for high-end VR systems and high-end phones. During my first user testing of the application, it was difficult for me to figure out the right questions for determining the user experience. However, this issue got resolved during the final stage of user testing and genuine feedback was received.

 Based on the results of user testing, the simulator does prove that it is helpful for teaching rules and regulations of the road and so does the majority of the users believed. For instance, each user were different. Few users liked to over speed, while others liked to break the traffic rules and thus the simulator allowed them to understand their individual mistakes. I have decided to continue working on this project to achieve its initial goals and create a simulator, which will incorporate almost all the rules from the manual. I will be including various levels in the game, where the user has to clear levels to get access to the difficult questions or instances as they progress. In addition, I will be making the simulator more interactive by including various AI elements such as the being fined by police for making mistake, creating ambulances, being fined for crossing the red traffic lights and many more.

In terms of my personal development, the project was also successful. The development was extremely challenging since the beginning and I got to learn the Unity Engine from scratch. In addition, I learnt to manage work and gained more experience on how to manage scope of the project and how to set smaller milestones to maintain and control the project's flow.

It can not only be used to train skill but can also be used to provide an experience in a rich immersive environment to maximum amount of people. Hence using this immersive VR simulator as a part of drive test satisfied and increased the learning gains of participants.

Lastly, I think that this game is promising and can have a lot of potential in the future. The idea of helping users to learn in a very immersive and fun way was very well received by the testers. They showed a lot of interest in the present state of the game and were excited to hear about the final state of the game. Educational games like these can become the new standard for learning skill for its enjoyable experience.

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Appendix A

Quiz test Questions:

- **The first rule of the safe legal turn is?**

    I.   to reduce your speed

    II.   to cut corners while turning

    III.   to move into proper lane well before the turn

    IV.   to increase your speed

- **What does this sign indicate?**

    I.   One-way street ahead

    II.   Look straight while driving

    III.   Go straight only   (Image 40: Go straight only)

    IV.   stop sign ahead

- **When you see a pedestrian crossing an unmarked crosswalk where there is no traffic signal, you should**

    I.   yield the right of way to the pedestrian

    II.   warn the pedestrian and proceed with caution

    III.   proceed because there is no traffic signal

    IV.   turn on your hazard light and proceed with caution

- **What does this sign mean?**

    I.   A traffic island or divider is ahead

    II.   A divider highway ends ahead

    V.   A blind curve is ahead   (Image 41: A Divider is ahead)

    III.   A sharp right turn is ahead

- **When you find two solid yellow lines between opposing lanes of traffic you must not pass**

    I.   at all

    II.   If the solid yellow line is on your side

    III.   If the broken yellow line is on your side

    IV.   If the solid yellow line is not on your side

- **What is the minimum speed on the Massachusetts turnpike?**

    I.   20 mph

    II.   60 mph

    III.   40 mph

    IV.   50 mph

- **HOV (high-occupancy vehicle) lanes are designated as ?**

    I.   Option 1

(Image 42: HOV option 1)

II.   Option 2
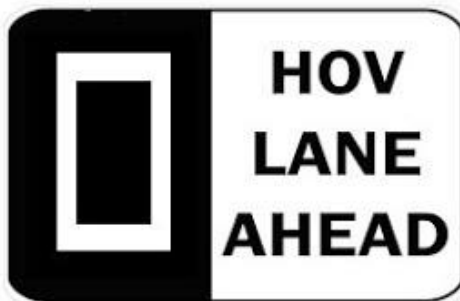

(Image 43: HOV option 2)

III.   Option 3

(Image 44: HOV option 3)

IV.   Option 4

(Image 45: HOV option 4)

- **What does this sign mean?**

   I.   There is one way road ahead

  II.   There is a circular intersection ahead

 III.   There is a parking area near the sign

 IV.   There is residential parking ahead

- **What does this sign mean ?**

  I.   A hospital zone

  II.   A flag person at a work zone

  III. A road crew ahead

  IV.   A crosswalk for blind pedestrians

(Image 47: Road Crew ahead)

- **Which of the following statements about making a turn is true ?**

  I.   Start from the lane closest to where you want to go

  I.   Start from the lane farthest to where you want to go

  II.   Always start from right most lane

  III. Always start from left most lane

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Appendix B

Post-Test Survey Questions:

	Disagree				Agree

- You started the simulator without any help   1 2 3 4 5
- The environment was immersive   1 2 3 4 5
- You understood what you were supposed to do   1 2 3 4 5
- You knew when you made a mistake   1 2 3 4 5
- You knew when you did something correctly   1 2 3 4 5
- You wanted to try again immediately   1 2 3 4 5
- You learned from your mistakes   1 2 3 4 5
- You were alert during the simulation   1 2 3 4 5
- You used the rear view mirror   1 2 3 4 5
- You followed the traffic rules   1 2 3 4 5
- You followed speed limit   1 2 3 4 5
- You liked to break the traffic rules while playing   1 2 3 4 5
- The directions to the next destination were clear   1 2 3 4 5
- It was a challenge to drive in dark environment   1 2 3 4 5
- You felt nauseous while playing   1 2 3 4 5
- You were able to remember few road signs   1 2 3 4 5
- Does this simulator require improvement   1 2 3 4 5
- It was a learning experience   1 2 3 4 5