On Virtual Reality as a Viable Medium for Competency Based Education

by

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Honors Thesis

Appalachian State University

Submitted to the Department of Computer Science

and The Honors College

in partial fulfillment of the requirements for the degree of

Bachelor of Science

May, 2015

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ABSTRACT

On Virtual Reality as a Viable Medium for Competency Based Education.

(May 2015)

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This research investigates the notion of combining emerging Virtual Reality (VR) technology with educational simulations for competency-based learning. This research was carried out through creating a virtual learning simulation that serves to teach a skill, and proposing a study study on college students to see if the particular skill they learned in the simulation can then be performed in real life. More specifically a 3D game world was created using the Unity 3D Game Engine, and the player model was integrated with Oculus Rift DK2 support, and Leap Motion V2 input, to teach college students how to perform a skill in 30 minutes or less (assuming they did not already possess this skill). Many researchers have demonstrated that VR can be used for educational purposes but few strive to actually connect the two on a fundamental level and instead focus on the skill that can be taught. For this reason, this research stands out and fills a gap in the scholarly conversation on VR in the educational realm.

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Chapter 1

Introduction

This undergraduate thesis presents both an overview of Virtual Reality (VR) as an educational tool, and also presents a rudimentary proof of concept for VR as a viable medium for competency based education. Throughout this thesis a discussion of both VR and its applications are presented, with special consideration towards the educational merit of the technology.

Chapter 2 focuses on the historical side of VR, and covers a concise overview of the technology since its conception in the early 1960s up until today. With a massive amount of development within VR in the past three years, Chapter 2 also goes into details about the current VR development trends.

Chapter 3 covers the historical and recent applications of VR for educational purposes. Over the years both the Department of Defense and NASA funded the technology and created a myriad of educational applications which are overviewed. As well, a look into the surgical applications of VR are discussed, as well as the potential STEM applications which are beginning to emerge.

Chapter 4 introduces and discusses at length the TieSim application, which as mentioned is meant to eventually serve as a proof of concept for VR as an educational tool. An overview of TieSim is presented, along with more detailed discussions of both the project's hardware and software. Of course development of TieSim was met with its fair share of obstacles which are examined, and finally the results of the project are outlined.

Chapter 5 outlines the proposed study for TieSim which would accompany a finished version of the simulation once development goals are met. The study itself is relatively simple

and its procedures are listed, along with all of the more minute topics related to performing a study on human subjects such as recruitment, consent, risks, privacy, and data concerns.

Chapter 6 wraps up the research presented in this thesis, and proposes where future work could be focused, as well as summarizing the topics broadly covered throughout this work.

Finally, Appendix A presents the materials submitted to and accepted by the Institutional Review Board (IRB) at Appalachian State University. Since the study was not performed, these documents could be useful for anyone taking this project up in the future who wishes to obtain IRB approval for a similar study. One can use these documents to craft a similar proposal which would have a good chance at being accepted as these were.

Chapter 2

Background

Throughout our society's history, advancements in technology have been a prominent factor that separate generations from those proceeding. Recently, our development and discovery of new and exciting technologies has increased at exponential paces since the invention of the computer. As well, with these new technologies our society has been shifting and developing in many different aspects. One of the more fascinating technologies that have arisen in this period of rapid development is known as VR. This particular technology aims to immerse users further into the conceptual world of computing and serves to trick the user into believing in a virtual world that doesn't really exist. This is most often done through a device known as a Head Mounted Display (HMD). The first HMD was created in the early 1960s, and since then computer scientists have been trying to perfect the technology in order to create fully realistic virtual worlds that instill a perfect sense of presence.

2.1 History of VR

VR is a technology with a particularly interesting past. In many ways VR has gone through waves of popularity in the public sphere, yet ever since its onset it has remained diligently used in certain circles. While we are currently experiencing a surge in VR adoption and advancement, the technology has often gone through periods of very little development since its invention. Furthermore, in different eras VR has been seen in different realms of use, from training to gaming.

Headsight

While a handful of patents existed for HMDs prior to 1960, the first HMD didn't appear until 1961. This HMD was developed by Philco Corporation by Comeau and Bryan, and was aptly named the Headsight [**?**]. This rudimentary HMD used a magnetic tracking system with a single CRT monitor mounted into a bulky helmet, and moreover showed a remote video. In the early days of HMD technology, all HMDs followed the same basic design as the Headsight project, that is they all remotely "streamed" video to the HMDs which merely showed the video projections. Many early HMDs, including Headsight, allowed for head tracking which could remotely move the camera transmitting the video feed, allowing for a user to look around an entire scene. The first major application for Headsight was used by Bell Helicopter Company to provide pilots with an alternate video see-through view [**?**].

Ivan Sutherland

As mentioned, early HMD technology such as the Headsight merely passed video through to a CRT inside a helmet. It wasn't until 1965 that Ivan Sutherland demonstrated the first tethered display system which would allow computer-generated images to be overplayed inside an HMD system. In his case, Sutherland's first project was called "Sword of Damocles", and it featured a set of CRT optical relays for each individual eye, allowing each eye to observe computer generated imagery [**?**]. Moreover, Sutherland's design allowed for these computer generated graphics to be superimposed onto the real environment surrounding the user. As the viewer moved around, the computer imagery would appear stable within the real environment. On the whole, Sutherland was the first to envision what he named the "Ultimate Display". This vision would guide almost all future development in VR, and it laid down three core tenants of VR technology. According to Sutherland, in order for VR to be a successful technology, VR worlds must appear real to any observer, a computer must maintain the world in real time, and manipulation of VR objects must seem realistic [**?**].

1965-1980s

With the tenants established by Sutherland, VR development would continue on a steady pace throughout the rest of the 1960s and well into the 1980s. During this time the primary funders, adopters, and users of VR technology were American military and scientific sponsors. For the most part, the major funders were the NSF, NASA, and the Department of Defense. The technology was mainly used for vehicle simulations, and the technology stayed out of the public eye. NASA would use the technology in their BOOM display to help aid astronauts in future space walks. On the other hand, the military used VR HMDs for training purposes. The technology was appealing to the military because it provided environments to train normally high risk and high stress skills, such as combat and field medicine. VR proved an invaluable tool for the military by allowing training to take place under pressure with no risk in failure. As well, both the military and the NSF used the technology to help with pilot training, allowing for pilots to train without the risk or need of expensive aircraft.

Michael McGreevy

Much like Sutherland in the 1960s, VR would again shift course in the mid 1980s due to the visionary work of one man, Michael McGreevy. McGreevy saw VR in a new light, and for the first time sought to integrate the technology into a growing academic subfield of computer science known as Human Computer Interaction (HCI). This new academic interest in VR fueled future research in the technology, and even today HCI still plays a primary role in VR research. Additionally, McGreevy was the first person to coin the term "Virtual Reality" in 1987, and the term has been in use ever since.

1990s

VR technology largely stayed out of the public eye until the 1990s, when media would aggressively latch onto the technology for better or for worse. In many ways the vast amount of media attention that VR received in the 1990s was related to the onset of video gaming. For example, the popular PC gaming magazine Computer Gaming World predicted that affordable VR HMDs would be widely available for public use in 1994. This unrealistic hype generated huge

Figure 2.1: Oculus Rift DK1 and control unit.

expectations that would be crushed when the public realized the limitations of the technology at the time. Large gaming companies like Sega and Nintendo both attempted to introduce VR onto their gaming platforms, but both failed spectacularly. Soon public interest began to fall, and again the technology returned to the private sphere of military and science uses for the most part.

2.2 Current VR Development

While the technology behind VR has been steadily advancing over the years, it wasn't until 2012 that VR finally began a surge in popularity, adoption, and advancement. Largely due to the work of one company, Oculus VR, and one man, Palmer Luckey, VR has been advancing at unprecedented rates since 2012. The media attachment to VR has returned from the 1990s, but this time the technology is far and above anyone's imagination. For the first time VR has entered into a public spotlight, and at every turn it continues to blow away any and all expectations of what VR is capable of.

Oculus Rift

In 2012, Palmer Luckey had one of the world's largest private collections of HMDs. He was a young man (only 19 at the time) obsessed with a technology that was in every way flawed. However, he was able to look past the flaws and envision a realistic HMD that could be built with technology available at the time, and would be able to provide a VR setting with a level of

Figure 2.2: Oculus Rift DK2 and tracking camera.

presence that had never been seen before. Luckey took his frustrations in the HMDs available at the time, and began building prototypes for a new era of HMDs. His earliest prototypes explored features such as 3D stereoscopy, wireless streaming, large field-of-views (up to 270 degrees), while at the same time cutting down on the bulkiness of the HMD with each iteration. By the time he was on his 6th prototype he thought he had built a proof of concept that would interest a niche market of HMD enthusiasts. Using this prototype he created his own company, Oculus VR, and launched a Kickstarter campaign to raise money in order to build and distribute the HMDs.

Luckey originally thought he would only interest around 100 investors in his Kickstarter campaign, and appropriately set a goal to raise $250,000. However, perhaps through the interest of high profile investors such as John Carmack (id Software), and Gabe Newall (Valve), Luckey found that his Kickstarter goal would be far surpassed. In fact, his Kickstarter would go on to become one of the most overly funded Kickstarter campaigns of all time, as it raised 974% of its original goal, or a total sum of $2.4 million dollars. Due to its Kickstarter, Oculus VR soon became the world's leading developer in VR technologies and has become the face of modern day VR.

As a result of the Kickstarter, Oculus VR used its massive influx of funds to develop its first widely available VR HMD which was sent out to Kickstarter backers and available for sale directly to developers on the Oculus VR website in late 2012. This HMD was known as the Oculus Rift Development Kit 1 (DK1), and emerged as the first ever widely successful

Figure 2.3: Sony Morpheus prototype seen at the 2015 Games Developer Conference.

HMD. The DK1 boasted a 7 inch screen, with a resolution of 1280x800 (16:10), which allowed for a single eye resolution of 640x800. As well, the DK1 also had rudimentary head tracking. Figure 2.1 demonstrates the boxy model of the DK1 and the control unit which was used for input and output to a computer.

Following the success of the DK1, Oculus VR continued to iterate on their success and released their second version of the Oculus Rift in 2014, known as the Oculus Rift Development Kit 2 (DK2). The DK2 featured massive improvements over the DK1, namely a higher resolution of 960x1080 per eye, a higher refresh rate, detachable and more manageable cables, and the omission of an external control box which was key to the functionality of the DK1. Recently, in February of 2015 Oculus VR announced that over 100,000 DK2 units had been shipped [**?**]. Figure 2.2 demonstrates the newer design of the DK2 as well as the tracking camera.

Since the release of the DK2, Oculus VR has released a mobile version of their HMD which runs via Android smart phone integration (Samsung Gear VR). In addition, Oculus VR has publicly stated that no further development kits will be released, and instead their next major HMD release will be a full consumer version. There is no confirmation of a release date as of yet.

Figure 2.4: HTC Vive prototype seen at the 2015 Games Developer Conference.

Sony Morpheus

Oculus VR was of course the first company to truly revolutionize VR tech in today's age, but that is not to say that they are without competitors. Rather, a handful of companies have begun to enter the VR development space and are placing claims on their own HMD technology. One of these companies is the Japanese tech giant Sony, and they have a codenamed HMD known as Project Morpheus in the works. As of the time of writing not much is known about Project Morpheus other than it is an HMD similar to the Oculus Rift that will be fully integrated into PlayStation gaming systems. The HMD is in a prototype stage, however, Sony has been showing the HMD, seen in Figure 2.3, at numerous gaming conventions with promises of a consumer release in the first half of 2016.

As far as the actual technical details are concerned, as of writing the latest known specifications for Project Morpheus are quite impressive. For starters, rather than an LCD screen, Sony has decided to use an OLED screen much like the Oculus Rift does. Unlike the Oculus Rift, the frame rate is a massive 120 frames per second, which could help reduce the risk of nausea associated with immersive VR. As well, the total resolution of Project Morpheus is 1920x1080, or 960x1080 per eye, along with a field of view of 100 degrees [**?**].

HTC Vive

Along with Sony, two other companies are making waves in the VR HMD space. These companies are the cell phone hardware manufacturer HTC, and the gaming power house Valve. Even fewer details are available for their prototype HMD as of writing, however, it has been shown recently at gaming conventions, and a potential consumer release could come as early as holiday 2015. The resolution on the HTC Valve HMD, named the HTC Vive, is slightly better than Project Morpheus at 1080x1200 per eye. However, the refresh rate on the HMD is said to be 90 frames per second, significantly lower than Project Morpheus. Yet, the HTC Vive differentiates itself from the competition by relying on two in room base stations which will allow the HTC Vive to track movement within a 15 feet by 15 feet space [**?**]. Figure 2.4 demonstrates the futuristic look of the HTC Vive, as it features numerous visible IR sensors across the face plate which differentiates itself from the similarly designed DK2.

Chapter 3

VR and Education

With the onset of new HMD technology driven by the Oculus Rift, VR is now expanding rapidly at the hands of brilliant engineers and researchers. This technology has grown so much in the past few years that research is finally beginning to surface regarding applications of VR beyond the stereotypical realm of gaming. Advancements in VR technology have allowed for a myriad of disciplines to integrate the technology into their own practices to create stunning results. In particular, the realm of education has been latching onto the concept of VR as a means for redefining how skills can be taught in the modern world.

3.1 Surgery

From an educational standpoint VR offers a wide variety of opportunities for learning. In particular, one of the largest applicational fields for VR as an educational tool is surgery. In the realm of health sciences, surgery is a very technical outlet that requires precise motor movements in order to be performed successfully. Obviously due to the high risk of failure associated with surgery (the risk of the patients' lives), the practice of surgical training is taken both seriously, and enthusiastically. Research on the topic of improving surgical training and skill is bountiful, and frequently carried out through high budget projects from the National Institute of Health (NIH).

As mentioned in Section 2.1, the 1990s was a decade in which VR technology was first brought to mass media attention. It was noted that most of these technologies were

unrealistic and public attention to the topic began to fade. In the wake of this media fallout VR development and research returned primarily to its historical roots of DoD and NASA funding, with a few exceptions. The largest of these exceptions was the NIH, which began seriously investigating the use of VR as a tool for training surgeons [**?**].

More specifically, the NIH was interested in the effects of VR in conjunction with laparoscopic surgery. As a brief overview, laparoscopic surgery is also commonly referred to as minimally invasive surgery (MIS), and it involves a very technical approach to surgery. Rather than approaching a surgical site directly and possibly involving messy insertions, MIS surgeries take place far from their operation location through small incision points (centimeters in length) elsewhere in the body. From these insertion sites a lengthy fiber optic cable system known as a laparoscope is inserted and directed to the operation site. This approach to surgery is highly preferred when it can be performed, as pain and hemorrhaging are greatly reduced due to the smaller incisions, and moreover recovery time is reduced as well. The actual surgery often takes place with the aid of a video camera attached to the laparoscope, whose output is fed to a monitor for the surgeon to use as their primary sight for the operation.

One can see why the NIH would be interested in improving laparoscopic surgery, and why they would be concerned with providing the best educational training available for laparoscopic surgeons. In this particular case, the NIH performed a lengthly series of research studies on using VR specifically to train laparoscopic surgeons, and moreover to determine if training through VR was effective [**?**].

The NIH first began this research in 1998 when they developed a system called MIST VR. MIST VR was a unique VR simulation made to model the movements needed to perform MIS, and it could also judge and score a user's particular skill in performing the surgery. The scoring system embedded in MIST VR was groundbreaking for numerous reasons, but mostly because before this there was no way to quantify a particular laparoscopic surgeons "skill". With MIST VR, the NIH found that the most experienced laparoscopic surgeons scored the highest, and correspondingly surgeons with less experience scored lower on a geometric progression. More interestingly, though, the NIH found that surgeons who trained with MIST VR became more efficient and saw a reduction in errors while performing roughly at the same speed. Thus, the NIH found that through VR they were able to assess a particular surgeon's skill level, and

also found a significant beneficial effect of training within VR compared to traditional methods [**?**].

Ever since the preliminary work done with VR as a tool for health training by the NIH in 1998, the NIH has continued similar research. However, with the advent of recent VR advancements, a myriad of new research projects using VR for health applications are starting to emerge. For example, a surgical training program in France has begun research into using VR to help assist in surgical training for open surgeries, rather than solely laparoscopic surgeries. This group is attempting to address a common problem in surgical training, which revolves around young surgeons not getting the most out of observational surgeries. Essentially, when a surgeon is in their early training they often stand in the operation room with an experienced surgeon and observe the experienced surgeon perform a full surgery. The surgeon in training, however, must remain out of the way for obvious safety concerns, and are forced to look over a crowded scene and try to make sense of what they are seeing.

There is room for advancement in this area, and a group in France is attempting to solve this common problem through VR. What they have done is quite fascinating: by taking two head mounted cameras and positioning them such that they mimic human eye placements, they can record an entire surgery and then later alter the video feeds such that they can be observed through a VR HMD. A user can then watch the entire video feed as if they are seeing the recorded footage through their own eyes, and can even hear after edited audio layered onto the scene. This means that these surgeons in training can now observe an entire surgery from the view point of the lead surgeon like never before, and more importantly they can listen to the lead surgeon as he explains his every move. Figure 3.1 demonstrates the camera rig used by the lead surgeon in action.

Clearly these studies show that VR can be used in a professional setting such as surgical training. More importantly, these studies show that VR can be used to teach incredibly necessary skills for these professions, and in certain circumstances VR is a better way to learn these skills rather than otherwise. Finally, in further research done by the NIH it was concluded that VR when used for proficiency-based training is presenting itself as a paradigm shift in surgical skills training [**?**].

Figure 3.1: Lead surgeon wearing VR camera rig.

3.2 Military Training

As was mentioned in chapter 2, one of the largest funders and adopters of VR technology for educational purposes has always been the United States' Department of Defense. The technology makes obvious sense for military training purposes, as it allows personnel to train for potentially hostile environments that are difficult to recreate in person. By using VR, the military can carry out combat training with absolutely no risk of failure, and can even use VR to help expose these soldiers to potentially life threatening situations in a completely controlled environment.

The military has been using VR since its early days in the 1960s, and has found the technology paramount for training simulations. Besides solely combat training, the military has used VR enthusiastically for training pilots. This is a natural usage extension from combat training, as VR can be used to create realistic flight simulations in which pilots in training can be exposed to a lifelike simulation with no risk of failure. In this case, VR is exceptionally useful, as failure in a real test case could potentially mean both loss of life and loss of expensive aircraft. Currently, VR pilot simulations are used in conjunction with extensive Augmented Reality (AR) controllers meant to closely mimic the actual instrumentation used by pilots. Because of this, the VR simulation is an even more effective training simulation, as the pilot in training is immersed not just visually but also in a tactile manner, increasing the sense of presence, and thus the effectiveness.

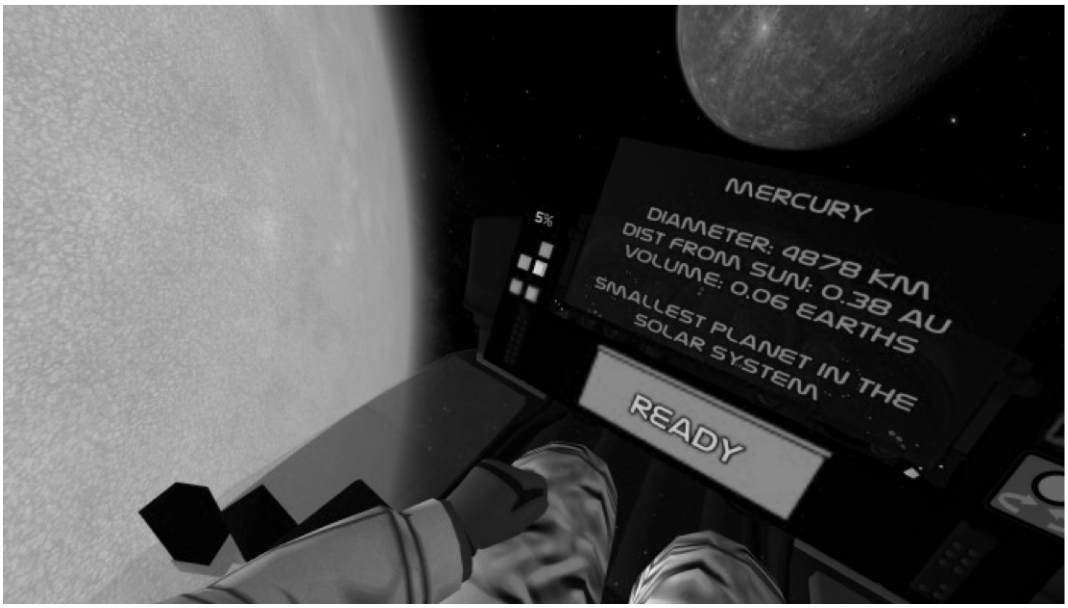

Figure 3.2: Screenshot of Titans of Space.

3.3 Stem

With the recent advancements in VR technology, the landscape of VR research and applications is quickly changing. For the first time, affordable and powerful HMDs are available to the public and the resulting applications that have been built using the technology have been increasingly impressive. While a great many of these applications are simply video games, quite a few are educational in nature.

A great example of a popular free application for the Oculus Rift is the extraordinary free application *Titans of Space*. In this application the player assumes the role of an astronaut in a spaceship which tours our solar system and gives an educational guide to the surrounding planets and stars. The simulation excels by providing a realistic scale to the astral bodies, which helps the player realize through their own sight just how big these astral bodies are, especially compared to each other. As seen in Figure 3.2, while the player is touring our solar system, the only prominent part of their spaceship in view is a display which lists educational facts and a brief synopsis of each solar body.

Clearly this application is an example of a STEM based VR application, and games like these can be used to inspire creative thinking [**?**]. Applications such as this one could be used

to re-interest students in STEM fields through new integration with exciting technology which increases student motivation to learn. As time progresses and HMD technology continues to develop, the number of educational simulations such as this will continue to grow, and if used appropriately in the classroom could be an exciting way to approach a topic.

Chapter 4

TieSim

Clearly VR is an advanced technology, and every day more and more applications are being developed targeting it as a platform. Yet, the majority of these applications are inherently video games built and targeted for entertainment. Of course this is to be assumed, since Oculus VR said themselves on their original Kickstarter that they wanted to build the first immersive VR headset for video games. Since the release of the DK1, and well into the life cycle of the DK2, the vast majority of applications built for these HMDs have been video games. In the end, video games are driving core development and adoption of VR, but there still must exist a space for educational applications.

For this reason, part of this research consisted of delving into the development process of building an immersive VR application for educational purposes. More specifically, a program called TieSim was built which aimed to create a learning environment where a user could interact with a stationary robot, and learn how to tie a men's neck tie on said robot. The reason this task was chosen was because learning to tie a necktie is a simple task which can be taught in 30 minutes or less. Moreover, TieSim's overall goal is to link the concepts of competency based learning with a VR application. Additionally, Chapter 5 explores the idea and realization of a proposed study in which a completed version of TieSim could be used on human test subjects to see if the skill was taught effectively and successfully. The rest of this chapter explores the technical details behind TieSim, including the hardware and software choices. As well, this chapter explores the hardware choice which ultimately hindered the advancement of development, and what a future student might be able to work on to get TieSim fully functional.

4.1 Project Overview

The concept behind TieSim is simple, TieSim is an immersive VR simulation which places the user in front of a stationary figure so that the user can learn to tie a necktie onto the figure. Teaching can be accomplished in a variety of ways, many of which can be intertwined. The methods currently in place in the simulation involve a massive monitor-like wall that sits in the user's foreground. On this wall a series of large picture and text based instructions guide the user through a series of nine simple steps in learning how to tie a half-Windsor knot.

Another technique which could be employed would be to hire a voice actor who could give professional quality voice instructions to accompany the visuals. For the purposes of early TieSim development, a voice actor was not employed primarily due to lack of funds, but one could be hired relatively cheaply on a site such as fiver where users offer on demand freelance skill work.

The setting of the simulation takes place in a vastly open room with no walls or ceiling in sight, Figure 4.1 demonstrates the opening scene with the user's hands out in front of them. The floor consists of a tiled pattern which extends past the field of vision. The user is placed in the seemingly center of the room, where they are found sitting at an empty desk. As mentioned, in the user's foreground is the instruction monitor, which at first prompts the user with a description of their scenario. Finally, sitting on top of the desk is a robot named Kyle who sits wearing a men's necktie. The user will learn to tie the necktie onto Kyle.

The overall development production for TieSim reached near completion throughout the work done during this research, however, due to a hardware limitation it was not completed in full. More details can be found in the following section on Hardware.

4.2 Hardware

A discussion on TieSim's hardware must, of course, start with the HMD. At the beginning of development, the most recent HMD available on the market was the Oculus Rift DK2, and as such it was used for this project. For a more in depth discussion on the DK2 hardware specifications see Chapter 2.2: Current VR Development.

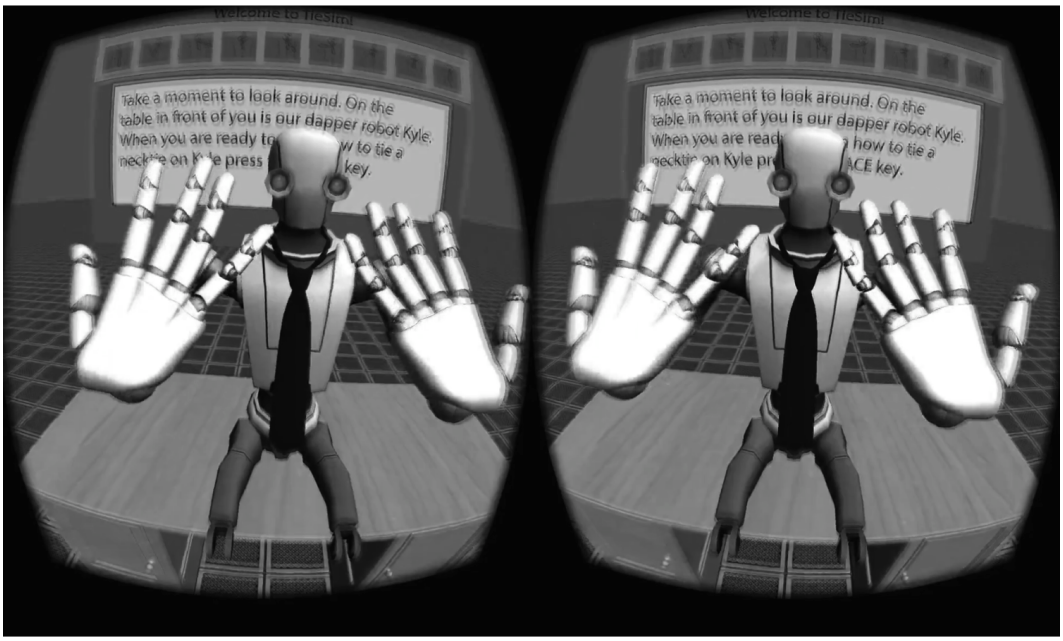

Figure 4.1: Screenshot of TieSim running with the user's hands in scene.

Besides the VR hardware, another piece of hardware known as the Leap Motion V2 was used significantly throughout development. The Leap Motion serves as an alternate input device from a mouse and keyboard, and is technically a piece of AR hardware. Essentially, the Leap Motion is a small USB device which uses two monochromatic IR cameras and three infrared LEDs to observe a hemispherical area up to a meter above the device. In this observation area the device is used to track hand and tool movements which can then be accurately modeled in a variety of development environments. Normally the Leap Motion functions by lying face up on a desktop surface; however, for the purposes of this product the Leap Motion was mounted onto the DK2 facing outwards. Further, when mounted onto the DK2 the field of views (FOVs) of both devices collide nicely, as seen in Figure 4.2, and allow both to work together without any gaps in FOV.

For this project the most obvious use of the Leap Motion in conjunction with the DK2 would be to use the device for primary input in the simulation. The Leap motion provides a more natural method of input, especially when considering the task at hand. Further, using an AR input device like the Leap Motion greatly increases the sense of presence a user experiences in VR. This proved to be the case from the author's anecdotal evidence in which having a

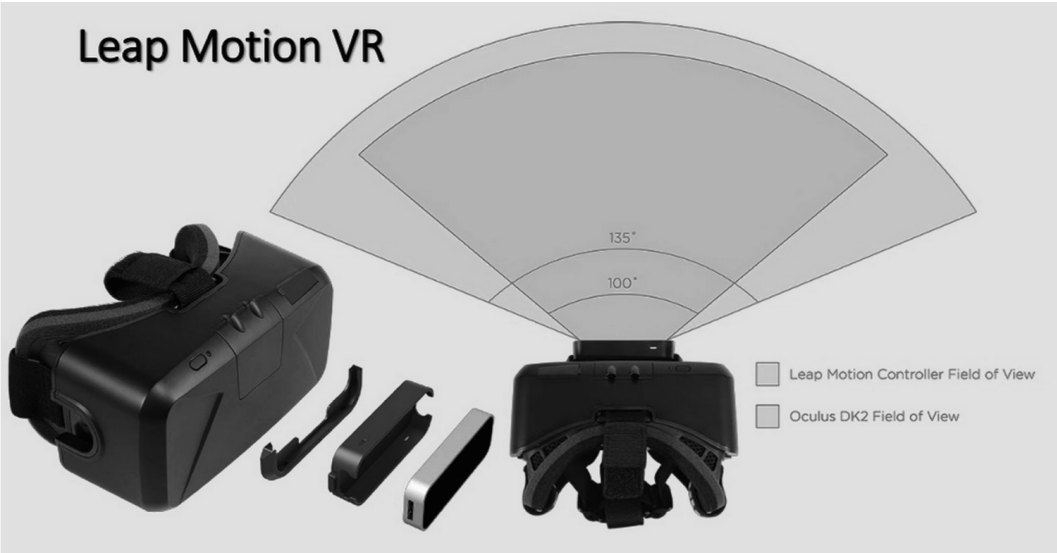

Figure 4.2: Visual reference of the Leap Motions and DK2's colliding FOVs.

model mapped to one's actual hand movements in VR space tended to help ease the transition into VR and reduce the disconnect experienced with the emerging technology. Ultimately, the Leap Motion was a natural choice for this project. However, its choice was perhaps what ended up being the largest setback of the entire development progress (see section 4.4: Development Obstacles).

4.3 Software

When working with VR there are only a few choices for software suites to work in. For starters, every major software suite available is first and foremost a game development engine, and of these suites there are two major choices, each with their own advantages and disadvantages. The first engine available is the newly open-sourced Unreal Engine 4 with built in Oculus Rift support. At the beginning of this project, however, Unreal Engine 4 was not available for free. It would have been considered except for its cost. Unreal Engine's biggest draw is that it is a AAA-quality engine capable of producing stunning applications with top-of-the-line graphics and systems. Of course, these great features come with an immense learning curve.

The other game engine option to consider for VR development is Unity3D. This is the engine with which TieSim was created, partially because it is the engine the author is most

familiar with, and also for other key advantages the engine has over Unreal. For starters, Unity3D has less of a learning curve, and it is incredibly easy to get working quickly within its simple workspace. As well, Unity3D offers drag and drop Oculus Rift support, and it tends to be the go-to engine for VR development. Normally the largest downside to using Unity3D is its hefty license fee; however, this project qualified for an educational license which is far more reasonably priced. More discussion will follow on working with Unity3D as it was the suite chosen for this project, yet it should be noted that although Unreal Engine was not chosen for this project, it is an equally viable engine to use for VR development.

Overall working within Unity3D is perhaps its largest draw because it is undeniably simple as seen in Figure 4.3. Beyond this aspect, Unity3D offers a variety of scripting languages to work with, namely Javascript, C#, and Boo Script. For TieSim, C# was chosen as the scripting language because of its robustness over the other two choices available, and the author's familiarity with the language. As well, both Leap Motion and Oculus Rift allow scripts to access their device APIs, and allow for customizable behavior inside simulations. For Leap Motion a variety of languages can be used, namely Javascript and C#, and for Oculus Rift C# is the primarily used language support. Thus C# was a fitting language to use as it allowed communication inside Unity3D with both the Oculus Rift and Leap Motion, and moreover overall scene interaction.

An additional software suite was used for the purposes of 3D modeling the tie model used in the simulation. The 3D modeling program Blender was used, as it is an open source suite with ample documentation.

Finally, TieSim is first and foremost an open source project under the MIT educational license. All of the source code for the project is available through Git and hosted via GitHub under the author's account at the following URL: https://github.com/cleebp/TieSim. As well, all of the most up to date code as of writing has been included at the end of this work on a DVD. The purpose of making this project open source was primarily because the author recognizes that many improvements can be made to this application (see section 4.5 Results and Conclusions), and by making TieSim open source, anyone in the world can contribute to the development of the project as a public good.

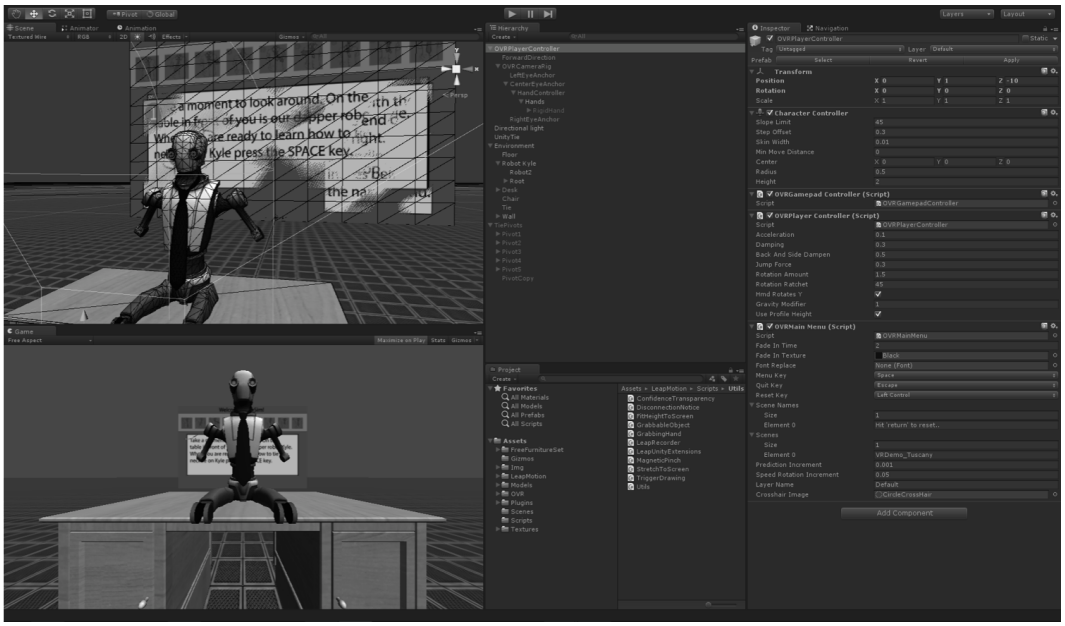

Figure 4.3: Screenshot of TieSim's Unity3D development environment.

4.4 Development Obstacles

Like all ambitious software projects, development of TieSim was met with its fair share of obstacles. For starters, before working on TieSim the author had little to no experience working with Oculus Rift development, and had never worked with Leap Motion hardware. As such, development was as much a learning experience as it was actual progress. This being said, development did progress fairly competently with the help of online resources, and some of the more outstanding obstacles have been listed below. Yet, by far the largest obstacle encountered in development of TieSim was ultimately working with the Leap Motion hardware.

To begin with, online resources for working with Leap Motion could be best described as scarce. Even the official documentation for the hardware's API is lackluster, seemingly because a major API rewrite occurred between the release of the V1 hardware and the V2 hardware. Much of the original API still remains in use, and these documents are fairly well documented, yet almost all of the now existing API used by the V2 is completely undocumented. This disconnect becomes even more apparent when following the tutorials supplied on the Leap Motion website, which all use the original API and as such don't work within the existing hardware and firmware. For these reasons, working with Leap Motion was an incredible pain,

and most internet searches for specific problems met with little to no results.

Additionally, Leap Motion ended up crippling development progression due to its lack of proper integration with Unity3D objects. As mentioned in Section 4.3, the 3D modeling program Blender was used to model a simple tie to be used as the core interaction object for TieSim. Needless to say, interaction with this object was critical for development progression, yet it was impossible to interact with this custom modeled object using the Leap Motion as input. The bulk of development time was spent trying any possible solution to this problem, however, it became clear that Leap Motion would halt all further development of TieSim (see section 4.5: Results and Conclusions).

4.5 Results and Conclusions

Ultimately, TieSim's development was completely sidetracked due to the limitations of the Leap Motion hardware (see section 4.4: Development Obstacles), and as such TieSim is currently in an unfinished state. That being said, it should be noted that the basic systems necessary for a fully functional TieSim have been developed and are integrated into the application. While there currently is no way to use input to interact with the 3D modeled tie, the majority of the simulation's scene has been built and is convincingly real. As TieSim currently stands, anyone with a DK2 can run the simulation's executable and will be thrown into the scene (see section 4.1: Project Overview).

Further development of this simulation is obviously a must, and the most direct way to pursue future development would begin with finding an alternative to using the Leap Motion for input. One could revert to using a standard gaming controller or mouse and keyboard layout; however, there are a myriad of new and exciting AR input devices constantly under new development. Migration to a different AR device that supports more minute interaction with objects in Unity3D is critical. Once a new input hardware has been chosen it should be able to be easily integrated into the existing project space. Since the systems for the sequential instructions are in place, development would need to focus on how to integrate with maneuvering the tie in order to trigger events which would advance instruction and alert the user.

These are not small development goals, and would take a significant amount of time. As well, although not essential, prior experience working with these technologies would be a bonus. With the project being completely open source, it is possible someone would take up these development goals, or alternatively a future honors student at Appalachian State could focus their own thesis work on continuing the development of TieSim.

Chapter 5

Proposed Study

In the original scope of this research a study was proposed which would effectively aim to prove whether or not the TieSim application is an effective teaching tool. As the research progressed, however, it became clear that the development of TieSim would take far too long to allow for an in depth study to take place. For this reason, the current chapter has been included to outline a proposed study to accompany this research in the future. All of the included materials were submitted to, and approved by Appalachian State's IRB for Spring 2015. As such, the proposed study can be carried out exactly as outlined, and one should expect a quick approval again from IRB in the future.

5.1 Procedures

The overall structure of this study is quite simple. Participants will be gathered individually by the PI in a controlled environment. For the purposes of the initial IRB submission the location was defined as a private study room in the Belk Library, though any secure office setting would work fine. Inside the study location will be a table with a mannequin and a couple of men's neckties, as well as a computer and the Oculus Rift DK2 headset with mounted Leap Motion V2 unit. The computer will serve two purposes, the first of which is to run the actual TieSim application, and the second is to securely record the participant's data (see section 5.5: Privacy). Each participant would be expected to commit an average forty minutes of their time to the study.

Upon the participant's arrival at the study location, they will be walked through the consent forms (see section 5.3: Consent), and will then be introduced to the study itself. Following this they will be shown how to wear the Oculus Rift DK2, and will then be immersed in the TieSim application. The simulation will take no more than 30 minutes, and will teach the participants how to tie a men's necktie in virtual reality. Participants will only have to sit and look around while using their hands as primary input to control the simulation. After the simulation is complete participants will remove the headset and will then be re-oriented into real life.

Following the simulation, participants will be given a real necktie and be asked to tie it on the aforementioned mannequin. Their success or failure will be recorded (see section 5.6: Data), along with how long it took them to achieve success or give up. Additional follow up questions will be asked to further identify the participant's experience with the application, and finally the study will be concluded. After all of the study's procedures have been completed, participants will have their name entered into a prize raffle to win a $50 Amazon Gift Card.

5.2 Recruitment

The ideal number of participants sought for this study should be in the range of 150 participants. Of course, it can often be difficult to find such a large number of volunteer participants in a short time, and thus in the original documents submitted for IRB approval, only 30 participants were specified. The targeted participant population is defined as college students (only eighteen or older). The targeted population is an appropriate group to bear the burdens of this research, and they are also a subset of the population most likely to receive the benefits of this research. The targeted participant population must also not already possess the skill the study aims to teach, and additionally if one gets motion sick easily they will be discouraged from participating (see section 5.4: Risks and Benefits).

Students will be recruited through an email containing the materials found in Appendix A.1. This email will be sent to as many departments as possible, and will also be printed out as a flyer and attached to departmental bulletin boards throughout campus. Participants will be encouraged to volunteer as they will be entered into a fair raffle drawing for a $50 Amazon

Gift Card for completing the simulation and answering the follow-up questions (see section 5.1: Procedures).

5.3 Consent

As discussed earlier participants will be given a consent form upon their arrival to the study. A copy of this form can be found in Appendix A.2. Each participant will be walked through the entire form by the present researcher before participating in the study. At any point before, during, or after this step of the study, if participants want to ask questions or are unsure of the study's procedures, they will be encouraged to ask about the process. After being walked through the consent form, participants will need to sign the form in order to begin participating in the study, though there are no known factors that might interfere with informed consent.

5.4 Risks and Benefits

As part of the official IRB approval from Appalachian State, this study was determined to involve minimal risk to participants. However, even though this study received such a classification it should be noted that there do exist some potential risks for this study (albeit minimal ones). The primary source of potential risk lies with the known side effect of motion sickness that can occur while immersed in VR. This side effect almost always occurs when the person being immersed in VR has a tendency to get motion sick easily from other sources (i.e. roller coasters, ski lifts, or motor vehicles). If a participant gets motion sick easily, it is entirely possible that they could feel lightheaded and dizzy as a result of the TieSim application. In such a case the participant should immediately take off the headset and be excused from the study to protect their health. Due to the health risks involved with VR, it is standard procedure to include a health warning at the beginning of all applications, and TieSim is no exception as seen in Figure 5.1.

It is of critical importance, that if a participant were to feel motion sick during the simulation, that the above measures be taken immediately. Furthermore, their data should not be kept as it is incomplete and does not help better the study. Only the researcher present will have knowledge of any identifying characteristics after the data is removed from the computer.

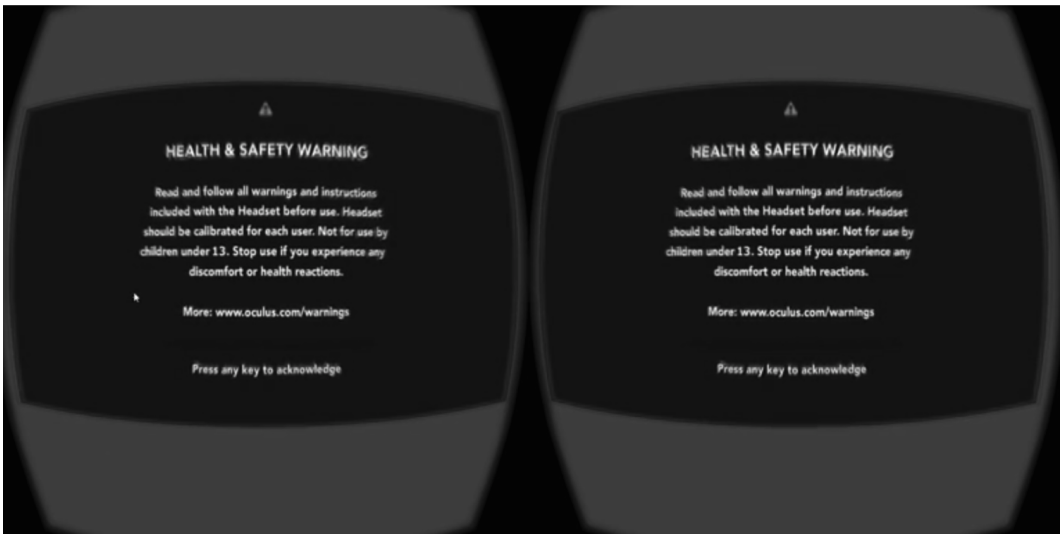

Figure 5.1: Screenshot of TieSim's health warning at launch.

The potential benefits of the study should be quite clear: as a result of the study participants will possibly have gained the ability to tie a men's necktie. As well, society may benefit from the study in that this research uniquely applies cutting edge virtual technology to an educational simulation. Depending on what the results of the study dictate, this research could go a long way to rationalize this new technology as a valid educational tool.

5.5 Privacy

The privacy of each participant is of utmost importance throughout the study, and it can't be stressed enough how important it is to keep the individual participant's data and identity secure. Only the principle researcher can be present at the time of the study, and all data must be recorded on a single computer behind the principle researcher's login and password. Additionally, the data recorded during the study (see section 5.6: Data), must be stored in an encrypted excel .CSV file. The only data kept will be non-identifying demographic information (i.e. age, sex, major), and the results of the study along with the follow-up questions. The data kept in the excel file will be entered into randomized rows, to ensure that the row value does not correlate to the participant's number (which will not be kept).

5.6 Data

After completing the simulation portion of the study, participants will be expected to attempt to replicate the skill taught in VR, and will then be asked a series of follow up questions. These questions can be found in Appendix A.3 and focus on a range of metrics. The most simple items recorded will be metrics such as how long it took them to tie the tie, how long they spent in VR, and simple demographics information. As well, participants will be asked to answer a handful of opinion questions regarding their experience in the VR simulation, and how effective they perceived the technology to be. These questions will be answered on a scale from 1-5, where 1 correlates with strongly disagree, 2 with disagree, 3 with undecided, 4 with agree, and 5 with strongly agree.

Chapter 6

Conclusion

Fundamentally, VR is an immersive technology which has yet to see a full proper consumer release. Before 2012, the majority of our society's interaction with VR was through often unrealistic glimpses at a futuristic technology that ultimately materialized in unfulfilling devices. Despite these setbacks VR has flourished throughout its history, and in the right settings it has proven to be a valuable and effective technology. Beyond the novelty of the technology, VR found a unique application in educational training simulations wherein the technology shined as both an effective and efficient tool.

Currently we are experiencing an unprecedented moment in the history of VR development. Because of the dreams of one 19 year old geek from California, VR is now undergoing a renaissance of development, and there are now three major companies vying for a successful consumer product. Only time will tell which of these companies will stand the test of time, or whether they can exist harmoniously in the same product space. However, there is no doubt that VR will be the technology of our near and real future. In this future the technology will focus on the stereotypical usage case of video games; but, as was seen in the history of VR, educational outlets will arise. Projects like TieSim will ultimately pave the way for others to expound upon the concept of VR as a viable medium for competency based learning, and in a reality with multiple consumer HMDs, competition will drive these applications to break surpass all expectations.

6.1 Future Work

This thesis ultimate lays the groundwork for development of an educational VR simulation, TieSim, which can be used as a proof of concept for VR as a viable medium for competency based learning. Research has previously proven VR to be specifically applicable and effective towards certain skills, such as surgery (see section 3.1: Surgery). However, there is a lack of scholarly research on proving VR is applicable towards skills based learning in general. TieSim in its current state does not prove this notion, however, it does present the building blocks to do so. As an undergraduate thesis it is ambitious work that was ultimately halted due to a key hardware setback.

The most obvious course for future work would be to take out the integration of the Leap Motion hardware which is currently halting future TieSim development (see section 4.5: Results and Conclusions). Once this hardware has been replaced it is not outside the scope of an additional undergraduate thesis to bring functionality of TieSim up to its original scope. Once development reaches this point, the simulation can finally be used as a proof of concept through a proposed study (see section 5.1: Procedures).

Appendices

Appendix A

IRB Materials

This appendix serves to aid future work on this research by providing the materials necessary to apply and receive IRB approval for the study discussed in Chapter 5: Proposed Study. Materials cannot be submitted exactly as follows, as namely the principle researcher and other researchers associated with the materials will have changed. Additionally, details regarding the study may change and as such should be reflected in any future edits to these materials. This being said, if the majority of the content submitted follows the guidelines demonstrated by these materials, one will almost certainly receive IRB approval.

The first section of this appendix covers participant recruitment, and is a copy of an example email which would be sent to seek participants for the proposed study. More information can be found in section 5.2: Recruitment.

The second section of this appendix covers participant consent, and is a copy of the consent form which would have been used to gather participant consent prior to participating in this proposed study. More information can be found in section 5.3: Consent.

Finally, the third section of this appendix covers follow up questions which would be asked after a participant finishes the training simulation. The form included is a rough draft and could easily be expanded to gather more data on the participant's experience. More information can be found in section 5.6: Data.

A.1 Participants Recruitment

SUBJECT: Virtual Reality study participants needed, $50 Amazon Gift Card drawing!

BODY:

Participants needed to study the effects of virtual reality on competency-based learning.

Your participation will require a 30-minute session of immersion in a virtual reality simulation with an Oculus Rift DK2 in a library study room to be determined. You will get to experience a convincing virtual reality simulation, which will aim to teach you how to tie a men's necktie through game mechanics. At the end of the simulation a real tie will be provided and a test will be performed to see if you retained the skill taught in virtual reality.

We are looking for any college student between the ages of 18-35 whom:

Does not already know how to tie a men's necktie
Does not get motion sick easily
Are comfortable with wearing a headset for 30 minutes

All participants will be entered into a raffle to win a $50 Amazon Gift Card.

Contact Brian Clee at cleebp@appstate.edu with "VR Study" in the subject line for more information!

A.2 Consent Form

Consent Form for Participation in a Research Study
Appalachian State University

An In Depth Study on Virtual Reality as a Viable Medium for Competency Based Learning

Description of the research and your participation

You are invited to participate in a research study conducted by Brian Clee. The purpose of this research is to investigate the effectiveness of Virtual Reality as an effective teaching tool.

Your participation will involve wearing an Oculus Rift DK2 for at most 30 minutes to learn how to tie a men's necktie. At the end of the simulation the headset will be removed and a real tie presented to see if the skill can be replicated in real life. The total time expected for the study is 40 minutes.

Risks and discomforts

There are certain risks or discomforts associated with this research. They include potential motion sickness associated with immersion in Virtual Reality, though if you are someone who does not get motion sick easily this should not be a problem.

Potential benefits

As a result of this study it is entirely possible you will gain the ability to tie a men's necktie. This research may help us to better understand the potential educational applications of Virtual Reality.

Protection of confidentiality

We will do everything we can to protect your privacy and will only record necessary results from your participation along with minor demographic information (age, sex, and major of study). Your identity will not be revealed in any publication resulting from this study.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

Contact information

If you have any questions or concerns about this study, or if any problems arise, please contact Brian Clee at cleebp@appstate.edu. Additionally you can contact the faculty advisor for this study, Dr. Dee Parks, at parksda@appstate.edu. If you have any questions or concerns about your rights as a research participant, please contact the Appalachian State University Institutional Review Board at 828-262-2692.

Compensation

For participating in this study all participants will have their names entered into a raffle to win a $50 Amazon Gift Card. The drawing will take place after all participants' data has been recorded and at such a time the winner will be contacted.

Age Requirement

All participants must be at least 18 years of age and must present proof of age in order to participate in the study, and be considered for compensation.

Consent

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant's signature_____ Date:_____

A copy of this consent form should be given to you.

This research project has been approved on 2/19/2015 by the Institutional Review Board (IRB) at Appalachian State University. This approval will expire on 2/18/2016 unless the IRB renews the approval of this research.

A.3 Follow Up Questions

VR Study follow-up questions, circle answers where applicable.

1. Did the participant successfully finish the simulation (yes / no)?

1b. Total time spent in simulation: _____

1c. If not, please describe what prevented participant from finishing the sim:
_____
_____

2. Was the participant able to tie the necktie in real life (yes / no)?

2b. Total time spent tying tie: _____

2c. If failed, what stage did they fail in? _____

2d. If failed, describe what difficulty the participant had:
_____
_____

3. How old is the participant? _____.

4. What is gender would the participant describe themselves as? _____ or prefer not to answer.

5. What is the participant's major or majors of study? _____

For the following statements answer on a scale from 1 – 5, where 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree.

6. VR was a helpful learning experience (1 2 3 4 5).

7. I felt comfortable in the VR simulation (1 2 3 4 5).

8. I am optimistic for the future of VR and education (1 2 3 4 5).

9. The simulation was an effective educational tool (1 2 3 4 5).

10. I would try VR simulations again if given the chance (1 2 3 4 5).

11. Overall, I was impressed by the technology (1 2 3 4 5).

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ACKNOWLEDGEMENTS

In the end this thesis would not exist if it were not for the encouragement and support from a handful of wonderful people. My thesis director, Dee Parks, believed in me throughout my undergraduate career and without her support I would not be in the position I am today. Both as an advisor, a professor, and a friend Dr. Parks is a one of a kind teacher and mentor that any student would be blessed to have. Additionally, I can't forget to thank my parents who encouraged me throughout my educational career, and have always believed in whatever crazy direction I lead my life. And finally, my best friend, and girlfriend, Danielle Russell, who never ceases to inspire me and make me a better person. Thank you all so very much.