MANIPULATION OF THREE-DIMENSIONAL SCENES AND ANIMATION USING IMMERSIVE TECHNOLOGY

by

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To my loving and supportive family who have always been there through the best and the worst.

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I give my thanks to my committee members and my thesis chair for their guidance and patience through this project.

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ABBREVIATIONS AND DEFINITIONS

3D – Three Dimensional

CGT – Computer Graphics Technology

HMD – Head Mounted Display

LED – Light Emitting Diode

OSVR HDK2 – Open Source Virtual Reality Hacker Development Kit 2 (xinreality.com, n.d.)

UI – User Interface

VR - Virtual Reality

IEEE - Institute of Electrical and Electronics Engineers

ACM – Association for Computing Machinery

Uncanny Valley - "Used in reference to the phenomenon whereby a computer-generated figure or humanoid robot bearing a near-identical resemblance to a human being arouses a sense of unease or revulsion in the person viewing it." (Oxford Dictionary, 2018)

Animation tools – Tools that allow for the manipulation of a 3D scene and "allows for the creation of motion on a frame-by-frame basis." (Glaag, n.d)

ABSTRACT

In animated film production, a great bulk of work goes into animating and scene layout. Currently, the industry is centered around flat screens and keyboard and mouse interfaces, which require a substantial amount of time to lay out scene sets and animate shots, resulting in high production costs and lengthy production schedules. This study was designed to determine whether immersive VR interfaces could reduce the time taken to lay out 3D scene sets and animate those scenes compared to traditional interfaces. More specifically, this study compared the time 38 participants took to set up and animate a 3D scene by using two different interfaces, e.g. a VR immersive interface and a traditional mouse and keyboard interface. Further, the study investigated subjects' interface preference. Findings show that the virtual reality interface was about twice as fast for laying out the scene as the traditional interface. When surveyed, participants preferred the virtual reality interface by a large margin over the provided traditional interface.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Animations and scene set up can take “months of multiple man hours” (Harmon, 2006). For example, it took 5.7 million man hours or 654 man years in total to complete Pixar’s Wall-E’s production, and Kung Fu Panda took 4.1 million man hours or 472 man years (“10 Blockbuster 3D Animated Films: Man Hours, Budget, Popularity,” 2008). In the current industry environment, computer graphics work for visual effects, 3D film creation, or animated portions can add chronological years and millions of dollars of cost to a project, averaging $50,000 of cost to each shot (Wright, n.d.).

The technologists responsible for creating the scenes require highly specialized training, in many cases beyond the education received in a university or technical program. In addition, retraining of personnel hired from other organizations who may have performed similar work can require significant investments leading to delays in productivity and increased costs. In the case of newly hired technologists directly from trade programs or university degrees, the training time and adjustment similarly lead to delays in income-generating activities. Many of the major animation studios producing animated films today use their own proprietary software, requiring a need for retraining beyond college. For instance, DreamWorks uses the proprietary software Premo (Bishop, 2014), and Pixar Studios made their own software called MenV (also known as Marionette), which was replaced by Presto (Paik & Iwerks, 2007), and Industrial Lights and Magic uses in-house package Zeno (Failes, 2014). With all the different software interfaces available and being created in this fast-moving industry, there is a need for a generalized interface for animators, inexperienced and experienced alike, that can be learned and used with ease with minimal amount of training.

A possible solution to this problem is virtual reality. As an example, in the gaming industry, with the assistance of an application like Google Blocks, a VR application that creates scene assets using primitive blocks, a game developer was able to create the assets and develop a short game in the span of two weeks (Hamilton, 2017), as opposed to months or longer.

There are currently no VR applications designed for production or professional animation. This is due to the extreme newness of the field. ACM SIGGRAPH held, for the first time, a presentation about a programming system for animation and VR in August of 2018 (Seyb, Grajetzki, Chin, & Wilkinson, 2018). Facebook released a technology demonstration for their Oculus Rift ("Quill," n.d.) which was-- by their own admission-- not close to a completely usable application and was not designed for production animation, and was released as a beta to the public in late 2016 (Oculus, 2016) originally as a VR painting program (Moon, 2016), receiving little to no fanfare. It mainly received coverage from small technology blogs (Amidi, 2018; Lang, 2016) and basic animation functionality, such as frame by frame editing, was not added until February of 2018 (Amidi, 2018). The initial version of Quill was designed only to give a person the ability to draw a specific project, and was not designed at the time as an animation package but as a painting package with some support for animation (Moon, 2016), much in the way that Adobe Photoshop can also be used to create animation.

Decreasing the time taken for animation creation and minimizing the time necessary to train employees on software interfaces can save money, improve the pipeline, and improve overall workflow. It is this study's hypothesis that with the use of immersive interfaces, animation production can become faster and more intuitive.

1.2 Research Question

Are immersive interfaces, utilizing current commercially available headset display technologies, faster and more intuitive for building 3D virtual scenes than traditional keyboard and mouse interfaces?

1.3 Hypothesis

H_{10} – There is no significant difference in the time taken to build the 3D scene between the compared interfaces.

H_{11} – There is a significant difference in the time taken to build the 3D scene between the compared interfaces. It takes less time to build the 3D scene with the immersive interface than with the traditional interface

H_{20} – There are no significant differences in reported preferences between the traditional and immersive interface.

H_{21} – There are significant differences in reported preferences between the traditional and immersive interface. Participants prefer the immersive interface.

1.4 Significance

The major consideration guiding this study is that if the technologist's pipeline could be made more efficient and intuitive, then the amount of time that the technologist spends on a task could be reduced. A reduction in time spent on any given activity should result in increased productivity and lower overall project costs. In addition, intuitive immersive interfaces should decrease training costs significantly, allowing for an organization to get employees into productive and meaningful activity significantly sooner than with traditional mouse and keyboard interfaces.

1.5 Statement of Purpose

The creation of a professional 3D movie scene is a complicated process needing the efforts of many people, even if the scene has low complexity, such as one with only a few props in the set and a single character. Even when reduced to just the operations consisting of creating the scenes using current animation software, the workflow for 3D animation is overly tedious, time consuming, and costly.

This study compared an immersive interface that would presumably allow for a more intuitive, and more efficient workflow than the current methods. It was hypothesized that animation and scene layout done in an immersive paradigm would be found to allow the animator to create scenes and position scene assets in a more intuitive way.

1.6 Assumptions

- It was presumed that the participants that would be recruited for this project would have had training in animation techniques and scene layout.

- That a degree of VR sickness would not be incurred that may adversely affect the time and efficiency.
- Participants could use computers.
- Participants would be over the age of 17 years of age.
- Participants would be unbiased towards either method of animation interfacing.

1.7 Limitations

This is a beginning piece of a project that will be further developed. It is hoped that in future work, the headset will be programmed to be able to operate across multiple platforms. In addition to the limitations discussed in the scope, the limitations for this project were:

- Haptic feedback would not be explored, as it is currently outside the scope of this project to implement (Mankey, 2014).
- Due to limitations on time during the development of the traditional interface, the traditional and virtual reality interfaces had a few quirks that were noticed by the participants. These would be fixed and improved for control in a future study.
- The complexity of the scene was designed so that the average participant completion time would be long enough that the learning curve could be overcome in the time the participant used the interface, and any difficulties would have noticeable increase in time taken.
- The project would not be about animating the camera movement and positioning.
- Scenes would be preloaded with the primitives at the starting point.

1.8 Delimitations

- Post-testing, the participants would be queried about their general level of discomfort from VR use.
- Participants would not be asked about their previous experiences with VR sickness, as this introduces other variables to be measured that add unwanted complexity to the research.
- Three sub-scenes would be assembled, and test sessions would be kept as short as possible. The time in each interface would be limited to no more than 30 minutes. If 30 minutes were exceeded, then a presumption of extreme difficulty would be made and notated accordingly.
- All assets would be exclusively made of 3D primitives (cube, spheres, cones, etc.).
- The scene size would not be excessively large for simplicity.
- There would be no scene camera.
- The participants would attempt to match their given primitives to a template of object positions denoting where the primitives should be placed and in what orientation and scale. Exact replication was not required.

CHAPTER 2. LITERATURE REVIEW

The realm of virtual reality dates as far back as the late 1920's, when the military developed flight simulators for pilots (VRS, 2017) and made its debut with the general populace in 1960's, with the patent application issued to Morton Heilig for the Sensorama (Burdea & Coiffet, 2003). Many of the seminal research articles in this field were published in the late 1990's, such as the work by Frederick Brookes' "What's Real About Virtual Reality?" submitted to IEEE in 1999, and "Virtual Reality: Scientific and Technological Challenges", written by the National Research Council, Computer Science and Telecommunications Board, Committee on Virtual Reality Research and Development in 1995.

The area of research for this project is specifically about 3D animation utilizing virtual reality technologies. This area is so new and rarely discussed in the academic realm that ACM SIGGRAPH had their first presentation paper on the subject in late summer 2018 (Seyb, Grajetzki, Chin, & Wilkinson, 2018). One of the main reasons for this is due to the majority of the progress and development of VR technology happening in private industry as opposed to academia. Furthermore, according to a survey by Bahçeşehir University in Turkey conducted in 2017, the number of VR HMDs at 151 Universities polled in 38 countries was less than 1.5 and had only increased to 5.6 by the end of 2017 (Bozorgzadeh, 2017). With this dearth of equipment availability in academia it is no wonder that the number of academic publications about VR in general are few and far between as of the time of this paper.

Unfortunately, private industry is not keen on exposure of new technologies before commercial release, in many cases, taking steps to protect their technologies from exposure with the use of non-disclosure agreements, trade secret regulation, and other contractual limitations to the extent those are allowed by national laws. These restrictions have made getting access to the documentation of current research extremely difficult. In addition, many cutting-edge advances in virtual reality are made outside of the academic sphere, making textbooks and studies on the topic obsolete even before release. Most new developments in VR are announced through product press releases, convention announcements, or technology blogs.

2.1 Animation Pipeline

Every professional animation studio has a pipeline that its team uses to create their products, each slightly different from the others. Without a pipeline, studios would not be able to produce animations efficiently or to their best quality. Most pipelines include three components: Pre-production, production, and post-production. The areas this project is concerned with is the latter stages of pre-production, specifically the pre-visualization and animatic stages, and the production stage. While some visual effects are added in post-production, those are not normally reliant on three-dimensional layout but are usually done during the compositing stages.

Pre-production usually encompasses the stages of idea conception, procuring funding, procurement of voice talent, script editing, storyboarding, pre-visualization and creation of an animatic (Picone, 2018). Production is the stage where the creation or filming of the animation or film takes place. This includes the acting, both voice and performance, scene layout, set building, motions, choreography, expression development in the case of 3D actors, and the final render. It is this stage that this study is primarily concerned with. Finally, there is post-production, which is predominantly covered by compositing of the many pieces of the film into a coherent story, editing of the scenes to remove unnecessary material, color correction and grading, the addition of background music, and the procedures for marketing and distribution.

The studio is given or produces an idea or proposal for a project. The idea is pitched, and if accepted, the project will begin. Once the storyboards have been finalized, pre-visualization begins. Pre-visualization is when low resolution representations of the scene are laid out and given rough animation to give a sense of what the scene will look like. It is at this stage where the directors will make the most radical changes to the story and script due to unforeseen story complexity. This project's effect on the pre-visualization stage has the potential to be immense, as the basis for all the remaining work is done here and radical changes require non-trivial effort on the part of the animation staff. From here, editors will create an animatic that lays out the general sense of the story.

In the following step, the high-resolution assets are be modeled, animated, and rigged, and sent to the animation department. The animators take the animation through multiple iterations of development, taking direction from the animation directors throughout the process. This section of the development process is the most labor intensive and time-consuming portion of any animation project. It is this part that requires legions of animation staff, many times across several teams and even numerous external contracting studios to manipulate the action and environments that this project is intended to benefit. This can be observed in the credits of movies such as those from Disney, DreamWorks, or Marvel studios.

Once animation is completed, the characters are styled with moving and reactive hair and outfitted with responsive clothes. In parallel with the character animation, the visual effects and lighting department are working together with the look artists, sometimes referred to as shading artists, to develop the overall final appearance of the animation. After all of that has been completed to the director's vision, the animation is given voice, sound, music, and final edits by the editing department, and is sent out to the general public (Fitzgerald, 2018; Harmon, 2006; Willett, Lee, & Castaneda, 2010).

Generally, the 3D pipeline starts at the previsualization stage and progresses through final edit. The stages of the pipeline that this study is concerned with operate from the previsualization stage, ending once animation is completed and until final rendering.

2.2 Animation Interfaces

The creation of complex 3D scenes is a tedious operation (Carmell, 2018; Ma, 2017; Safavinia, 2017), consisting of loading the asset, translating the asset to its position, possibly positioning to the ground or environmental plane collision point, rotating it with respect to the camera and other context aspects of the scene, manipulating, for instance, the 3D character's joints to attain the necessary pose.

The tedium and workload grow as the number of items in the scene increase due to the increased time and coordination necessary to move each item into position. Several methods for solving the large scene populating complexity issue have been created with varying levels of utility: random placement of instances based on maps, crowd simulation systems, computational modeling of natural patterns, and others.

A major drawback to these systems is that the creator loses creative control over the placement of scene assets, and the sheer number of inserted assets makes modifying the scene to match the director's vision even harder since the technologists(s) are unaware of the relative locations of items placed in the scene. At this point, finding a manually placed asset among the computationally placed items is similar to the proverbial needle in a haystack.

2.3 State of the VR Industry

The VR industry is fast moving, with analysts reporting in previous years that the industry could reach USD 45.09 billion by 2025 (Pokric, 2017). This amount is impressive, considering the "debut year" of the consumer VR industry is considered to have started in 2016 (Wheelock & Beccue, 2016).

For the consumer VR industry, many applications have been proposed, but the game and film industries are the main areas where VR has found most success in the consumer space (Pokric, 2017), and where consumer interest goes, entertainment generally follows. The games industry has, by far, been the area that has seen the most interest and application of VR technologies for both developers and consumers (Lang, 2018). Game developers surveyed in the 2018 annual Games Developers Conference were shown to have had most interest in developing games for VR in comparison to other experimental media (Lang, 2018). However, despite this interest by developers and the tech savvy, awareness of VR technology still lags in the consumer arena (Beck, 2016), which holds back the explosive progress that had been predicted in more productive years (Wheelock & Beccue, 2016). While Gaming VR has slowed its linear evolution, VR is in favor of spreading its influence laterally into similar fields, such as in animation.

Games and animation are very different fields, but with some intersections and overlaps. One of these intersections happens to be the modern cutscene. The Oxford dictionary defines a cutscene as "a scene that develops the storyline and is often shown on completion of a certain level, or when the player's character dies." Modern games, starting from the age of Pacman, have utilized character animation and cutscenes, but were not given such names until Lucasarts' Maniac Mansion ("Cutscene (Concept) - Giant Bomb," n.d.). Cutscenes almost always require animation, regardless of the video game’s graphic medium, such as retro 16-bit pixel art or high-resolution ray-traced 3D renders. Originally, cutscenes used minimal animation (Pacman, 1980) however, over the years, the complexity of the animation and plotlines used in these cutscenes have progressed from the emotionally themed Mrs. Pacman in the early days, to nearly feature film quality cutscenes provided in games such as Heavenly Sword, released for the PS3 in 2007, to the semi-realistic cutscenes seen in games such as Call of Duty and the Halo series, published by Microsoft from 2001 to 2018**,** which morphed into a number of 3D animated feature films and a 3D animated series.

Cutscenes and animated movies, though cutscenes have grown to be longer and more cinematic as budgets grow larger and consumer demand rises, have different creative processes and have different requirements to be successful. Even with these differences, the methods to create a game’s 3D cutscenes and a 3D animated film are the same. Both require extensive environment creation, rigged and articulated characters, and a continuity for the individual pieces. A cutscene in a game does not always need to be self-contained and is sometimes shown many times in a short period of time in the case of a difficult level where the player often dies. In animated movies, the story must be self-contained, and will usually only be viewed once in the context of the plotline of the whole story.

A further difference between the two is that fewer technical mistakes are tolerated by the audience of an animated film versus game players. If a game falls into the Uncanny Valley, either in gameplay or through a cutscene, it is normally forgiven and seen as a necessary shortcut due to faster turnaround in game pipelines (“Animation for Games vs Animation for Movies | Pluralsight,” n.d.). Whereas even a slight dip into the Uncanny Valley for an animated film may cause revulsion at worst, and a disruption of the immersive experience at best. Game cutscenes may have a wide range of quality dedicated to a scene depending on many factors and a game cutscene may not be fully rendered when shown, instead utilizing the game's default engine to depict the story. Regardless, both the game and the animation need to have equal attention paid to the detail of the motion and interaction of the various assets within the environment.

VR technology has been traced back to as far as the 1960's, with the "Sword of Damocles" at the University of Utah. VR made its entrance to consumer games with fits and starts followed by quick failures for the next 50 years (Huaman, 2018). As quoted by Bowman et al: "Research in 3D interaction and 3D display began in the 1960s, pioneered by researchers like Ivan Sutherland, Bob Sproull, Fred Brooks, Andrew Ortony, and Richard Feldman." (Bowman, Kruijff, Laviola, & Poupyrev, 2005) Since the development of low-cost LED displays in the 1990's, VR/AR headsets have been leveraged to enable professionals to conduct work and research much easier than before, being used in many industries for construction, engineering, medicinal practice, entertainment, and various government and military operations (Webster et al, 2014). It wasn't until the mid-2010's when high density LCD/LED screens became inexpensive enough to make headsets wearable for more than mere minutes at a time. Oculus Rift led the charge in beginning accessible VR headsets when its Kickstarter campaign began in 2013 (Dredge, 2016). Facebook bought the Oculus Rift in 2014 for $2bn. (VRS, 2017) In more modern time periods, the year 2016 has been called the 'debut year' of VR, according to Tractica's 2016 analysis article (Wheelock & Beccue, 2016).

VR technology has been falling short of industry expectations from as early as two years ago (Rosenberg, 2018). According to Kellen Beck from Mashable.com, many Americans are not even aware of the technology's existence (Beck, 2016). There are also industry professionals that believe that while VR headsets remain tethered that “anything requiring the user to wear a cumbersome device will ultimately fail.” (Wheelock & Beccue, 2016)

Current industry is dominated by a handful of companies, with the dominant models in American being HTC Vive and Oculus Rift platforms, with the Playstation VR usually relegated to the console sphere (Telegraph Reporters, 2018). On the open-source side of the commercial sphere is the OSVR HDK series, developed originally by industrial VR manufacturer Sensics and manufactured by Razer (Hayden, 2017). Finally, there is a plethora of Chinese clone hardware of varying quality and reliability (Fink, 2017; Midha, 2016). Due to the wide range of issues involved with both hardware and software support, the Chinese hardware options were excluded from consideration in this study.

There have been many small company solutions for VR scene creation and manipulation No references could be found for the dearth of VR plugins except for this quote by the EA CEO:

> “People seem to have come to terms of the fact that VR while an unbelievably wonderful innovation for how you consume interactive entertainment and all forms of entertainment for that matter is going to take a couple of years at least to going to get to a point where it is truly a mass market consumer opportunity.” (Amjad, 2017)

This opinion is likely shared by many large companies and may be a reason why no large companies has created an officially supported VR interface for their software.

Most of the hardware uses hand wands and joysticks, such as used in the dominant VR HMDs, but hand interfaces like the LEAP exist (Guna, Jakus, Pogačnik, Tomažič, & Sodnik, 2014). The predominant human input into VR is hand wands, joysticks, and position tracking (either through infrared, sonic, laser tracking, and recently eye-tracking (“Eye tracking research in immersive virtual environments,” 2017)).

The Chinese VR technology has exploded in the years since VR became popular in 2016 (Midha, 2016), and offerings in the commercial market vary widely from sub-par Google Cardboard mobile headset copies (Fink, 2017) to cutting edge 8k technology such as Pimax’s recently revealed Hyperreal Pano, an HTC Vive clone. Though the Pano is marketed as “8k” technology, implying the total width of 7680×4320, but in fact is more accurately referred to as “dual 4k”, as written by Engadget author Robert Lai in his article from 2017 (Lai, 2017).

2.4 Interface Evaluation

“Evaluation is the analysis, assessment, and testing of an artifact. In UI evaluation, the artifact is the entire UI or part of it, such as a particular input device or interaction technique.” (Bowman, Kruijff, Laviola, & Poupyrev, 2005) “We define usability in the broadest sense, meaning that it encompasses everything about an artifact and a person that affects the person’s use of the artifact.”

The article by Bowman et al. makes the argument that “evaluation should not only be performed when a design is complete, but that it should also be used as an integral part of the design process.” (Bowman, Kruijff, Laviola, & Poupyrev, 2005). According to Bowman et al. (Bowman, Kruijff, Laviola, & Poupyrev, 2005), evaluation of an interface, is best done in iterations, until measures have been satisfied, such as budget limits or deadlines. They also have stated that tasks to be evaluated are better off being broken down into taxonomies, or classifications, of tasks.

According to Usability.gov, the online national resource for UX research design, there are at least three different types of testing an interface: First Click Testing, Heuristic Evaluations and Expert Reviews, and the System Usability Scale. The First Click testing is showing the participant the interface or website and observing what the user clicks first in order to complete their intended task. This is useful for testing intuitiveness. Heuristic Evaluations and Expert Reviews is when you recruit experts in usability to review your interface and compare it against "accepted usability principles." This is a very thorough, but time consuming and requires access to industry professionals. The System Usability Scale is the most effective for small studies, being the standard for quick evaluations of interfaces in the UX industry, with references in over 600 publications as of 2011. (Sauro, 2011)

Previous works of published academic research that are directly useful for the purposes of this research's methodology are few as far as the researcher has found. A similar research thesis completed by a student in the CGT department of Purdue West Lafayette explored the benefits of using a custom pinch-glove for virtual reality interface control as opposed to the traditional wand controller that has become commonly used in the industry (Mankey, 2014). As it was stated in Mankey's work, haptic feedback will also be beyond the scope of the development for this project, due to the complexities involved with designing flexible hand tracking devices that are comfortable to wear by most users.

CHAPTER 3. METHODOLOGY

The goal of this exploratory experiment was to determine whether immersive technologies could decrease the amount of time and training necessary to complete 3D scene building tasks compared to the current traditional animation interfaces To compare the interface types, participants were randomly assigned to one of two interfaces and switched to the other while timing measurements and qualitative comments were taken. Following the completion of the tasks, the participants were then given a questionnaire over their preferences and opinions.

3.1 Study Design

The study used a within-subject experimental design and collected both quantitative and qualitative data, with individuals as the unit of measurement. The participants were recruited using convenience sampling within the Computer Graphics undergraduate and graduate schools. All participants were volunteers without compensation other than the enjoyment of using a new virtual reality interface. Methods of recruitment were flyers, professor recommendations, and in-person recruitment.

3.2 Variables

The dependent variables (DV) were the time taken to complete the scene placement task; the user interface preference, the usability score of the VR interface, the motion sickness levels of users. In addition, the think-aloud protocol was used to collect comments from the participants as they were performing the required tasks. The independent variables (IV) were the interface type (traditional versus VR), the participants' animation and VR experience, their gender, age, and education level.

3.3 Population and Sampling

The target population of this study was animators, ranging in experience from beginners to industry professionals. The sample of this study was animation students of Purdue University, both from the main campus at West Lafayette, Indiana and the statewide campus in New Albany, Indiana. The age range was from 18 years to 50 years. Upon consultation with the Purdue Statistics Department, a minimum of 30 participants was deemed necessary for completing the statistical calculations for accurate and generalize-able results. A total of 38 students participated in this study, with 2 participants' data being incomplete and unusable for the analysis of time.

3.4 Study Procedure

Participants were randomly assigned to one of the two interfaces of this study to start the study. Participants came to the lab. Once participants were seated, they were given a packet containing a consent form, a pre-task survey asking for basic demographic data, a post-task survey, and a System Usability Survey (SUS).

After completing a pre-task questionnaire and explained their participant rights, participants were assigned one of the two interfaces:

• Traditional mouse and monitor interface

• Virtual reality headset and immersive interface

The interfaces were preceded by a brief (2 to 3 minute) instructional video explaining the task scenario and controls of the interfaces. Participants were asked to place 3D objects based on the printed 11x17 inch reference image placed in front of them during the study, shown in Figure 1. This was intended to simulate the steps needed to create 3D scenes in an average animation production environment. The scene comprised of two cones and two cylinders, a sphere, a castle model, a moat, and a road. For the virtual reality interface, a virtual fen placed around the outer bounds of the scene. This was to prevent the participant from using the teleport function to go beyond the environment and becoming lost and disoriented.

The displays were screen-captured using software that recorded time taken to move each object into position as well as overall time taken to complete the level. Recording time was started once participants were cued to start and recording time ended once participants finished setting the objects and animated the last bounce of the ball out of three bounces towards the castle. Only the test headset, monitor screen, and participant spoken comments were recorded. During testing, the participants were encouraged to speak their observations aloud. All recordings were labeled with the numerical ID assigned to the questionnaires.

Before starting their task, participants were shown a scenario video explaining their objective in this study. Also provided for participants was an 11x17 inch physical print-out of the final layout of the scene they were to assemble.

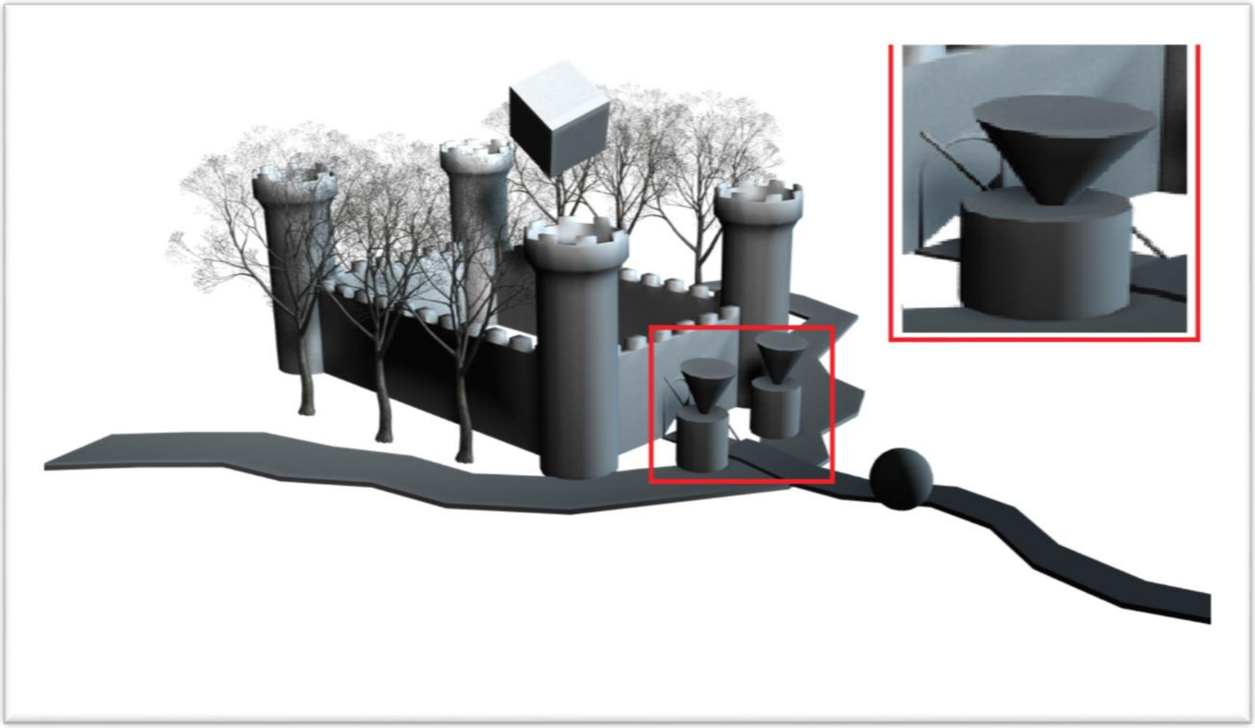


Figure 1 11x17 inch Printed Reference Target for Participants

Participants were then shown a short instruction video of the interface they started with. For each interface, participants were given 15 minutes to create the 3D scene from the provided print-out, which acted as a reference with which to position a sphere representing the moving subject of the animation. Once the environment was created, participants were to position the sphere in 5 distinct positions, representing keyframes in a bounce animation. For this study, an environment representing a fantasy medieval castle scene was the target, and the sphere acting as a simplified avatar for a protagonist. This was selected due to the ubiquity of the scenario to participants regardless of their cultural backgrounds.

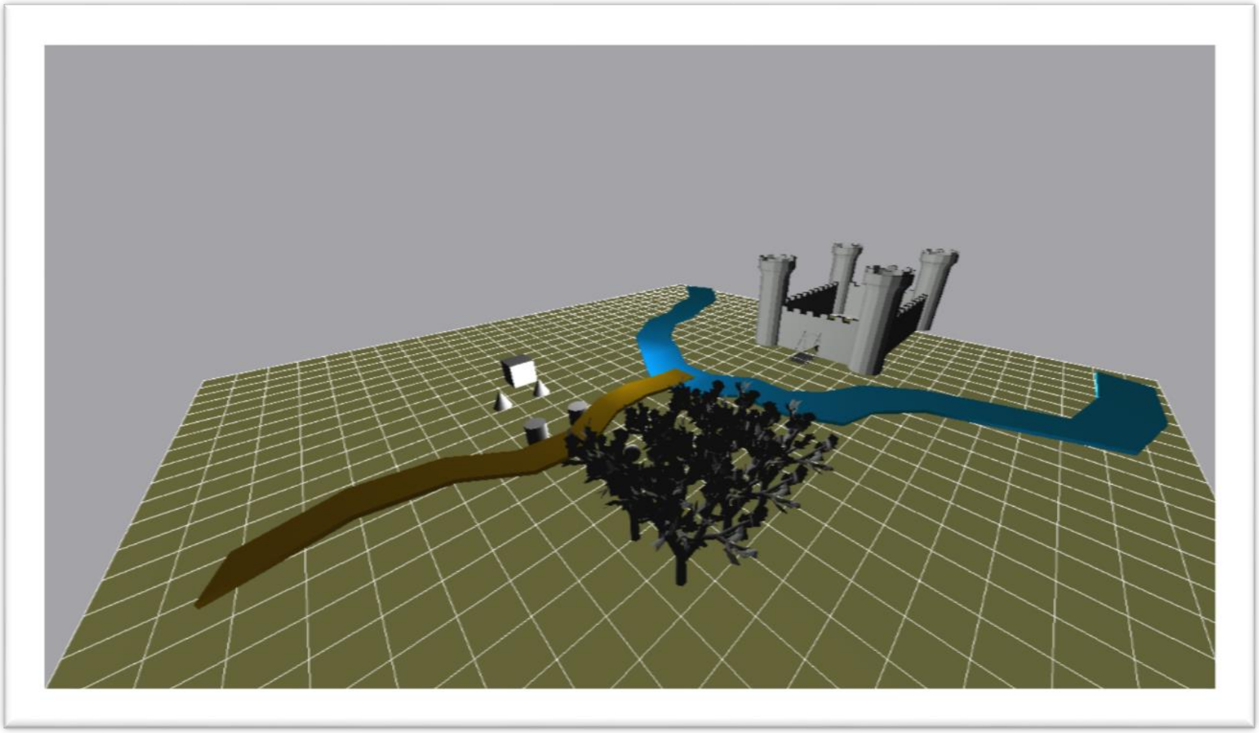


Figure 2 Item layout upon opening traditional interface.

After completing the first assigned task, participants watched a six-and-a-half-minute video that was intended to serve as a way to refresh participant's memory of the reference image, as well as space out faster participants from the slower participants when testing pairs. It was hoped that the time gap between the use of the two interfaces would reduce possible learning bias between the interfaces. After watching the video, participants moved to the second interface, watched the corresponding instruction video and completed their task. After completing their final task, participants filled out a post-task survey, asking for their preference between the two interfaces, and a System Usability Survey asking about the usability of the VR interface. The Usability survey was only given for the VR interface as all participants were familiar with various forms of traditional interfaces from previous experience.

3.5 Data Collection and Analysis

Data was collected through audio and computer screen recordings through the program OBS Studio. Participants were asked to speak aloud their thoughts and comments about the interface during use and were observed by the researcher as they completed their tasks. The researcher stood nearby but stayed silent unless participants asked for clarification or reminder of the features that were introduced in the videos. Once the task was completed, the researcher took the participant to the next step in the study. Participant completion was entirely voluntary, and data was collected anonymously. The participants that withdrew from the study or abandoned the task before completion were not included in the statistical analysis.

An independent sample T-test was used to determine whether the difference in time between the two interfaces was statistically significant, and box plots were used to compare the final time results against the demographic data collected, such as age, gender, campus location, education level, animation experience, and VR experience.

3.6 Evaluation Instruments

The evaluation instruments were: the pre-task, post-task survey, the SUS survey-- all printed on US Letter size paper, recordings of spoken comments, and audio and screen recordings of participants’ interactions with the interfaces, including total time to complete all required tasks.

Before participants began the first half of the study, the pre-task survey contained 5 questions, asking for the campus, age, experience with animation, experience with VR, and a qualifying question about whether they experience motion sickness:

- Which Purdue campus are you located: West Lafayette New Albany
- What is your age: Four nominal scale questions, ranging from 17 or below; 18 to 22; 23 to 29; 30 or above;
- How much experience using animation interfaces: No experience, Beginner, 6 months to a year, one to 5 years, 5 to 10 years; 10+ years.
- Have you used Virtual Reality (VR) before: Yes or No
- Do you have a history of motion sickness: Yes or No

The post-task survey contained 5 questions, asking about whether they experienced motion sickness, and if so, on a Likert scale of 1 to 10, how much; as well as which interface they preferred, which was easier, and which was more intuitive for use, and any comments or thoughts they had about the interfaces:

During this test, did you experience motion sickness or nausea: Yes No

If yes: on a scale of 1, slight dizziness, to 10, heavy nausea and disorientation?

If no, skip this question: Likert scale from 1 to 10

Which interface did you find easier to use: Traditional VR

Which interface did you find more intuitive: Traditional VR

Which interface did you prefer overall: Traditional VR

Any comments or suggestions: Open ended qualitative question for collecting comments.

The SUS survey contained 10 questions, listed below, each testing different aspects of usability of the VR interface according to the UX field's well-tested standards for generic interfaces and websites:

1. I think that I would like to use this system frequently: 5-point rating system - 1 strongly disagree to 5 strongly agree

2. I found the system unnecessarily complex: 5-point rating system -1 strongly disagree to 5 strongly agree

3. I thought the system was easy to use: 5-point rating system - 1 strongly disagree to 5 strongly agree

4. I think that I would need the support of a technical person to be able to use this system:

5 point rating system - 1 strongly disagree to 5 strongly agree

5. I found the various functions in this system were well integrated: 5 point rating system - 1 strongly disagree to 5 strongly agree

6. I thought there was too much inconsistency in this system: 5 point rating system -1 strongly disagree to 5 strongly agree

7. I would imagine that most people would learn to use this system very quickly: 5 point rating system -1 strongly disagree to 5 strongly agree

8. I found the system very cumbersome to use: 5 point rating system -1 strongly disagree to 5 strongly agree

9. I felt very confident using the system: 5 point rating system -1 strongly disagree to 5 strongly agree

10. I needed to learn a lot of things before I could get going with this system: 5 point rating system -1 strongly disagree to 5 strongly agree

3.7 Stimuli

The stimuli for this study were the VR interface, comprised of a VR headset and two handheld wands; a traditional graphical interface, using a computer mouse; and a print-out of the final result the participants were assembling. At the New Albany campus, convenience testing was conducted in the Boiler Student Room, a room set aside for special use or student gatherings. At the West Lafayette campus, two rooms were also used for convenience testing: Knoy 352, a general conference room, and Heavilon Hall's Virtual Reality room.

The VR device used for this study was an HTC Vive VR suite, primarily consisting of the headset and hand wands. This headset was chosen due to its general availability and wide compatibility with game development software like Unity and Unreal Engine 4, as well as its ease in programming. Unity was used for building the VR testing environment.

The traditional interface was created using Lazarus/FreePascal, an implementation of the object programming language, allowing for complete customization of the system by the researchers. This was used due to resources available to guide the researchers through the process of creating a new graphical interface.

Two 11x17 inch print-outs of the target object layout were printed in order to avoid bias due to poor participant vision or by low-resolution blurriness of the image. Both print-outs were placed in an easily visible location in front of each of the interfaces for ease of switching participants between stations.

For the rooms used on either Purdue campus, both interfaces were set up on desks at least eight feet apart to allow enough space for two participants to complete the interface at the same time without impacting or interfering with each other. The area set aside for the VR testing measured at minimum 10 ft x 10 feet to prevent the VR participants from hitting the walls or other VR equipment while moving their controllers. The station for the traditional interface was always at a desk with a comfortable office chair, computer monitor and computer mouse and was facing away from the position of the VR station. This allowed the participant using the traditional interface to operate without the motion of the VR interface participant distracting them from their task. VR participants were given the option to stand or to sit. Most VR participants chose to stand while completing their task and were instructed to stay in one place as much as possible to avoid hitting walls or desks. A few VR participants chose to sit, which did not appear to have a noticeable effect on their task completion time.

CHAPTER 4. DATA ANALYSIS AND RESULTS

A total of 38 participants participated in this study, but two participants' timing data was incomplete and therefore were not considered in the analysis. Demographic information gathered about the participants included: Age, gender, education level, experience with animation, experience with VR, and whether participants were subject to motion sickness. Participants were informed that the test was set up to simulate the role of animator at a small studio. They were then randomly assigned to one of the two interfaces. An instructional video for the interface they were assigned to was shown and they were given 15 minutes to build the 3D scene. The 3D objects' positions were indicated by a print-out reference. The participants were then asked to position a sphere, representing the focal character, into three positions representing three keyframes of an animated sequence, showing the sphere bouncing down the road toward the pre-positioned castle provided in the scene.

4.1 Quantitative: Preference, Usability Score, Time

The quantitative results include: total time taken by each participant to complete the task, participants' demographic data, participants' preference between the two interfaces, and usability measures of the VR interface (answers to SUS questionnaire)

Once participants had completed both interfaces, they were asked to choose their preferred interface. Out of the 36 participants who filled out the survey, 34 preferred the VR interface and 2 preferred the traditional interface.

The usability score calculated from the SUS survey was 47.63. This score is below the range value of 68, where average interfaces would generally be expected to score using the SUS survey (Sauro, 2011). This puts the VR headset at around the 20% lower percentile compared to other interfaces tested with this survey. This means that the immersive interface could use some improvements if it were to be implemented commercially but performed well in its capacity compared to the traditional interface, as shown by the completion times. These values were calculated in accordance with the SUS Usability organization's instructions on the official website ("System Usability Scale (SUS) | Usability.gov," n.d.).

The demographic data were used to categorize the timing data to allow for meaningful comparison between groups. The survey category that was not compared against task completion time was the Usability Score of the VR interface, as this was not a measurable demographic. The SUS survey was only applied for the VR interface because of the hypothesis focus on whether the VR interface could outperform the traditional interface and was not related to the time taken to complete the task.

Table 1

Comparison of All VR and Traditional Data.

	VR	Traditional
Mean	6.4025	10.5016
Variance	9.470	14.278
Independent P Value	0.0000037	

Table 1 shows the time data of all participants grouped by the interface used. The mean for the VR, (*M* = 6.40), is nearly half of that of the traditional mean, (*M* =10.50). This supports the hypothesis that the immersive interface would take less time to complete the task than traditional. The independent sample P value of the mean time of the interfaces was also calculated as $p < .001$, significantly less than the standard of significance alpha= .05, and thus the null hypothesis, “no difference in the time taken while building a 3D scene between the compared interfaces” is rejected.

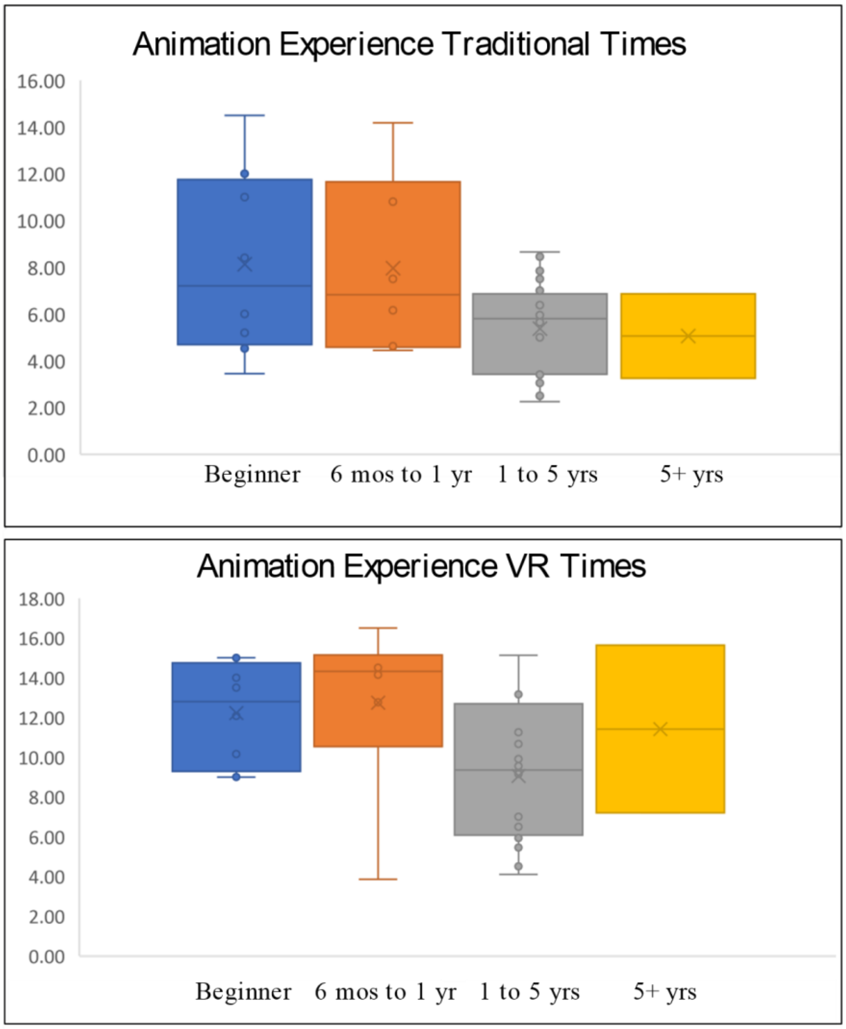


Figure 3 Data for Animation Experience

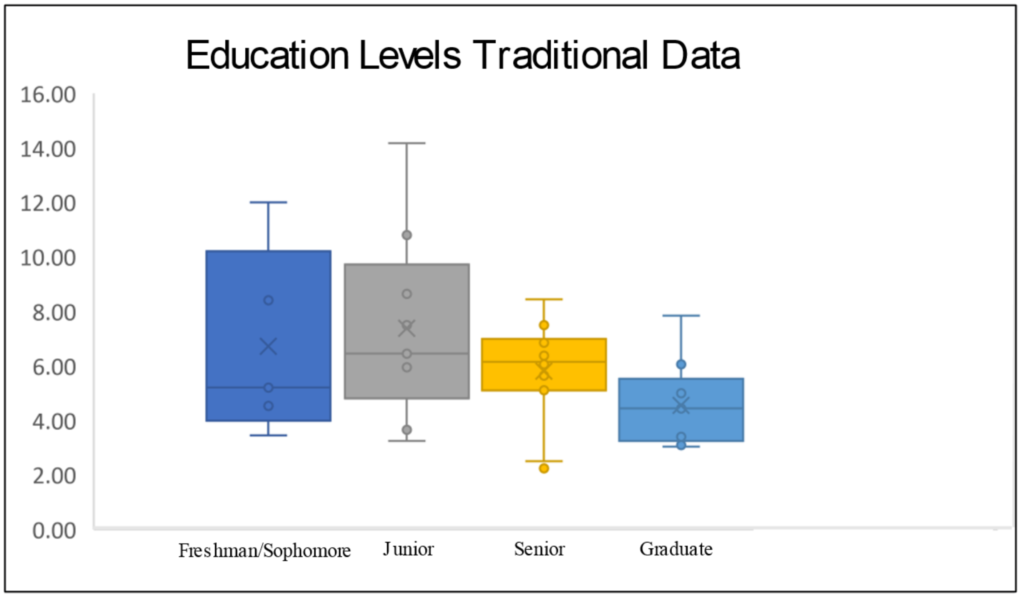
Figure 3 is a box plot that compares the traditional interface times of the users, grouped by their level of animation experience. The categories of experience are: Beginner, defined as less than six months of experience; six months to one year, one year to five years, and five or more years. These plots show that the more experience the users had, the faster the task was completed. This seems to indicate that more experience in navigating objects around a three dimensional in general greatly affects the participant's performance. The demographic with the fewest samples was the 5+ years of experience category. The performance between beginners, those participants with less than 6 months of experience, was not significantly different from those with up to a year of experience, (p = 0.2610). Those participants with up to 5 years of experience performed the VR tasks with the least average time, while the group with 1 to 5 years performed the traditional tasks with the least average time and with the least variation.

Table 2

Data for Animation Experience

VR	Beginner	6 months to 1 year	1 to 5 years	5+ years
Mean	8.14	7.96	5.38	5.06
Std Dev	3.997374	3.838524	2.003688	2.552655
Traditional				
Mean	12.22	12.74	9.05	11.42
Std Dev	2.542877	4.517065	3.39995	5.96091
Paired P Value	0.054093	0.160081	5.5E-05	n/a

Paired P Value compares the VR data samples to the Traditional data samples to determine significance. The 5+ years group had only two samples, therefore p-value could not be determined.



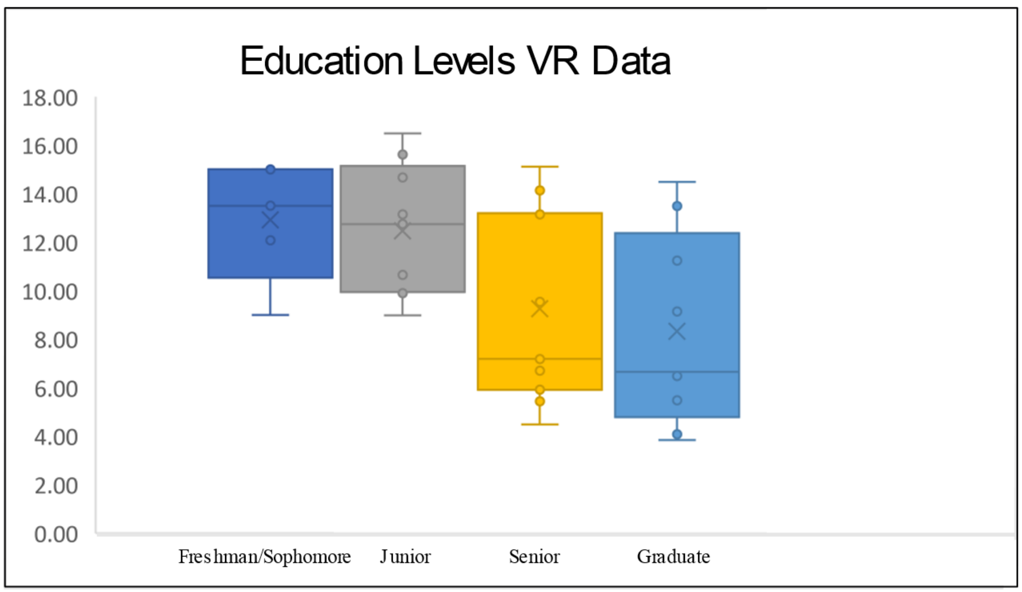


Figure 4 Comparison of Education Level Interface Times

Figure 4 and Table 2 is a set of box plots and tables showing time to complete tasks based on education level . The categories for education level were: Freshman, Sophomore, Junior, Senior, and Graduate, as represented by the number of years the students have been in university. These data were self-reported and are assumed to be accurate.Due to the nature of convenience sampling, only one sophomore participated in the study. This data was merged into the freshman group data.

For all education groups except the freshman and sophomores, there was a significant difference in task completion time between VR and traditional, with all VR completion times nearing half that of the traditional interface times. A possible reason for this may be that the freshman and sophomore group had little enough experience with traditional 3D interfaces that the learning curve was significantly higher for both interfaces compared to the other groups.

For the education level, it can be assumed that there was a positive correlation between education and animation experience in the participants. As seen in Figure 4, the more education users had, the more quickly they adapted to the interfaces. Another factor related to education level was the age of the participants, as it can be shown that the higher the education level, the older the average participant in that category would be.

Animation experience and VR experience were compared to the total time taken to complete the VR interfaces to check for relation. For those participants that indicated experience with VR, there was more variation in time taken to complete the task, but for those that indicated no experience, the average time taken and the upper and lower range were actually about the same as those with experience. It was determined that there was not a significant difference between the times of the participants with experience ($M = 6.5$) and those without ($M = 5.6$). One reason for why this may be is that the complexity of the task assigned to the participants was low enough that prior experience in VR provided few advantages and, conversely, no experience caused few disadvantages. The task of moving an object from one position into another using the wands may have been intuitive enough that very little training and explanation was necessary to complete this particular task.

Those participants with more animation experience took less time to complete the VR tasks than those with less experience. This may possibly be explained by the participants having better understanding of three-dimensional space, as well as a better understanding of how animation scenes are composed, even while using the VR interface. Another possible explanation could be that the more experienced participants may have had experience with multiple animation interfaces, leading to this group being more adaptable to new interfaces and the associated learning curves.

Table 3

Data for Education Level Groups

VR	Freshman/Sophomore	Junior	Senior	Graduate
Mean	8.02	7.39	5.81	4.56
Std Dev	4.449722	3.451348	1.921805	1.591023
Traditional				
Mean	12.46	12.48	9.27	8.34
Std Dev	2.505623	2.730425	3.916381	4.724677
Paired P Value	0.1716	0.0110	0.0215	0.0280

Table 4

Virtual Reality Data for Virtual Reality Experience

VR Exp	Yes	No
Mean	6.56069	5.614
Std Dev	3.23962	2.172149
P Value	0.4706	

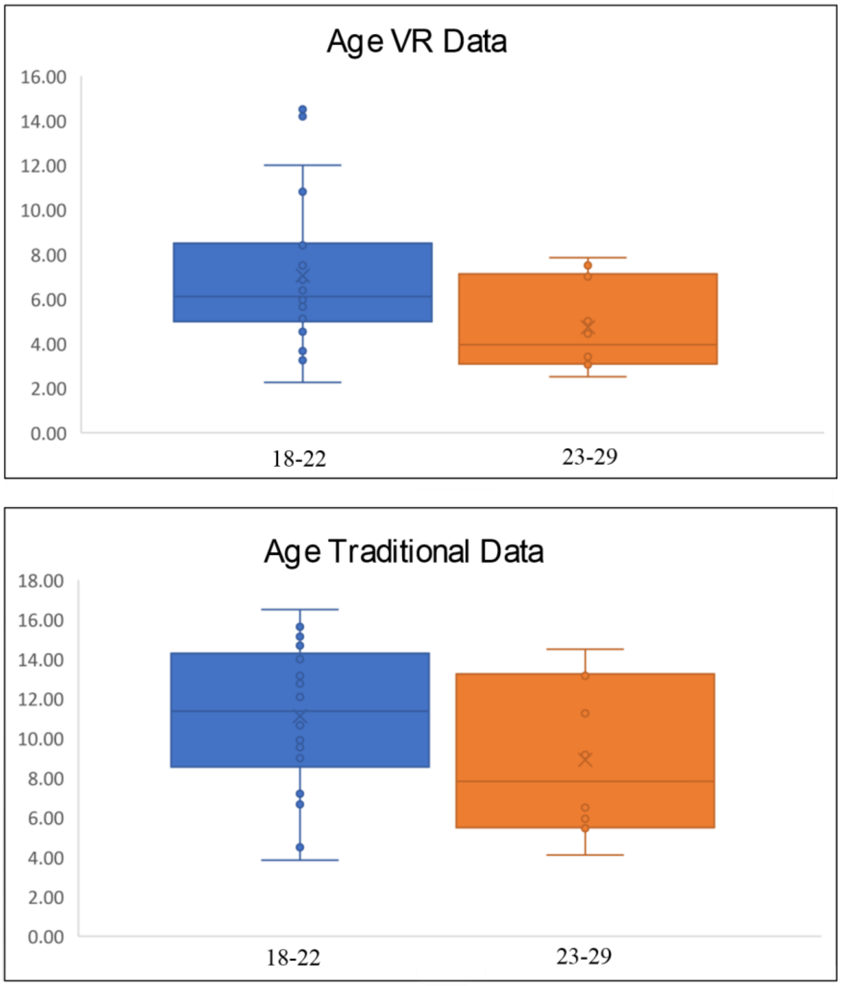


Figure 5 Comparing Age Against Interface Times

Figure 5 compares the two major age categories of the participants tested. The box plots compare age groups to time taken to complete the tasks. The survey asked for four different ranges of age, from 17 and under, 18 to 22 for traditional college student age, 23 to 29 for non-traditional or graduate students, and 30+ for others. No participants were younger than 17 nor older than 30. The highest number of participants were in the traditional college age, twenty-two total, with nine total participants at 23 to 29 years of age. The times of the participants that did not complete the study or dropped out of the study were not included.

As researchers had expected, the older participants had a faster average time to complete the tasks (*M* = 3.99, *SD* = 1.87) than their younger peers (*M* = 7.08, *SD* = 3.20). This trend held true for both VR and traditional interfaces. Researchers initially considered that the older demographic may have a harder time with learning the VR interface than those younger, who have been more acclimated to the technology. This could be explained by a higher chance of the older students having more animation experience than the younger group, as well as having better visual cognitive abilities and more generalized experience with graphics technology. It may also be that those older participants were not old enough to have a different learning curve than the younger group or any difficulty with current technology.

Table 5

Data for Age Groups

VR	**18-22**	**22-29**
Mean	7.0868	3.99625
Std Dev	3.201965	1.870388
P Value	0.0009	
Traditional		
Mean	11.2	8.70375
Std Dev	3.617127	3.992919
P Value	0.1390	

The p-value for the VR group was compared between both age groups and found to be significant, but the p-value between the traditional age groups was not found to be significant.

Table 5 compares the task completion data between male and female participants. Far more males volunteered for the study than females, with 20% of participants being female and

80% male. One possible explanation for this is that males compose a majority of the Graphics Technology students. Another possibility that is not exclusive to the previous suggestion may be that males are more interested in the VR technology than females.

The average task completion time between males and females for the traditional interface was not significantly different, with the male sample having slightly less deviation in the VR tasks (*SD* = 1.54) despite having more samples than the female group (*SD* = 3.35). The average time for the female group in the VR interface (*M* = 5.97) was slightly lower than the male group's VR interface time (*M* = 6.50).

Table 6

Data for Male v. Female

VR	**Male**	**Female**
Mean	6.504827586	5.978571429
Std Dev	1.542178422	3.357409312
P Value	0.5438	
Traditional		
Mean	10.53862069	10.34857143
Std Dev	3.94550352	3.257117481
P Value	0.8812	

Table 7 compares the interface time data between the two campuses sampled in this study. This was another angle of study that the researchers felt would add more clarity to any disparities that may appear in the data. Each campus has different campus cultures and teach different animation software, as well as different levels of exposure to VR technology, so it was included in the data gathered from participants to avoid a potential confounding variable.

The average time and variation were not significantly different as the researchers expected, although the times that the West Lafayette students completed the VR interface were somewhat faster than the New Albany students on average, but not significantly. The average traditional times were also not significantly different between the campuses and were consistent between the campus groups.

Table 7

Virtual Reality Data between Campuses

VR	**New Albany**	**West Lafayette**
Mean	7.45	6.00
Std Dev	3.64618	2.804137
P Value	0.27153	
Traditional		
Mean	10.59	10.47
Std Dev	4.20996	3.688482
P Value	0.794752	

4.2 Qualitative

Also gathered in this study were comments from the participants and observations made while conducting experimentation. Participants were asked to speak their thoughts and comments aloud while using the interfaces, which were recorded with their consent. Most participants were vocal about their experience while a few remained quiet in both the tasks and the surveys.

Spoken comments were quite varied, many looking at the tasks analytically, asking about how the software was made, what features were programmed, and how the design was chosen. Others were excited about a new VR system that they had not seen or experienced before, some describing the experience as “playing with blocks in the sandbox again.” There were comments about some incidental anomalies that occurred during the VR testing, where large objects in the scene would release from the controller’s grip and “fly away”. Participants mostly marked the VR interface as their preference on their post-task survey, mentioning the intuitiveness of the interface making it simpler to place objects within the scene more quickly.

The traditional interface met a lot of comparisons with other 3D programs, often met with neutral responses upon start of the study. There was a bit of consternation from the participants that there was not a keyboard shortcut functionality included with the traditional interface and mentioned it also on their survey comments. It should be noted that keyboard shortcuts were intentionally omitted to avoid additional complexity in the training of the interface. There were a few students who found the traditional interface quite frustrating, mostly with the camera motion and the rotation of the objects within the scene, while others mentioned that they would have preferred the traditional interface over the VR interface should they use it for assignments or animations. Some participants mentioned that a more familiar traditional interface would have been much faster to complete the assigned tasks, though this confirms the experience bias the study was working to neutralize.

CHAPTER 5. CONCLUSION

5.1 Usability

VR has yet to be widely adopted by animation studios for their movie animation workflow. It is posited by this study that the reason for this is that VR may still be too young, or undeveloped in its current form, forcing studios to have to develop their own proprietary internal software. As an example, due to the lack of available commercial software and the need to create their own, the studio Artefact in 2017 created the pre-visualization software “Storyboard VR”. The project was quickly abandoned, never passing alpha release, and is not planned to receive another update at the time of this writing (Amidi, 2017).

It has also been said by animators in the industry that it can take several months for a studio to fully switch to a new piece of software, and studios often stay on the same version of software that they currently use even if there is an update because of the risks involved with not having “field-tested” the new update for bugs or changed workflows (FlippedNormals, 2019). It can be inferred that if the chance of commercial software bugs would prevent companies from adopting the use of updated software, then the bugs that inevitably come about in any new development would be far more concerning to the companies. Commercial animation VR software is therefore still undeveloped and not widely used within the industry in the current environment.

Therefore, it is this study’s objective to collect more evidence in support of VR’s uses for the animation pipeline. Findings show that VR has benefits that might save studios time and money in both the short and the long term, which can make the technology more attractive for studios to adopt.

Starting this study, it was assumed that VR would have a slight advantage over the traditional interface, due to the three-dimensional nature of VR as opposed to the two dimensions to which traditional monitors are constrained and the ability to use the head to view the scene and use both hands to move and rotate objects. It was thought that there would be a steeper learning curve to learning VR for the first-time participants who had never used VR before, which was proven to not be the case. Users who reported no prior experience with VR had only a slightly lower median time than those who had prior experience.

It was also assumed that there would be a significant bias towards the traditional interface, even if it were stripped down to the bare basics, due to the greater familiarity that most participants were assumed to have. This was also proven not to be the case. It was of concern of this study that the animation software typically used on Purdue campuses was too complex if participants were new to the interface or were new students of animation. Purdue New Albany, for instance, has trained its students in Cinema4D, and West Lafayette has trained its students in Autodesk Maya. It was of concern to the study that should Maya or Cinema4D be used, participants would either be significantly more familiar with the traditional to not be of useful comparison to the VR or that the beginner user subset would have too high of a learning curve to the complex interfaces of the software. Even if both software were to be used depending on the campus, there would then be many variables introduced between the differences in the professional software, such as whether Maya is easier to use or if Cinema4D is faster for placing objects or individual software performance speed. In order to avoid biases and added variables, it was decided that the study should produce a basic interface with all the standard features of animation software, but without any extra UI features or shortcuts that would require extra demonstration or explanation by the researchers. The VR interface was of similar simplicity in order to keep the bias at a minimum.

It was observed that the more experience with animation a given participant had, the less inconvenience learning the bare traditional interface seemed to pose and the faster they were able to complete the task. Conversely, the participants who were new to both animation and VR generally found both interfaces similarly daunting, and a few took up to the entire 15 minutes on both interfaces. Interestingly, those that took a long time on both interfaces showed a greater likelihood to indicate on their surveys to prefer the traditional interface over the VR.

It was also observed that a wide range of experience levels with animation paired with no experience with VR predisposed participants to give the VR higher ratings and more positive comments, even if they found no issue or were neutral to the traditional interface. It is supposed that this is due to the novelty of the technology.

Female participants gathered for this study seemed more predisposed to the traditional interface and were more methodical in their workflow and commentary, while seeming more unsure and confused when introduced to the VR for the first time, needing further reminders of the instructions given in the video. Most female participants quickly became more confident with the VR interface after a few minutes had passed. There were many fewer female participants than male, but despite this, the median time between the groups of participants had no significant difference on either VR or traditional interface.

5.2 Limitations

There are a few limitations that may reduce the confidence in the study results in comparison to similar works, such as the relatively small sample size and the traditional interface design. For this study, a new traditional interface was programmed. We had previously little experience with programming full interfaces and were under a shorter time period to produce a viable and convenient interface. The quality of life features on the interface, for instance, the rotation widget and the orbit widget could have been more precise in their degrees of rotation and more accurate to the movement of the mouse, but were not found to be of significant concern to the committee at the time of the experimentation. Should future research be done on this subject, we believe that the traditional interface would be more intuitive and closer to what participants would expect.

Many participants complained that not having keyboard shortcuts or an undo feature was part of the reason why they preferred the VR interface over the provided traditional interface. In the VR interface, however, an undo function was also not provided, and the goal was to keep the capabilities of the two as equal as possible. We believe that if the implications for the study were more succinctly explained, then it may have made more sense for those participants who held that opinion.

Even with the limitations outlined, the results of the study could still be of merit for adding to the body of information pointing to the increased usage of VR in the animation industry. In working with large scenes, and having large workspaces for the animators, we believe that VR could be of high value in saving time and increasing productivity in a studio's pre-production and animation workflow.

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APPENDIX A

QUALITATIVE DATA

Feedback question: **Any comments or suggestions?**

I feel like the rotation system was the main thing holding the traditional setting back. If I used Maya or Unreal Engine, I would be more familiar with the controls and the IDE would be easier to set objects where I wanted
What makes the PC interface difficult is rotating the viewport with the largely inaccurate FOV angle, and rotating the shapes as axis doesn't match up with modeling software like Maya.
The traditional interface was difficult to navigate – after rotating it, I couldn't get it to go back to its initial rotation and the transformation tools were rotated differently than they should be and I couldn't get them to return to their initial orientation.
More obvious shadow interaction with the floor in both by especially the VR would be helpful.
Keyboard shortcuts are usually what can make or break with traditional interfaces; the VR interface was just as simple as the traditional but was much more intuitive by nature.
The reason for liking the VR interface better is because the traditional one presented in this research did not have a good movement tool. If I was using a standard software (ie Maya) I would have preferred it, because of the amount of precision I have. However, the VR one can potentially give a more organic feel to the placements of the objects.
The VR was very easy to use, but it is imprecise and glitchy. The traditional software has a learning curve, but is much physically easier.
I think the way you control the objects in traditional is just hard to use. Comparing Maya it doesn't have any advantages in controlling views so it was hard to manage.
The ability to move my body in tandem with my anticipated animation gave me a vicarious sense of motion that felt truly fun – I'm not a 3D animator but I think I would enjoy being one with this hands-on fidelity! Rough movement and keys are so quick are so quick to do (for me as a novice at least!)
The VR was much better but the 'traditional' wasn't what's normally used—the study seems biased towards VR as I've used much easier programs that could've done the same thing in ¼ of the time.
The traditional interface is a bit slow/unresponsive.

I use both a mouse and keyboard in traditional setting. Having a keyboard would make this a lot easier, but VR would still be more efficient and intuitive.
I definitely think VR would be useful for posing characters and blocking in animations and would definitely be interested to see future developments in VR animation.
VR was easier to use, though I believe I could work just as fast in both mediums with proper software. I found moving my view in VR to be less intuitive.
Fix the transformation tool! Fix the orbit tool! Fix everything!
I loved the VR! However, if I was working on a project, I would want to use the traditional method. I found the items easier to control in the traditional 3D space.
If this interface that you call traditional ever becomes a thing, i goreentee mass protests/riots from studios.
It’s a lot more fun in VR.
The geometry controls on the PC felt as if they were not centered and should be fixed.
VR: make sure bridge/road doesn’t fly to the ceiling with slight touch.
While the traditional interface is easier to use, the VR interface gives designers a greater degree of creativity because you are creating your vision in a 3D space and not manipulating a 3D space on a 2D display.
There might be a bias as the traditional interface seemed unintuitive compared to other 3D programs.
My only issue is that “traditional” was unlike most traditional software I’ve used. All controls were very buggy and difficult to use. Why not use the keyboard? If you truly want to find pros and cons of each method, let them use their advantages: use the keyboard and familiar moveset, and let us use the buttons on the VR controllers (if necessary).
Hard to move camera for traditional.
The traditional was nice but the field of view was funky. I only felt sickness during the traditional section.
The traditional interface lacked many features for camera movement that other programs like Maya contain. However, VR controls I kind of prefer over Maya ones too.

The ‘traditional’ interface’s rotational tool is so broken it was nearly impossible to use.
I liked the VR a lot but I’m not sure how comparable they are—trad. Offered no way of changing the pivot or moving objects and camera at the same time.
VR I could be a little more precise in a much quicker time and being able to move the object and rotate it at the same time made it much better.
Traditional was very weird not like other softwares, so VR seemed easier.
The traditional interface without all the tools I’m used to used made everything very clunky. The vr headset feels much easier to pick up and use than the traditional interface as well, where you have to learn all the tools that make life easier.
I struggled a lot with the camera and controls in the traditional. VR was much more controllable.
The traditional interface felt like it was fighting me every step of the way, both with manipulating objects and manipulating the viewport.

APPENDIX B

Consent Form

For IRB Use Only

RESEARCH PARTICIPANT CONSENT FORM
Manipulation of Three Dimensional Scenes Using Immersive Technology
Dr. Nicoletta Adamo-Villani
Computer Graphics Technology
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign this form, be sure you understand what you will do and any possible risks or benefits.

What is the purpose of this study?

The purpose of this study is to answer the questions: Between traditional and VR interfaces, which is more efficient for the commercial animation workflow, and is the proposed VR interface usable? The study will proceed for two, potentially three semesters, and subject involvement will only be required for the maximum of 90 minutes for which they are recruited. The researchers plan to recruit a minimum of 30 people for this study, and up to 120 people at the maximum.

What will I do if I choose to be in this study?

You will complete a brief, six (6) item pre-task questionnaire. This questionnaire is for the purpose of categorizing your experience with similar subjects, as well as screening eligibility for the study.

After completing the questionnaire, you will be seated and randomly assigned to one of the two interfaces:

- Traditional keyboard, mouse, and monitor interface, or
- Virtual reality headset and gesture-based interface.

You will complete levels within the interface where you will be presented with basic 3D virtual objects (spheres, cubes, cones, etc.) and asked to place them within their respective marked destinations. Time taken to move each object into position, as well as overall time taken to complete the level will be measured. Your test headset and monitor screen will be recorded, and you will be asked to speak your observations aloud.

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After one interface's tasks are completed, you will watch a brief, unrelated entertainment video. This is for reducing bias caused by repeating tasks between interfaces.

You will then be assigned to the other of the two interfaces, and perform the same tasks that were completed in the previous interface.

Prior to leaving, you will again be asked to fill out a short ten (10) item usability and a five (5) item preferences survey. The Usability survey is the System Usability Survey, which will include 10 rating scaled questions regarding the usability of the VR interface. The preferences survey will ask you to rate your preference between the interfaces that you used.

How long will I be in the study?

You will be in the study for only the time required for you to complete the requested tasks, or a maximum of 90 minutes. There will be no follow-up contact.

What are the possible risks or discomforts?

Risks are kept at minimum: You will be seated and completing everyday tasks with a computer or virtual reality headset. Discomfort will be minimal, as the virtual reality interface is designed to be as static as possible to reduce disorientation when using the headset.

Are there any potential benefits?

Potential benefits are the early use of a proposed virtual reality interface with gesture-based controls, which is not widely propagated in consumer markets. You may enjoy the tasks completed in the virtual reality headset. You may also learn more about virtual reality interfaces.

The following disclosure(s) is(are) made to give you an opportunity to decide if this(these) relationship(s) will affect your willingness to participate in the research study.

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight. There will be no identifiable information collected and the study data gathered will contain no information that will trace back to you in any way.

What are my rights if I take part in this study?

Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Who can I contact if I have questions about the study?

If you have questions, comments or concerns about this research project, you can talk to one of the researchers. Please contact Alexa Sears at email: sears9@purdue.edu or 812-225-6973, the principal investigator, Dr. Nicoletta Adamo-Villani, at email: nadamovi@purdue.edu or 317-966-2508 in case of dire concern.

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If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:

Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant St.,
West Lafayette, IN 47907-2114

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

____ _________________________
Participant's Signature Date

____
Participant's Name

____ _________________________
Researcher's Signature Date