UTILIZING VIRTUAL REALITY TO TEACH DRUM RUDIMENTS

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ABSTRACT

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Virtual reality (VR) offers the ability to learn new topics and advance one's knowledge and skills efficiently and accurately. Due to a small amount of research in the area of VR as a tool to teach an individual an instrument, specifically the drums, a VR application has been built to teach an individual five drum rudiments. This research aims to understand if VR is a viable option as a method of teaching drum rudiments to those with little or no experience. The qualitative and quantitative results of this study indicate that the utilization of VR technology to teach drum rudiments is feasible.

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CHAPTER 1: INTRODUCTION

Virtual reality (VR) offers the ability to learn new knowledge and skills efficiently and accurately. These skills may come in many different forms including preparing for a presentation at work, rehabilitation for patients suffering from a physical injury or psychological disorder, or even military training. VR may even be used in situations to provide a safer environment and provide an efficient manner to train individuals in a particular skill (Abich et al., 2021). In addition, the incorporation of VR into the training process is cost-effective and allows users to receive real-time feedback on their performance (Yu et al., 2023).

Aside from training in a workplace setting, VR also can teach users how to excel at a skill pertaining to a hobby, interest, or occupation. While research on VR training has started to become more relevant within the past few years, there seems to be a gap in the research done on VR in regard to teaching an individual how to play an instrument. Particularly, in this paper, the focus is on the ability of a VR system to teach a user how to play five drum rudiments through an application called "*VRumset*". The intent behind teaching these specific rudiments is to give users basic rhythmic patterns that can be built upon (Lavoie, 2023). The user may then apply the skills they have learned from the application to future practice in harder rudiments or on a real drum set.

A real drum set is typically an investment that requires thoughtful consideration, especially for a beginner. One must potentially learn sheet music or find a teacher, have adequate space, be knowledgeable in what drum parts they would like to invest in, be conscientious of the noise levels for those around them, and be ready to pay a rather expensive price for a complete drum set (Yu et al., 2023). Not only this, but individuals wanting to test the waters with drums may find that learning sheet music or finding a teacher is an extra hassle in their starting experience of drumming. These grounds can be intimidating for a prospective beginner drummer. The rudiments that will be taught in this application can easily be learned without the use of sheet music and will let the user experience the fundamentals of drumming without the stress of learning sheet music. This application will allow users to decide if drumming is something that they would like to pursue or invest in and allow them to experience what drumming is like without the latter concerns.

In this VR application, an individual interested in learning how to play the drums will be taught five basic rudiments and be allowed the ability to "free-play", the action of playing freely without being directed or taught a rudiment, with a drum set. The five drum rudiments that can be learned in this application are as follows: single-stroke roll, double-stroke roll, flam, paradiddle, and double paradiddle. A tutorial will guide the user on the controller settings, setting their seated position, how their accuracy is tracked, and how to hit a drumhead, cymbal, or tap a pedal.

The main goals of this research are to provide further insight into utilizing VR to teach a user a skill, specifically the basics of an instrument. Currently, there is little research done on the use of VR to teach a user how to play drum rudiments. An application, such as the one that will be created in this study, will help to fill in some of the gaps that exist in VR instrument research, specifically with regard to drumming. The research question to be explored and answered by this research is, "Can Virtual Reality (VR) be used to teach a novice musician drum rudiments?"

This paper will be organized as follows: the introduction will establish the background, motivation, potential limitations, and similar applications. Next, a literature review will be conducted to examine the ability of VR to train a user in a particular area or teach an individual a new skill and the current state of instrument research in VR. A methodology section will cover the models utilized, an overview of the environment, audio, and testing procedures. An outline of the completed project, testing results, and outcomes will be explored after the completion of the system. Finally, the research will be concluded, and future work will be proposed.

1.1 Definition of Terms

In this section, relevant terminology will be discussed and explained in further detail to get the reader acclimated to the nature of this research.

Virtual Reality. Virtual Reality (VR) is described as a three-dimensional environment in which a user may traverse and interact with what has been created with a computer. While immersed in this virtual environment, the user may be able to move objects or themselves and complete particular tasks. When a VR application or experience is created correctly, the user may experience something called a sense of presence, or the feeling of actually being in an environment (*What is virtual reality?*, 2017*)*.

Polygon Count. Polygon count is the number of objects that a 3D model is composed of. Polygon counts may range from a high number to a low number. The higher the polygon count, the better the quality of the model. The drawback to a high polygon count model is that it can create slower loading speeds in websites or applications. Therefore, it is important to find a good balance of polygon count to create the most authentic VR experience possible (*3D Model Polygon*…, n.d.).

Asset. An asset is a representation of any item that may be used in an application. An asset may take the form of an audio file, texture, 3D model, or another file type that the Unity platform maintains (*Asset workflow,* n.d.)

Force feedback. Force feedback refers to, "the simulation of real-world physical touch, while in a simulated environment such as VR, by way of motorized motion or resistance" (*What is force feedback…,* 2022*).*

Haptic feedback. Haptic feedback is the ability to interface with users through touch, vibrations, motions, or force and pressure (*What Is Haptic Feedback?*, 2022).

Latency. Latency is a crucial component of VR that delineates the time that is taken between the user performing a motion or action and the system actually displaying the action back to the user (Kundu et al., 2021).

1.2 Application Mechanics

To teach the user each of these rudiments, markers will be utilized to show the user what drumhead, cymbal, or pedal they should hit. Currently, the only part of the drum set that the user is allowed to practice on is the snare drum. These markers will be visualized as highlighted circles that appear around the head of the drum, cymbal, or pedal. The user will be allotted 1 minute per rudiment to practice and during that time their accuracy will be tracked. At the end of the 1 minute, the rings will disappear, and the user will be shown their accuracy as a percentage that is based on whether or not they struck the snare drum with the correct hand. The user will not be limited in the speed that they start at, so if they wish to begin learning a particular rudiment at a faster speed, they will be allowed to do so.

1.3 Motivation

For the author, who personally plays drums, an application such as this would have been extremely useful when beginning to learn drum rudiments. Drum lessons can be both costly and hard to find depending on where the individual lives (Johnson, 2020). On the other hand, some individuals are not ready to make the financial investment that it takes when buying a drum set (Johnson, 2020). Additionally, some would first like to have a beginning experience to see if drumming is something that they would be potentially interested in. Space is also a limit that comes with owning a drum set. The utilization of a VR headset and the *VRumset* application will allow individuals to have the potential to learn five drum rudiments without the use of sheet music or a teacher. Moreover, *VRumset* will also aid those who do not have an adequate amount of space, such as apartment living, or have noise limitations.

1.4 Potential Limitations & Possible Solutions

With any application in VR, there comes a set of challenges that pertain to making the experience as realistic as possible. The first limitation of an application of this kind is the ability to have forced feedback. Haptic or forced feedback is especially important with learning musical skills, such as playing the drums, as it is important to be able to feel some kind of force or response back (Serafin et al., 2016),(Lang, 2019). This issue could potentially be resolved through the use of external sensors. For example, a user could potentially set up a stack of books or some other objects and place a sensor or pad that would recognize when they strike the object of their choosing, thus giving the user the kind of force feedback that is to be expected with a real set of drums.

Another limitation that should be explored is the latency issue that has seemingly been pointed out from similar virtual reality musical instrument (VRMI) applications (Serafin et al., 2016). Latency is important as the human mind can recognize differences in lag greater than 20 ms when it comes to an action that is performed in VR (Kundu et al., 2021). Subsequently, if a latency issue arises within a VR application, this could lessen the authenticity of the experience of the application. It should be explored as to whether this issue is related to the polygon count of the 3D models that were utilized in other VRMI research or rather a lack of advancement in VR technology. If so, low-polygon count models should be utilized to resolve this issue, or at least improve it.

The final limitation that may affect the immersion of this application is the virtual use of the hi-hat and kick drum. The hi-hat and the kick drum pose an issue for the VR experience as they require the use of the feet to control. Most, if not all, VR headsets do not come with external sensors and controllers for use by the feet. Some similar applications have utilized buttons on the VR controllers to allow the user to manipulate the hi-hat or strike the kick drum, but it should be mentioned that some of them also offer external pedal support. The use of the buttons on the controller, however, will take away from properly teaching a user how to play the drums. Foot technique in drumming is just as important as hand technique and must be practiced all the same to build coordination and rhythm (Kleiber, 2012). Similar to the forced feedback limitation, a solution to this would potentially be the use of an external device to recognize foot movement. There exist a few external foot pedals that could be connected via USB or Bluetooth that may prove to be useful in reconciling this issue. These pedals may be able to be mapped to a key on the keyboard, and when the pedal is tapped a corresponding key on the keyboard that is recognized as the hi-hat or kick drum pedal will be triggered. However, that may pose certain limitations as well, as the user will have to have the pedal and potentially their virtual reality headset wired into a computer in order for the foot pedal to function properly. This may be considered a limiting factor as it forces the user to stay wired to something and also invest in another piece of equipment.

CHAPTER 2: REVIEW OF LITERATURE REVIEW AND ANALYSIS

In the literature review portion of this research, two main areas will be covered and analyzed– the effectiveness of VR in teaching or training a skill and the implementation of musical instruments in VR along with the ability of VR to teach a novice how to play a musical instrument. Each of these sections will be crucial to the context of applying the use of VR to teach an individual how to play drum rudiments.

2.1 VR as a Training Tool

A literature review conducted by Chavez and Bayona (2018) examines the use of VR in the learning process. The authors reviewed thirty pieces of literature that were published between the years of 1999 and 2017. In this research, the aim is to identify particular characteristics of VR and how it affects the learning process. The research questions are crucial points that will aid in this study and are as follows:

RQ1: What are the important characteristics or attributes that must be defined for the successful implementation of virtual reality technology?

RQ2: What is the positive effect on the learning process that allows the implementation of a virtual reality technology?

The nature of these research questions and the determinations obtained through extensive literature review will be considered during the development of the *VRumset* application to develop an environment that best aids in the learning process.

The researchers reinforce that some of the most important attributes of VR include immersion, interaction, movement, and animations. While these attributes are ones that they considered generally the most effective, they also noted that the weight of these attributes depended on the area of interest that the VR application was being made for. In an educational setting, for example, immersion is usually of greater importance than it would be in a medical rehabilitation setting to make the simulation as authentic as possible depending on the skill needing to be learned. Overall, however, the researchers discovered that interaction was of utmost importance in many areas of research that they reviewed.

To answer the second research question proposed in this research, the authors discovered a multitude of positive outcomes that resulted from the use of VR in a learning or training environment. Chavez & Bayona state, "The results are highlighted as effects in the learning process of the implementation of virtual reality in order of importance. These are: improving learning outcomes, living experiences that are closer to reality, intrinsic motivation, increasing interest in learning and the skills, such as those most mentioned by the authors." Similarly, to the outcomes relating to the first research question, results conclude that particular positive effects are emphasized more greatly in certain areas of interest than others. These results will also be taken into account during the *VRumset* application design since it has been concluded that many educational settings prioritized immersion when creating a more realistic learning environment.

Additionally, Abich et al. (2021) also conducted a literature review on the effectiveness of VR. According to the researchers, "The goal for this review was to take a domain-agnostic perspective to identify the knowledge, skills, and abilities (KSAs) that have been trained effectively or enhanced with the use of VR." They propose that because VR reaches across several different domains of life, it is important that the effectiveness of this kind of technology to an individual is analyzed. One of the most prominent areas of research that have been analyzed concerning the effectiveness of VR in a training setting is the medical and surgical fields.

A particular area that had pressure to use a more technological approach rather than that of animal training for surgery was microsurgery. The authors recognized that "the appeal of VR technology was based on the potential cost-effectiveness, portability, and safety of training in virtual environments. Of the research mentioned, the general outcome was that performance was found to be significantly better with VR training and resulted in an improved learning curve, faster task completion, and less tissue damage and unnecessary movements compared with non-VR training groups." This aids in the evidence that VR can be a useful training instrument when attempting to learn a new skill.

Additionally, the authors discovered two educational analyses, one centering on the use of VR in basic classroom knowledge and the other in the area of construction engineering. The main highlights found in these two educational studies were the ability to operate in a safe setting and the opportunity for the students to learn outside of their normal routines. Both of these factors, according to the authors, can aid in students' motivation and engagement in an activity.

Other research analyzed by the authors pertained to the use of VR for safety and industrial training. Within the area of safety, the research and systematic evaluation for effectiveness seemed to be quite limited. There were not a significant number of conclusions or points that could be drawn from the use of VR in safety training, as much of the literature that the authors had analyzed described advancements and disadvantages of VR in general training environments. The authors propose that before recommendations are raised for safety training with VR, randomized controlled tests need to be carried out. In the area of industry, the authors reviewed two studies; however, both of the studies were conducted in the early 2000s and therefore lacked updated and current technologies and research surrounding VR. Nevertheless, the specific benefits of VR when used in an industrial setting occurred when the assignments combined visuals and the ability to interact with objects in the environment.

This research found that proof exists for the notion that VR can improve spatial ability, psychomotor capability, and knowledge gain, in training settings. VR cannot be utilized simply to show videos or have the user read a document; it becomes most effective when the user is able to actually interact with their environment. To maximize the usefulness of VR in training environments, instructional methods and task types must also be recognized and further structured. Additionally, a set of standardized approaches should be adopted to adequately aid in the comprehension and evaluation of how effective VR truly is for training purposes within future research.

In addition to understanding the overall effectiveness of VR, it is also crucial to investigating VR within a training environment. An article by researchers Thomsen et al. (2016) examines the use of VR in a medical setting. In their study, the authors tested the ability of a virtual reality cataract surgical simulator to improve skills within the operating room. Between April 2014 and March 2015 nineteen Danish surgeons specializing in cataract surgery were enrolled in this research, with the intent to enroll surgeons of all proficiency levels. The VRmagic EyeSi simulator was utilized for this study and was conducted in Denmark. The surgeons were then required to train on the system until they were able to reach a pass/fail result of 600 points over the period of 2 back-to-back training periods.

The surgeons were required to complete three successive, uncomplicated, cataract operations before and after their training periods. Uncomplicated meaning that the operation was performed under anesthesia, the patient was over the age of 60, and the best-corrected vision with other methods besides surgery for visual acuity of the patient was greater than 1/60 before the operation occurred. The authors utilized the Objective Structured Assessment of Cataract Surgical Skill (OSACSS) scale in order to measure technical performance. Additionally, they were able to test the reliability of this scale using a statistical technique created by other researchers, Cronbach et al. and analyze different kinds of biases that could appear in this study.

The results found that amateur surgeons and those surgeons who had completed less than 75 surgeries showed great improvement in operating room performance. The novice surgeons showed a 32% improvement and the mid-level surgeons garnered a 38% improvement after the virtual reality training. The veteran surgeons, on the other hand, did not seem to gain any improvements with the virtual reality training. Nonetheless, these outcomes proved that skill-level-based virtual reality training could improve both.

2.2 Musical Instrument Implementation in VR

Research conducted by Serafin et al. (2016) introduces the concept of Virtual Reality Musical Instruments (VRMIs). The authors first assign the difference between VRMIs and Virtual Musical Instruments (VMIs), "...we distinguish, on the one hand, between virtual musical instruments (VMIs), defined as software simulations or extensions of existing musical instruments with a focus on sonic emulation, for example, by physical modeling synthesis¨ (Valimaki and Takala 1996) and, ¨on the other hand, virtual reality musical instruments (VRMIs), where the instruments also include a simulated visual component delivered using either a head-mounted display (HMD) or other forms of immersive visualization systems…." This discrepancy is important as there is much more research within the world of VMIs than in the world of VRMIs, perhaps due to how novel and more advanced VR technology is. An interesting aspect of VRMIs is that they can aid VMIs in the manner of adding an immersive experience, which in turn can create a new way to understand and encounter music.

Additionally, the authors have proposed a list of organizational guidelines for developing a VRMI after an extensive review of other existing proposed recommendations. The principles are as follows: design the system for feedback and mapping, lessen latency, avoid cybersickness, employ existing skills, consider both natural and "magical" interaction, consider display ergonomics, create a sense of presence, represent the user's body, and incorporate a social aspect. Each of these principles proposed by the researchers should be considered when creating the *VRumset* application and could help bring the application to its greatest potential. The challenge will be incorporating these principles in order of importance and considering the timeframe given to develop *VRumset*. Specifically, creating a sense of presence, latency reduction, and avoiding cybersickness will be the main principles that will be initially focused on during development.

With regard to evaluation techniques the authors state, "Evaluation of digital musical instruments involves several different parties, including instrument makers, novice and skilled performers, and the audience." The evaluation framework they have created has been created through the nine design principles presented earlier. Additionally, the framework is composed of three different layers. The first layer describes interaction procedures. The second layer of the framework describes cybersickness, virtual body representation, and sense of presence which are all VR-specific points. Finally, the third layer pertains to the standards, objectives, and experience for VRMI users. The standards provided by each of these evaluation layers will be beneficial to consider during and after the creation of *VRumset* as they provide a way to test if the previously stated principles have been implemented to some degree.

The authors conclude that the main hurdle in the field of VRMIs is that more sophisticated VRMIs must be able to be created from present VR music technologies and to do this, feedback through multiple methods, also known as multimodal feedback, and constant physical interactions with the instrument must be put into place. They reinforce that learning a traditional musical instrument takes much practice to master and that practicing techniques could advance through the use of VRMIs. This study is extremely beneficial to understanding the concept of VRMIs, the factors that make a good VRMI, and ways to evaluate if a VRMI has been created effectively.

Research conducted by Yu et al. (2023) describes the importance of educational design regarding VRMIs. The authors state, “Literature has demonstrated that meaningful gestural and bodily interaction that aligned with the instructional material would benefit students' learning..” More specifically, they wanted to test the effectiveness of “the embodied design (low and high level of embodiment; LoEmb and HiEmb) and visual cues (low and high level of visual cues; LoViz and HiViz) on students' musical instrument learning. “ To carry out this research, four virtual Yangqin, a type of stringed instrument, were created. Additionally, 112 college students were inducted into the research and randomly put into four different testing conditions.

The methods of the study involve introducing the participants to the basic music theory and yangqin playing techniques. The participants were then taught the basics of the yangqin’s “string and pitch arrangements” using a familiar Chinse song. The authors were then able to test the students’ skills through the execution of another well-known Chinese song. The researchers then were able to further evaluate the participants’ performance on the yangqin using a Musical skill performance (MSP) test composed of three conditions: Completion rate (CR), Error rate (ER), and Rhythm score (RS). These methods of testing may be useful to consider when conducting the testing phase of research on the *VRumset* application.

When concluding this study, the researchers ascertained that the condition of LoEmb resulted in a greater completion rate, HiViz resulted in greater rhythmic correctness, the combination of LowEmb and HiViz aided in the aided in overall performance and decreased errors, and the combination of HiEmb and HiViz both aided in the reduction of mental workload and improvement in educational effectiveness with learning material among test subjects. These results support the use of visual cues when learning how to play a VRMI. Specifically, markers as visual cues on drumheads and cymbals within the *VRumset* application should aid in the learning process based on the findings from this study. Additionally, the results of this study show that benefits must also be weighed when deciding how to implement an educational design with regard to a VRMI.

Another article by researchers Serafin et al. (2017) details the manner in which VR could serve as a method of teaching musical skills. Specifically, in this case, the researchers have detailed the manners in which those students in K-12 may benefit from the use of music education in VR (and in some cases AR). Some of these include training specific musical skills, such as rhythm, overcoming stage fear, connecting with students in different locations, and teaching music composition.

The researchers begin by noting the current state of music education for students K-12. In Western countries, it has been pointed out that music education has fallen victim to budget cuts and has thus removed the potential advantages that music can bring to children. Additionally, the researchers claim, "Early studies are showing that learning and retention improves significantly in a virtual space. Since the senses are combined a much more immersive visual and physical classroom for learning is provided." Not only this, but VR can also give students living in different locations the ability to connect with one another through music.

Additionally, other commercial and academic applications have been presented along with their prospects in music education. These applications include The Music Room, Soundstage VR, Audioshield: Block the Beats, The WaveVR, and Stage Presence. Each of these applications has been able to successfully combine VR and a musical aspect or instrument. The applications are compatible with either the HTC Vive or Oculus Rift headsets

One interesting application that has not been released commercially showcase a VR drum simulator and VR drum synthesizer, as seen in Figure 1. Figure 2 shows the same drum set inside of a large stadium to presumably help combat stage fear or train stage presence. It should be noted that this application has not yet been utilized for educational motives; however, the authors have stated, "Informal observation showed that children of different ages, from around six years old can easily learn how to play the virtual drums given the intuitive mapping and resemblance to a real drum. Unsurprisingly, they also find the experience entertaining." On the other hand, low-quality haptic feedback was recognized as a problem arising from this application and is considered a crucial element by skillful drummers. This issue is an important factor to consider when creating the *VRumset* application and should potentially be considered a higher-priority feature to be improved upon or implemented.

Figure 1: VR Drum Simulator - A screenshot from the paper *Considerations on the use of Virtual and Augmented Reality Technologies in Music Education* showcasing a VR drum simulation created by one of the authors.

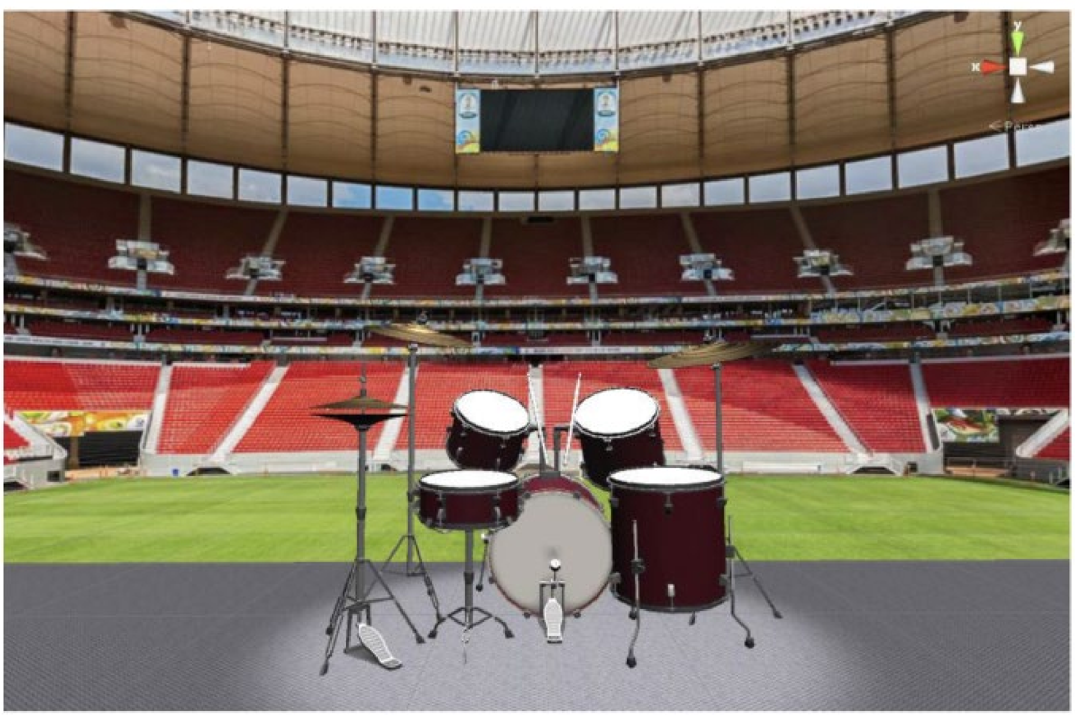

Figure 2: VR Drum Synthesizer - A screenshot from the paper *Considerations on the use of Virtual and Augmented Reality Technologies in Music Education* showcasing a VR drum synthesizer created by one of the authors.

To conclude their research, the authors note the potential of VR and AR to be practical methods of training in the field of music education. The topics covered in this research may aid in the development of *VRumset* in ways such as including what features should and should not be prioritized. For example, the issue of low-haptic feedback considered a crucial element of playing the drums by experts should be a high-priority attribute (Lang, 2019). On the other hand, a lower priority feature may be the subject of overcoming stage fear. This is due to the nature of *VRumset* being an application that targets novices who want to learn how to play an instrument rather than those who would like to train in the performing aspect of music. Nonetheless, all of these elements are important in recognizing the manners in which VR can support those who are interested in music education or performance.

2.3 Similar Applications

It is important to review what kind of similar VR applications have been created and if there is a teaching component attached to them to properly assess what kind of technology is available for this area of interest and what can be done to improve upon these applications. Currently, few similar VR drumming applications exist. Each of these applications seems to target the entertainment side of drumming and music. However, one or two of these applications do include some sort of educational component, which is the focus that inspiration will be drawn from when creating the *VRumset* application. Additionally, some of these applications offer pedal support to be able to use and control the hi-hat and kick drum more authentically. At least one application even offers hit velocity parameters, the notion of adjusting the sound based on how hard the drumhead or cymbal is hit, to make the hitting of the drum set sound more realistic.

The first drumming VR application that will be discussed is an application called

Paradiddle. *Paradiddle* offers a wide variety of features including a teaching component that walks the user through ten drum lessons, hit velocity to allow the system to recognize how hard the user hits the virtual drumhead or cymbal, the ability to record the session, load songs of the user's choosing, and more (Lang, 2019). *Paradiddle* was created using the Unreal Game Engine 4 and the audio system was created using FMOD Studio. In Figure 3, a screenshot showcases the environment and setup that *Paradiddle* offers. The use of markers is a feature that will be included in the *VRumset* application.

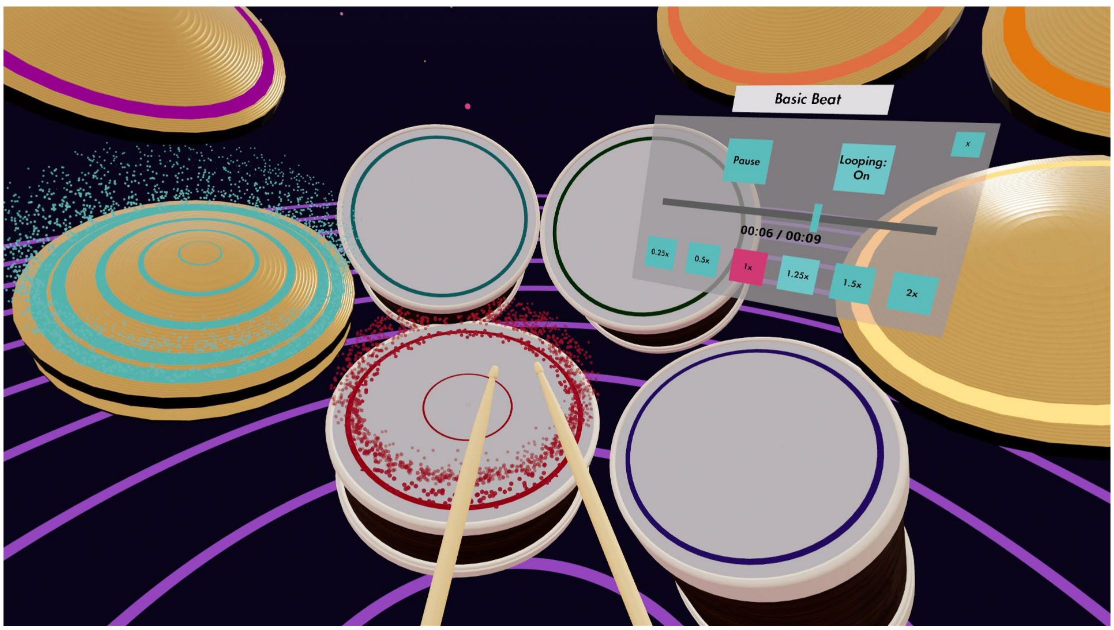

Figure 3: *Paradiddle* Application - A screenshot showcasing the *Paradiddle* VR drumming application.

Another VR drumming application is called *DrumBeats VR*. *DrumBeats VR* allows the user to play in a variety of different scenes and gives access to a few different kinds of drum kits. This application does not seem to focus on an educational aspect of drumming, but rather more for entertainment purposes. It does, however, give the user rings or markers on when to hit a particular drumhead or cymbal as the song progresses, which may be considered a form of teaching to some. The rings that appear around each cymbal and drumhead are similar to how the markers will appear in the *VRumset* application to allow the user to know when to hit. Figure 4 shows the style that the

DrumBeats VR application takes when allowing its users to play songs. A series of color-coordinated, highlighted markers appear to be coming at the user in a sequence that will line up with each cymbal and drumhead.

Figure 4: *DrumBeats VR* Application - A screenshot of the *DrumBeats VR* application showcasing the particular functionality of guiding the user through a song.

According to reviews from Steam.com on the *DrumBeats VR* application, one of the biggest issues that critics had with this application was the functionality of the drums– in particular, the hit detection. Other reviewers stated that they would like to see support added for external pedals. Although this application does not directly take an educational approach to playing the drums, the reviews will aid in how the *VRumset* application is developed and how these issues may be improved upon.

The last application that will be reviewed in this research is titled *Smash Drums Demo*. *Smash Drums Demo* does not seem to offer a specific educational aspect to playing the drums but rather allows the user to play along to different rock songs with a chosen scale of difficulty. Figure 5 shows the *Smash Drums Demo* environment along with the different gameplay modes and the user's score or ratings in each mode.

Although this application does not have an educational focus, it is useful to see how the developers created this application and what aspects of the application can be drawn from, such as the UI or environments. One element that may be important in the construction of the *VRumset* application is the choice of font. The font used in the UI of the Smash Drums Demo is a bit hard to read and could be improved upon by choosing a font that is clearer for the user to read.

Figure 5: *Smash Drums Demo* Application - A screenshot of the *Smash Drums Demo* application showcasing the UI for the different types of game modes and difficulty rating based on the user's performance.

The applications that have been reviewed aid in understanding what is available to those who are interested in learning how to play the drums. Each of these applications provides valuable insight into what can be improved upon or drawn from to make the *VRumset* application as effective as possible. The next section will take a deeper look into the effectiveness of VR in teaching or training a user in a particular skill and the research that has been done relating to musical instrument adaptation within VR.

CHAPTER 3: METHODOLOGY

The goal of this project was to develop a VR drum set with an educational component to teach users five drum rudiments. For this application, the Unity game engine has been utilized for development. This is software that provides built-in features such as 3D rendering, collision detection, and physics to build the system (Sinicki, 2021). User-made assets, such as 3D models, have been employed to build the environment, drum set, and drumsticks. In addition, a collection of audio and visual assets has been used to create the sounds for the drum set, environment, and user interface (UI). The following sections will go into greater detail regarding the components and tools that have been used to build the application for this research.

3.1 Models

The models utilized in this application are models that have been found online, both free and those that come with a fee. The drum set that has been used comes from Batería / Drum Set by johnathanborges3d on the modeling platform website Sketchfab.com. The drumsticks that have been utilized come from GrabCAD.com by the artist David Belovic. The drumsticks will appear on their own in the simulation without hand visuals in order for the user to better see the drums without a pair of virtual hands in their field of view. Any other models utilized add to the ambiance and feel of the virtual studio in which the application is set.

3.2 Environment

The environment for this application is set in a music studio-like room. The other assets that will exist in this environment are textures and other models to make the user feel as if they are in a music studio environment. The lighting will be moody but bright enough for the user to see the drum set and follow the markers used in each drum lesson.

Figure 6 shows the early stages of the environment and the placement of the drum set in the *VRumset* application.

Figure 6: *VRumset* Preliminary Environment - A screenshot of the preliminary stages of the *VRumset* application environment.

3.3 Audio

The audio assets that have been used in this application include a sound byte that correlates to the hi-hat, both closed and open, the snare drum, the kick drum, the tom drums, the floor tom, the ride cymbal, and the crash cymbal for each drum. A sample of each complete rudiment will be available for the user to listen to within the rudiment scene or stage. In addition, there is a short sound that denotes when the user has completed a rudiment.

3.4 Scripts & Framework

There are a series of scripts that have been used to make this application function. The UltimateXR framework is an open-source tool that aids in the VR development process. UltimateXR allows developers to create VR applications that allow the user to easily grasp and handle objects, provide tools to make development easier, and provide advanced UI components. In addition to this, there are scripts that handle the progression between scenes or rudiment stages. Other scripts include those that allow for audio to be heard from the drum set when the user strikes a drumhead, cymbal, or pedal, logic for the markers appearing in the correct order, and accuracy tracking. Additionally, a script that logs date/time, accuracy, final total hits, and number of correct hits at a constant rate throughout each rudiment. The framework of the log script was provided by Andrew Lawson, a Computer Science student from UNCW. A raw sample of the accuracy tracking log can be seen in Figure 7.

```
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 85.82677%    Final Total Hits: 127   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 84.49612%    Final Total Hits: 129   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 84.49612%    Final Total Hits: 129   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 84.49612%    Final Total Hits: 129   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 83.20611%    Final Total Hits: 131   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 83.20611%    Final Total Hits: 131   Final Total Correct Hits: 109
2023-09-26T11:11:55    Accuracy: 83.20611%    Final Total Hits: 131   Final Total Correct Hits: 109
```

Figure 7: *VRumset* Accuracy Sample Tracking Log - A raw sample of an accuracy tracking log showcasing the date/time, accuracy, final total hits, and final total correct hits.

3.5 Application Development

Development for the *VRumset* application occurred between the end of May 2023 and mid-September 2023. A virtual journal was kept to record the progress of the application during each day that it was worked on. This journal helped to provide a good summary of what features of the application were being built and what challenges were being faced. The lobby of the application was built first to give the user a hub where they could watch a tutorial, select from a list of rudiments, or go to free play. Figure 8 shows the lobby of the application where the user may listen to a tutorial, choose a rudiment to begin practicing or go to the “free play” scene. Figure 9 displays the UI on the tablet that allows the user the option to begin practicing, watch a rudiment guide, choose a different rudiment to practice, or go back to the lobby. Figure 10 displays the UI on the tablet when the user has completed a rudiment and shows their accuracy. Figure 11 shows the video guides that appear within each rudiment scene that serve to provide the user with insight into the pattern they will play when they actually begin to practice. Figure 12 shows the marker around the snare drum that indicates which hand the user is meant to strike with.

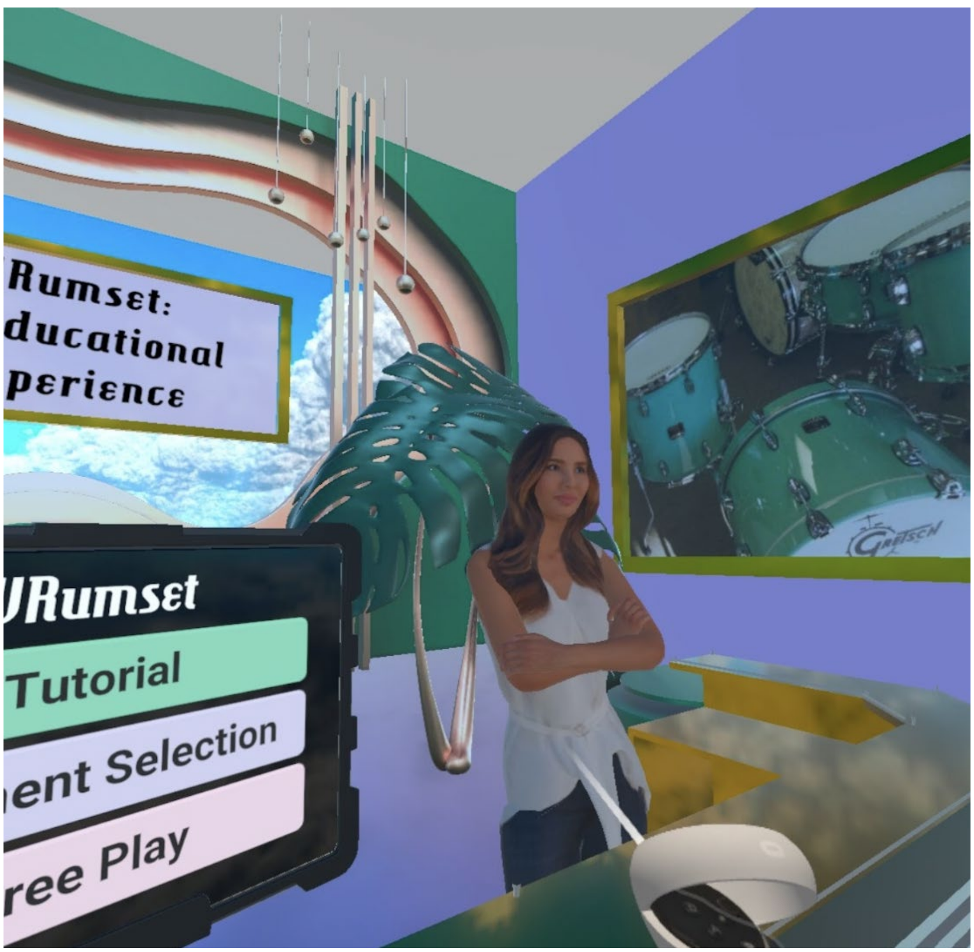

Figure 8: *VRumset* Lobby - A screenshot from the *VRumset* application of the lobby.

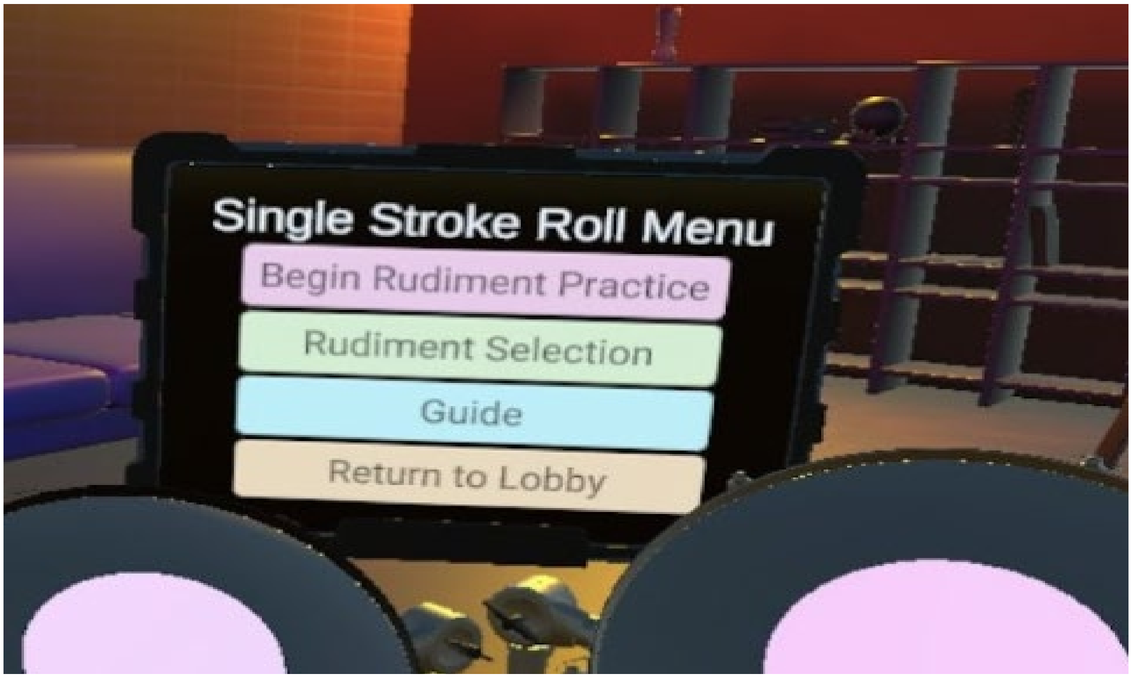

Figure 9: *VRumset* Rudiment Main Menu UI - A screenshot from the *VRumset* application showcasing the UI that appears on the tablet within each rudiment scene.

Figure 10: *VRumset* Rudiment Accuracy UI - A screenshot from the *VRumset* application displaying the accuracy UI that appears on the tablet after a rudiment is complete.

Figure 11: *VRumset* Rudiment Video Guide - A screenshot from the *VRumset* application, displaying the video guides that appear on the tablet within each rudiment scene.

Figure 12: *VRumset* Rudiment Practice - A screenshot from the *VRumset* application showing rudiment practice in progress.

CHAPTER 4: RESULTS

Testing has been executed in the form of qualitative and quantitative trials using a Meta Quest 2 VR headset. The first analysis involved using a survey to determine experience with drumming and VR, how effective users believe the *VRumset* application is at teaching a drum rudiment, and overall opinions regarding their experience with the application. Furthermore, the second study logged users' accuracy while they learned each of the five rudiments. An examination of the logs has been determined to understand the averages of accuracy by the participants for each of the rudiments.

The study group for the testing purposes of this application was aimed at both undergraduate and graduate-level Computer Science students. Participants were collected through an email sent out to the Computer Science graduate student body and an announcement on Canvas to the students enrolled in the Object-Oriented Programming course. Testing for this project occurred between September 25 and October 11. By the end of the testing period, 25 subjects completed the rudiments in the application and the post-survey.

4.1 Post-Survey Analysis

The survey that has been utilized for the section of this study consists of twenty-four questions to determine the quality of the experience by the user. Appendix A shows the survey questions that were asked of the subjects after completing the tasks required in the *VRumset* application. Many of the questions have originated from the NASA Task Load Index (NASA-TLX) and the System Usability Scale (SUS) tools. The NASA-TLX assessment, shown in Appendix B, is useful for understanding the mental load of the application on a subject. The SUS is useful for understanding and measuring the usability of the application. Appendix C displays the SUS assessment tool. There are calculations that can be performed using both the NASA-TLX and the SUS. However, due to the scale of the survey questions used for the NASA-TLX questions and the improper use of all questions for the SUS, those calculations will not be performed in this paper as they could not be entirely accurate without the use of all the questions and the correct graduations.

However, the Likert scale was used for the majority of the NASA-TLX and SUS-inspired questions. Thus, the general feeling or attitude of the participants towards each individual question and the system as a whole can be determined from the results obtained by calculating the Likert scale scores. The results from this calculation will allow for the understanding of how the participants felt towards their experience with the *VRrumset* application and may aid in understanding the viability of this application teaching a novice how to play five drum rudiments.

The first five questions serve to understand some useful characteristics regarding the participants such as their drumming and VR experience. 88% of the participants indicated that they were right-handed. The survey results then established that 88% of the participants had never taken drum lessons before. Additionally, 88% ranked their experience with drumming as a 0 or a 1 on a scale of 0 to 5. An answer of 0 or 1 indicated either no experience at all or an extremely low familiarity with drumming. The high proportion of those who had little to no experience with drumming was desirable as they matched the demographic that the *VRumset* application targets. With regard to VR experience, 80% of participants indicated that they had utilized VR technology in the past. The *VRumset* application does not necessarily target those with or without VR experience. However, it could be possible that those who have used VR in the past are more likely to try a VR application such as this one.

The next fifteen questions served to understand the mental workload of the subject and the usability of the application. A subject to be noted with regard to question 11, "There was too much inconsistency in this application" had a flipped scale that resulted in confusion expressed by the participants on how to answer the question. The reason for the flipped scale was to try and make sure that the participants were reading through the survey questions carefully. However, instead of using a question that produces meaningful data for the study, a different question that asked something more obvious should have been used to gauge whether or not a participant was answering the survey thoroughly. Thus, the question should be excluded from the examination as the confusion of the participants caused it to make the question provide valuable data.

Appendix D shows the Likert scale calculations made for each of the fourteen Likert items. Table 1 displays the scoring range that was utilized for the Likert scale calculations. Based on the scores received from these calculations, participants generally indicated that the mental demand to use this application was low (2.08) and the physical demand was very low (1.48). Most participants believed that with regard to their success in completing all five rudiments was above average (3.92). The participants generally felt that their discouragement, aggravation, and stress levels were very low (1.36) while using this application.

Table 1: Likert Scale Scoring Range

	Value	Range
Strongly Disagree / Very Low	1	1.00 - 1.80
Disagree / Low	2	1.81 - 2.60
Neutral / Neutral	3	2.61 - 3.40
Agree / High	4	3.41 - 4.20
Strongly / Very High	5	4.21 - 5.00

The scoring range of the Likert scale used for this research.

The rest of the fourteen questions revolve around the usability of the application. Generally, the participants strongly disagreed (1.40) that the application was difficult to use. Additionally, they strongly agreed (4.36) that most people could learn how to use this application easily and they strongly disagreed (1.24) that they needed to learn a lot of things before using the application. A majority of the participants felt neutral (3.16) on whether or not they would frequently use this application. The readability of the font size had a neutral (3.08) score. The participants strongly agreed (4.84) that the colors used in the application were adequate enough to easily distinguish the environment. They also agreed (3.76) that the video tutorials that appeared in the application were helpful.

Outside of the usability of the application, the subjects agreed (4.12) that their knowledge with regard to learning drum rudiments had increased after using the *VRumset* application. Finally, the participants also agreed (4.02, 3.84) that they could apply what they learned from the *VRumset* application to a real drum set and would be interested in continuing to learn how to play drums after using this application.

An overall sentiment score may be calculated for the fourteen questions. However, some of the questions (#1, #2, #4, #5, and #8) are stated in a manner in which a lower ranking on the scale is considered positive. For example, an answer of "Very Low" is considered positive with regard to question 1, "How mentally demanding was it to use this application?" Thus, the easiest way to normalize these questions is to restructure the responses in the same manner as the majority and reperform the Likert scale calculation. The equation for the calculation of the overall sentiment score for these questions is calculated as shown in Figure 13. The score of 3.94 received from the overall sentiment score indicates that the participants felt mildly positive towards the *VRumset* application.

Question #1 (3.56) + Question #2 (4.52) + Question #3 (3.92) + Question #4 (4.64) + Question 5 (3.60) + Question 6 (4.36) + Question 7 (3.16) + Question 8 (3.76) + Question 9 (3.08) + Question 10 (4.84) + Question 11 (4.12) + Question 12 (4.02) + Question 13 (3.84) + Question 14 (3.76) = 55.18 / 14 questions = 3.94

Figure 13: *VRumset* Survey Likert Calculation - The calculation to display the overall sentiment score for the fourteen questions.

The short answer questions aimed to understand what the participants liked and did not like about the application, suggestions for improvement, and any bugs that they experienced while using the application. Most of the participants indicated that they liked the environment and the simplistic nature of the instructions. On the other hand, the participants indicated that they did not like the audio and visual lag that could occur and the font size of the text that appeared on the tablets. With regard to improvement, the participants indicated that they would like to see more complex rudiments, utilization of other parts of the drum set, an increase in the text size for better readability, a fix for the lag to create more responsive hits on the drum, and a timing element such as a metronome. As for the bugs that were discovered during the use of the application, the subjects indicated that they experienced freezing, sequence numbers overlapping or becoming stuck even when striking correctly, lag in the visual guides, and delays with buttons on the menus.

It should be noted that Participant #7, an individual who was an experienced drummer, indicated verbally that they did not believe that the application was of any benefit for them. Additionally, in the post-survey, the subject indicated that their knowledge with regard to drum rudiments and whether or not they would use the application again was very low. Although it would have been beneficial have more than one experienced drummer try out the VRumset application, this does support the aim of this application towards novices rather than someone who is more experienced. Additionally, this participant's overall rudiment accuracy was 67.60%. This is to be expected as the participant most likely played at a speed with which the system could not keep up.

4.2 Accuracy Logging Analysis

The accuracy logging study took into account the hit accuracy of the user within a one-minute time period. This time allocation should allow the user to have an adequate amount of time to complete multiple rounds of a rudiment, either successfully or unsuccessfully. The results from the quantitative portion of this study indicate the average accuracy among all participants. Additionally, the individual average accuracy results of each participant have been calculated. Table 1 shows the rudiment accuracy average and the individual participant average, as well as individual accuracies for each participant within each rudiment.

In this first rudiment completed by the participants, Single Stroke Roll, it is shown that the average accuracy (81.94%) is the lowest average of any of the five rudiments. This is most likely the result of the participants adjusting to the VR controls and environment. In the next rudiment, the Double Stroke Roll, the average accuracy

(98.42%) is significantly higher than the Single Stroke Roll rudiment average accuracy. Presumably, this is because the participants became more comfortable in their environment and using the VR controls.

The last three rudiments: Flam, Paradiddle, and Double Paradiddle show rudiment average accuracies (93.01%, 92.18%, and 92.62% respectively) that are relatively similar. They are, however, lower than that of the Double Stroke Roll rudiment average accuracy. There are two potential reasons for the lowered accuracies of these last three rudiments. The first reason is that bugs within the application such as freezing, lagging, and marker glitching were reported most often by the participants both verbally and in the free response portion of the post-survey with regard to these last three rudiments. The second possibility for the lower scores could be that the rudiments became increasingly complicated, with Single Stroke Roll being the most simplistic and Double Paradiddle being the most complex.

When analyzing the participant accuracy averages, the scores across each rudiment for a particular participant seem to be relatively close in nature. Individually, however, some participants had high accuracies in a few rudiments and then very low accuracies in other rudiments. This is presumably due to the participant experiencing one or more of the bugs mentioned previously in that given rudiment. Additionally, the lower accuracy scores could be due to the participant accidentally moving around in the scene and losing their place in front of the drumset.

Lastly, Table 3 showcases what the rudiment accuracy results look like when Participant #7, the experienced drummer, and outliers are removed from the table. When the outliers are removed, it can be seen that all of the rudiment averages slightly increase, although not by an extremely significant amount. It is still important to showcase these results with the outliers removed as we are able to see what kind of impact they really made to the original data.

Table 2: Accuracy Logging Results

	Single Stroke Roll %	Double Stroke Roll %	Flam %	Paradiddle %	Double Paradiddle %	Participant Average
Participant #1	100.00%	100.00%	80.49%	91.67%	94.37%	**93.30%**
Participant #2	85%	98.85%	97.73%	100.00%	100%	**96%**
Participant #3	100.00%	100.00%	100.00%	100.00%	100%	**100.00%**
Participant #4	**NaN%**	96.77%	99.34%	90.91%	94.79%	**95.45%**
Participant #5	98.88%	100.00%	100.00%	97.85%	100.00%	**99.35%**
Participant #6	100%	100.00%	95.88%	100.00%	98.94%	**99%**
Participant #7	86.96%	95.33%	16.87%	79.78%	59.09%	**67.60%**
Participant #8	93.68%	98.84%	91.60%	87.10%	96.20%	**93.48%**
Participant #9	88.89%	100.00%	94.03%	94.23%	93.62%	**94.15%**
Participant #10	51.35%	99.63%	93.06%	57.02%	52.88%	**70.79%**
Participant #11	93.75%	93.24%	93.18%	85.05%	98.01%	**92.65%**
Participant #12	82.61%	97.47%	95.72%	67.60%	88.18%	**86.32%**
Participant #13	3.33%	97.87%	**NaN%**	100.00%	**NaN%**	**67.07%**
Participant #14	50.13%	91.54%	98.17%	86.05%	88.64%	**82.91%**
Participant #15	90.28%	97.75%	99%	98.84%	99.07%	**96.98%**
Participant #16	100.00%	100.00%	94.59%	98.73%	96.84%	**98.03%**
Participant #17	100.00%	100.00%	97.14%	95%	100.00%	**98.43%**
Participant #18	100.00%	98.73%	97.18%	96.81%	98.91%	**98.33%**
Participant #19	98.36%	100.00%	100.00%	98.55%	95.71%	**98.53%**
Participant #20	69.85%	99.24%	99.35%	88.83%	77.46%	**86.95%**
Participant #21	99.19%	100.00%	99.30%	97.09%	99.23%	**98.96%**
Participant #22	100.00%	100.00%	100.00%	100.00%	100.00%	**100.00%**
Participant #23	68.67%	96.19%	90.91%	95.65%	98.92%	**90.07%**
Participant #24	79.17%	99.06%	100.00%	98.96%	97.17%	**94.87%**
Participant #25	26.67%	100.00%	98.86%	98.89%	94.74%	**83.83%**
Rudiment Average	**81.94%**	**98.42%**	**93.01%**	**92.18%**	**92.62%**	**91.63%**

This table showcases the overall average accuracy obtained for each rudiment and the individual accuracy averages of each participant

Table 3: Accuracy Logging Results with Outliers Removed

Participant #1	100.00%	100.00%	80.49%	91.67%	94.37%	**93.30%**
Participant #2	85%	98.85%	97.73%	100.00%	100%	**96%**
Participant #3	100.00%	100.00%	100.00%	100.00%	100%	**100.00%**
Participant #4	**NaN%**	96.77%	99.34%	90.91%	94.79%	**95.45%**
Participant #5	98.88%	100.00%	100.00%	97.85%	100.00%	**99.35%**
Participant #6	100%	100.00%	95.88%	100.00%	98.94%	**99%**
Participant #7	**86.96%**	**95.33%**	**16.87%**	**79.78%**	**59.09%**	**67.60%**
Participant #8	93.68%	98.84%	91.60%	87.10%	96.20%	**93.48%**
Participant #9	88.89%	100.00%	94.03%	94.23%	93.62%	**94.15%**
Participant #10	51.35%	99.63%	93.06%	57.02%	52.88%	**70.79%**
Participant #11	93.75%	93.24%	93.18%	85.05%	98.01%	**92.65%**
Participant #12	82.61%	97.47%	95.72%	67.60%	88.18%	**86.32%**
Participant #13	**3.33%**	97.87%	**NaN%**	100.00%	**NaN%**	**67.07%**
Participant #14	50.13%	91.54%	98.17%	86.05%	88.64%	**82.91%**
Participant #15	90.28%	97.75%	99%	98.84%	99.07%	**96.98%**
Participant #16	100.00%	100.00%	94.59%	98.73%	96.84%	**98.03%**
Participant #17	100.00%	100.00%	97.14%	95%	100.00%	**98.43%**
Participant #18	100.00%	98.73%	97.18%	96.81%	98.91%	**98.33%**
Participant #19	98.36%	100.00%	100.00%	98.55%	95.71%	**98.53%**
Participant #20	69.85%	99.24%	99.35%	88.83%	77.46%	**86.95%**
Participant #21	99.19%	100.00%	99.30%	97.09%	99.23%	**98.96%**
Participant #22	100.00%	100.00%	100.00%	100.00%	100.00%	**100.00%**
Participant #23	68.67%	96.19%	90.91%	95.65%	98.92%	**90.07%**
Participant #24	79.17%	99.06%	100.00%	98.96%	97.17%	**94.87%**
Participant #25	26.67%	100.00%	98.86%	98.89%	94.74%	**83.83%**
Rudiment Average	**85.28%**	**98.55%**	**96.33%**	**92.70%**	**94.07%**	**93.39%**

This table showcases the overall average accuracy obtained for each rudiment and the individual accuracy averages of each participant after the outliers have been removed

CHAPTER 5: CONCLUSIONS AND FUTURE WORK

In this research, the aim was to answer the question, “Can Virtual Reality (VR) be used to teach a novice musician drum rudiments?” A literature review was conducted on other works exploring the use of VR with regard to instruments, however, is still lacking a lot of broad research. Based on the qualitative portion of the study which produced results obtained from the Likert scale calculation, it was found that the attitude towards the *VRumset* application was generally positive. The quantitative portion showed relatively consistent and decent accuracy scores for each rudiment as well, indicating that generally the participants were able to complete the rudiments with good accuracy. On the other hand, there should be improvements to the application especially with regard to the lagging and responsiveness of the system. The results of this work show that VR is a viable option to learn drum rudiments for those with little to no experience in drumming.

5.1 Future Work

The future work of this project would entail fixing elements that many testing subjects found to be a bug or issues, especially those that pertain to lag and the font size that appeared within the application. Additionally, incorporating a new testing method that involves having participants use the VRumset application and then are given a real drum set to determine whether or not they could apply what they learned from using the application to a physical drum set.

There is a potential new research question that has arisen from the work done in this study. The recreation of this project within an Augmented Reality (AR) environment may garner an ideal combination of both technology and the real world to learn drum rudiments. An AR application that incorporates the use of markers that appear around a real drumhead on a drum set to indicate to the user when to strike would allow the user to have a truer kind of force-feedback which is truly needed to advance one's drumming skills.

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APPENDIX A

VRumset Post-Survey

The purpose of this survey is to gain feedback regarding the usability and design of the *VRumset* application. Thank you for trying out *VRumset* and answering these survey questions!

Your participation is voluntary. You may refuse to participate or may refuse to answer any question. You may stop at any time without penalty.

* Indicates required question

1. Are you left-handed or right-handed?

* *Mark only one oval.*

* *Mark only one oval.*

1 2 3 4 5

Very Low

* *Mark only one oval.*

	1	2	3	4	5
Strongly Disagree					

24. Did you experience any issues (i.e. bugs, freezing, inconsistencies) while using the application? If so, please describe the issue(s). *

APPENDIX B

Figure 8.6

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand How mentally demanding was the task?

Very Low Very High

Physical Demand How physically demanding was the task?

Very Low Very High

Temporal Demand How hurried or rushed was the pace of the task?

Very Low Very High

Performance How successful were you in accomplishing what you were asked to do?

Perfect Failure

Effort How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low Very High

APPENDIX C

System Usability Scale

© Digital Equipment Corporation, 1986.

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

APPENDIX D

Question #1 How mentally demanding was it to use this application?			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Very Low	1	9	9
Low	2	8	16
Neutral	3	6	18
High	4	1	4
Very High	5	1	5
Likert Score			2.08 (Low)
Question #2 How physically demanding was it to use this application?			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Very Low	1	15	15
Low	2	8	16
Neutral	3	2	6
High	4	0	0
Very High	5	0	0
Likert Score			1.48 (Very Low)
Question #3 How successful do you believe you were in completing all five rudiments?			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Failure	1	0	0
Below Average	2	1	2
Average	3	5	15
Above Average	4	14	56
Success	5	5	25
Likert Score			3.92 (Above Average)
Question #4 How discouraged, stressed, or annoyed were you while using this application?			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Very Low	1	18	18

Low	2	5	10
Neutral	3	2	6
High	4	0	0
Very High	5	0	0
Likert Score			1.36 (Very Low)
Question #5 This application was difficult to use.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	18	18
Disagree	2	5	10
Neutral	3	1	3
Agree	4	1	4
Strongly Agree	5	0	0
Likert Score			1.40 (Strongly Disagree)
Question #6 Most people could learn how to use this application easily.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	0	0
Disagree	2	0	0
Neutral	3	1	3
Agree	4	14	56
Strongly Agree	5	10	50
Likert Score			4.36 (Agree)
Question #7 I would use this application frequently.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	3	3
Disagree	2	1	2
Neutral	3	12	36
Agree	4	7	28
Strongly Agree	5	2	10

Likert Score			3.16 (Neutral)

Question #8 I needed to learn a lot of things before using this application.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	19	19
Disagree	2	6	12
Neutral	3	0	0
Agree	4	0	0
Strongly Agree	5	0	0
Likert Score			1.24 (Strongly Disagree)
Question #9 The text size that appeared in this application was readable.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	3	3
Disagree	2	7	14
Neutral	3	5	15
Agree	4	5	20
Strongly Agree	5	5	25
Likert Score			3.08 (Neutral)
Question #10 The colors used in this application were adequate enough to easily distinguish the environment.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	0	0
Disagree	2	0	0
Neutral	3	0	0

Agree	4	4	16
Strongly Agree	5	21	105
Likert Score			4.84 (Strongly Agree)

Question #11 My knowledge, with regard to learning drum rudiments, has increased after using this application.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	1	1
Disagree	2	1	2
Neutral	3	3	9
Agree	4	9	36
Strongly Agree	5	11	55
Likert Score			4.12 (Agree)
Question #12 I could apply what I learned from using this application to a real drum set.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	0	0
Disagree	2	3	6
Neutral	3	3	9
Agree	4	8	32
Strongly Agree	5	11	55
Likert Score			4.02 (Agree)
Question #13 I would be interested in continuing to learn how to play drums after using this application.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**

Strongly Disagree	1	0	0
Disagree	2	1	2
Neutral	3	7	21
Agree	4	12	48
Strongly Agree	5	5	25
Likert Score			3.84 (Agree)

Question #14 The video tutorials that appeared in this application were helpful.			
Sentiment Level	**Numerical Value**	**Responses**	**Total**
Strongly Disagree	1	0	0
Disagree	2	4	8
Neutral	3	7	21
Agree	4	5	20
Strongly Agree	5	9	45
Likert Score			3.76 (Agree)