Creating Music with Virtual Reality

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Abstract

Virtual Reality is an ever-expanding technology, with a vast market for related hardware and software to be explored. This being said, if you are looking to explore the field of music creation at this point in time, Virtual Reality is not the place to go. Over the recent years that Virtual Reality has soared in popularity, Music themed games have appeared. The majority being rhythm based or novelty. This prototype software attempts to address this by letting users explore and learn the world that is real music creation with immersive instruments and learning tools. Two evaluations have been conducted over the course of the project and have shown that the system is very usable and has interest for further development in the area.

1 Introduction

Virtual reality is not a new technology, however with all of the recent advancements in hardware and other technologies Virtual Reality has sky-rocketed in popularity in the recent years.

The VR community has been hit with a massive influx of games being adapted for VR due to the incline in popularity. Examples of this are Superhot VR [1] and Skyrim VR[2]. Both games original versions are huge successes when it came to the original ship but decided to create a Virtual Reality adaption. Aside from these large game development companies the Indie game market for VR is thriving also, if you search on the steam marketplace [3] for the tag “VR” and “Indie” there are 2’726 games ready and available to download.

The aim of this project is to explore the potential of creating music in virtual reality. While there are music themed games in VR already, they tend to be more rhythm focused rather than a simulation of actual instrument functions. This software serves as a tool to let users play with instruments in a virtual space, giving them the freedom to explore and learn more about certain note structures and instruments using in game hints and tool tips. The software is modelled after a music studio where they would have the instruments lying around for band members to use on their own free will.

This report provides the background information on Virtual Reality, including its history, uses in the present day and how music is used in the technology. An overview of the project, leading into the methodologies and hardware that were used and the reasoning behind their choices. Initial ideas followed by a user survey that was carried out to give these initial ideas direction and priority. The system was evaluated using a design evaluation in the early stages. Post feedback ideas and implementation of the system sections are next concluded by a final task-based evaluation where the users will complete tasks, have a short discussion and fill out a SUS (system usability scale) and possible starting points for future work.

2 Background

2.1 History of VR

The idea of Virtual Reality or an “Artificial Reality” can be tracked the whole way back to roughly the 1960’s when Morton Heilig created a multi-sensory simulator called the Sensorama. This played pre-recorded film and sound, aided with scent, wind and senses of vibration to make the user feel like they are truly experiencing the film.

Sword of Damocles
Ivan Sutherland proposed an "ultimate solution" for virtual reality[4]. An artificial world construction concept that would include graphics that were interactive with feedback, sound smell and taste. This leads us to the next advancement which is "The sword of Damocles" the first VR system created with hardware. Ivan Sutherland constructed a device which is considered as the first Head mounted Display that implemented tracking[5]. This HMD was suspended from the ceiling hence its name "The sword of Damocles" referencing the ancient Greek story where a sword over people's heads.

Figure 1 Sword of Damocles

VCASS

1980s when Thomas Furness at the US Air forces research labs developed an airborne systems simulator called the VCASS[6]. Giving pilots a way to simulate flight. These pilots wore head mounted devices that augmented out of window views describing flight path and targeting information. When technologies get adapted by the military the standard and quality of the technology usually skyrocket.

Figure 2 Vcass

This was a big leap and started to shape the way VR and HMD's were designed going into the future.

Boom
The Boom was commercialized in 1989 by the Fake Space Labs[6]. Boom is a small box containing two monitors that you view through eye holes. The user grabs this box and keeps it by their eyes as they move around to navigate the virtual world, while they move a mechanical arm measure their position and orientation of the box.

Virtual Wind Tunnel.
Made in 1990s by NASA the Virtual wind tunnel allows the observation and investigation of flow fields with the help of BOOM and Data Glove[6]

Cave
The 1992 cave (CAVE Automatic virtual Environment) is a virtual reality and specific visualization system. Instead of using head mounted displays it projects stereoscopic images[6].

All of these advances greatly enhanced the user experience especially spatial audio allowing immense amounts of sound depth and variability via different sound levels through each ear mimicking distance and location to keep up immersion. The technology was quickly picked up by games companies like Nintendo from the 90s onwards but one development in the 21st century really skyrocketed the popularity of VR development.

Oculus Rift
In 2010 a 17 year old student who loved VR named Palmer Luckey developed his first prototype of the Oculus Rift a HMD that solved the problems of Latency, weight and quality. He then displayed it at E3 and got the product funded for over 9x its goal. Two years later the Rift debuted. This blazed the trail for other mainstream devices to be created as the target audience was interested.[7]

HTC Vive
Phil Chen, the CCO for HTC[8] explains that he stumbled upon VR, then by chance HTC

met the games company Valve, In June 2016 after the popularity of the Oculus Rift, HTC released their "Business Edition" of the Vive for $1200 which produced many professional license and warranties. Later, in November 2016 HTC announced a tether-less VR upgrade kit made by TPCAST with a price of $249. Most recently in 2017 Vive released details on a finger tracking controller called the knuckles, Which would detect finger movements creating an enhanced immersion when it comes to using specific objects in VR.

Figure 3 HTC Vive

2.2 VR in present day

Virtual Reality (VR) is a computer generated simulation that replicates the real world using various media, this type of entertainment tries to immerse people while surrounding them with familiar real world functionality. VR has been gaining more and more traction in recent years with the huge technological advances that the industry has made. For example, the HTC Vive, affordable options like google cardboard[9] and other types of easily accessible tech.

Figure 4 Google Card

The uses of VR have kept growing over the recent years from gaming to job teaching wherever VR can be implemented people are trying it. For example the university of Louisville use VR in cognitive behaviour therapy to treat patients with anxiety's or phobias like flying or heights.

On the other side of the field VR gaming is starting to become more accessible and more affordable so more large publishers have been creating VR games or VR versions of their games. The biggest example as of very recently is Valve bringing out a new game to the half-life series, one of the biggest pc gaming series ever made[10]. People have been waiting for this addition to the series for 13 years just for valve to tell everyone it's a VR only game, Very conveniently released along the same timeline as Steam (valves parent company) releases their own VR headset.

Figure 5 Valve Index

In 2017 steam had around 1000 VR games on its market, as of today in the first quarter of 2020 there are 3785 games on the market. This shows that there is a steady demand and rise in popularity for these games. Compared to 2017 many of the games now released are fully polished rather than being people's attempts at using VR technology.

2.3 Music in VR

In the music field VR has been used mostly to make rhythm games with the biggest example being beat sabre. A game where each controller is used as a sword and you swipe at blocks in specific directions that appear in time with a backing track. There have been some games such as playthings [11] that was released 4 years ago in 2016 where you use drumsticks to hit various objects like hot dogs or plants to make music.

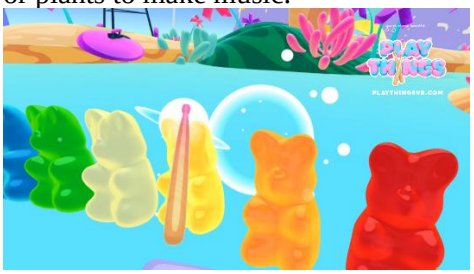

Figure 6 Play Things

These games either have no freedom of creation when it comes to actual music production or have no methods to actually teach the user about music.

A Game that is not VR however tried to replicate the real intuitive controls of using an instrument was Wii music (2008)

Figure 7 Wii music

Wii music[12] tries to teach the user about timing [figure 7] in the bottom right you see four notes signifying a 4:4 time signature. The game uses this to keep the player in time and know how many beats there are to play in a bar. Wii music is not VR or a Digital audio workstation however I believe many elements from this game, mainly the intuitive and creative approach to controlling instruments was quite large in pioneering how VR controls were developed in the same respect.

The creation of music using existing DAWS (Fruity Loops[13], Garageband[14], and Ableton[15]) can be very difficult for new users due to the steep learning curve required and the large amount of features that they are overwhelmed with, this may also be a barrier for new users to learn more complex musical theories.

Figure 8 FL studio

LYRA VR

LyraVR[16] is a very early development game that is a creative music space for Virtual Reality. There is a lot to love about LyraVR and **a lot of inspiring** features. However that being said I believe there is much missing. There is no importation or exporting features, or any educational tools, it is purely music creation.

Lyra Vr has a system where you almost draw all of your notes in mid-air and can make shapes like spirals, cubes etc. in mid-air and link them with “loop lines” This is a very smart idea but can leave the work area very cluttered.

Three years after LyraVR’s Release in 2017 it is still in a Beta phase giving updates as recent as January 2020. The game only has 20 reviews, but they are all overwhelmingly positive. Most giving praise and a slight change that they would appreciate, for instance one user said:

“I just can't believe you guys did all of this work and didn't make an "undo" button”.

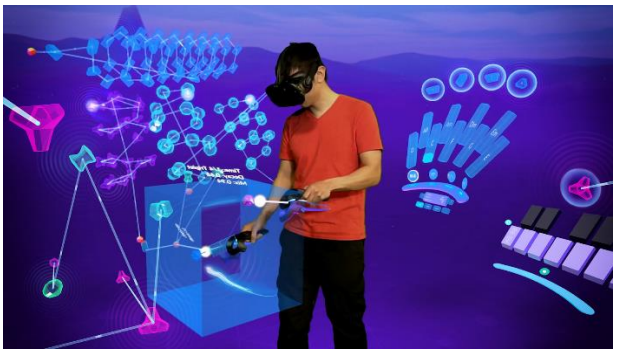

Figure 9 Lyra VR

3 Overview of Product

The product is an open studio-like VR experience for any device that can use SteamVR[17]. This VR experience allows the user to get creative and interact with musical instruments using immersive controls modelled after real life movements. This project has been built using two iterations of user feedback. One on a design stage and the other on an end stage functional build.

The final build is a unity project that requires no additives as it contains everything for the system. This is ran using SteamVR[17]. Upon play the user gets dropped into the music suite, The aim of the software was to give the user an open look at what it would feel like to be in a music studio/environment and have free reign on all of the equipment/instruments.

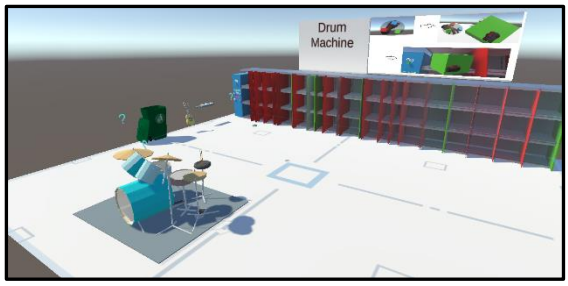

Figure 10 View of system scene

The aim was to give the users a feeling of free roam, but if they wished to learn more there are optional tutorial hints that would teach them about music and signs around the in game area to show people how to use the instruments, for instance with the drum machine there is a large sign board telling the user what actions to take.

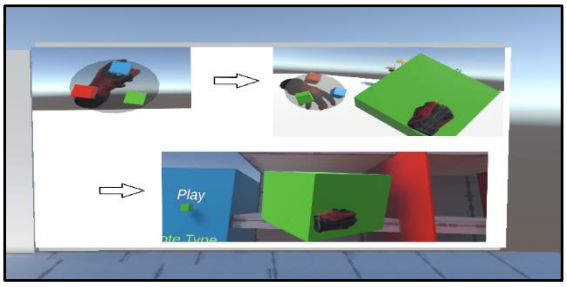

Figure 11 Drum machine help Billboard

There was a large decision that went into not including a forced tutorial. Although tutorials can increase play time by as much as 29% in the most complex game, When the game is simple and straightforward. It is suggested tutorials are not justified for games with mechanics that should be discovered through experimentation, also forcing tutorials can make the player lose interest [18]

Movement inside the game is the standard widely used in VR, this was decided while looking through ways to create movement in VR outside of the confines of your real-world space. There are two main ways to move inside VR, this is gliding or "stepping" in a direction using directional input, this however makes users very motion sick if they are not physically walking in real life[19]. The alternative is teleportation.

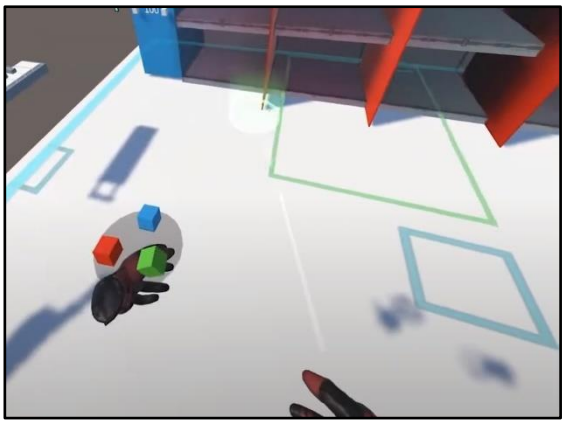
Figure 12 Drum "Watch menu"

SteamVR and the large majority of VR games in which movement is important have a teleportation option. This has led it to be a built-in function within SteamVR and its control scheme. This is what led me to use this as the main way of transportation in the system aside from real world movement.

To prompt users to interact and show these users how to interact and grab objects the system shows a "ghost controller" with the required input glowing on the controller [figure 13] This is to aid the user with their self-exploration while not forcing learning or mandatory tutorials.

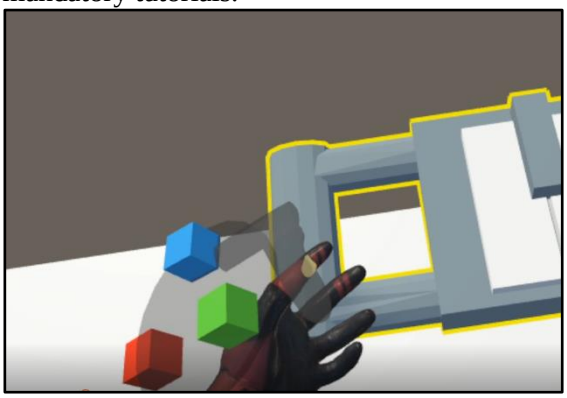
Figure 13 Ghost controller

Each of the featured instruments have a unique and real-world inspired controls, as well as a drum machine inspired by the "pattern" tool in modern DAWS [figure 14]

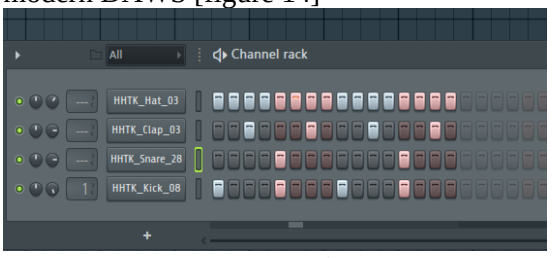

Figure 14 Drum Pattern in FL studio

The Drum machine is a large structure taking up a large wall of the area. With a design based off a supermarket shelf to keep familiarity high. There are large signs above the drum machine depicting how it is used and what it is. The drum machine is paired with the "watch menu" on the back of the users left hand that hosts a variety of drums to choose from and place inside of the machine.

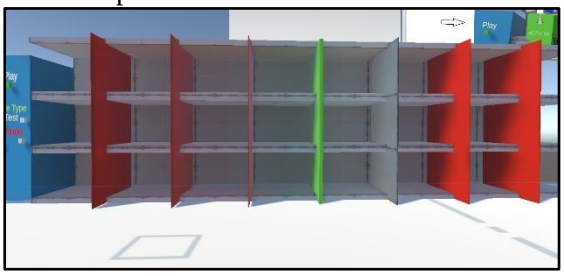

Figure 15 Drum machine shelves

The user is to choose a drum from the watch[figure 12], which they can test and preview each one by tapping. After they have selected their drum, they can grab it and duplicate the drum from the watch and place it within the drum machine wherever they would like.

The drum machine comes with a control block at the side of the machine in which the user can play the pattern, set the tempo in BPM (beats per minute) and the types of notes. These options are: Quarter notes (crotchet notes), eighth notes (quaver notes) and sixteenth notes (semi Quaver notes). These notes will let you fit more notes per beat, for example eight notes will let you get 8 notes per beat.

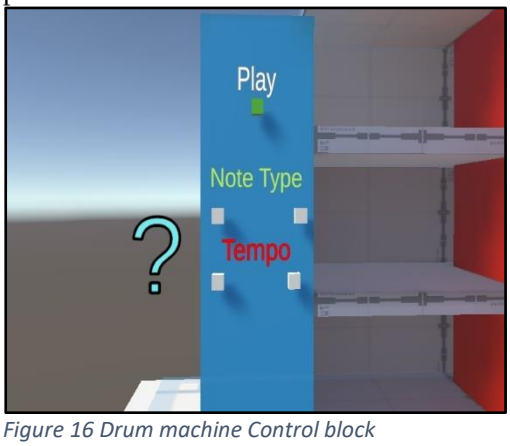

Figure 16 Drum machine Control block

The Keyboard is equipped with a handle at the side to show the user that they can lift and position it wherever they please, using the keyboard in the system is the same as real life. The keys are set to be pressed down and will trigger a sound that will fade away when un-pressed. This instrument was designed to be carried around with the user so that they can set up an environment that was comfortable to their height or if they wished to have a rest and sit.

The guitar was made to model how a real guitar would function as it faces away from the user when first picked up. This is how guitars are meant to be held so players with guitar experience would not feel awkward bending their arms and controllers to get the instrument to a comfortable position. As the user's non holding hand moves up and down the fret board the guitar registers to play higher and lower notes corresponding with the hand position. Finally, the sound is finally played when the user presses the right trigger to simulate strumming the strings.

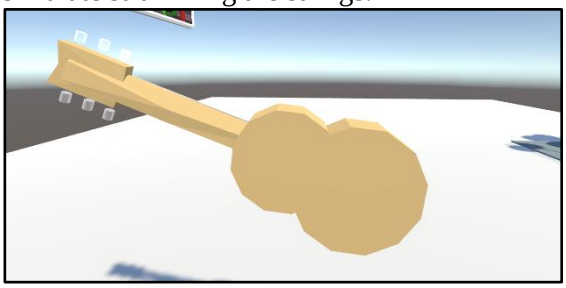

Figure 17 Guitar rotation example

Finally, there is a real playable drum kit that is designed around the average seated height of an office chair. Once seated the user can pick up drumsticks with the controller and play the drum kit exactly how you would in real life. Hitting each drum with the stick will give you the sound of the drums. This sound plays every time each stick objects enter the specified drum, meaning drum rolls and fast playing is very accurate. Timing and complicated playing is extremely achievable as I tested whilst playing Jazz beats on the drums.

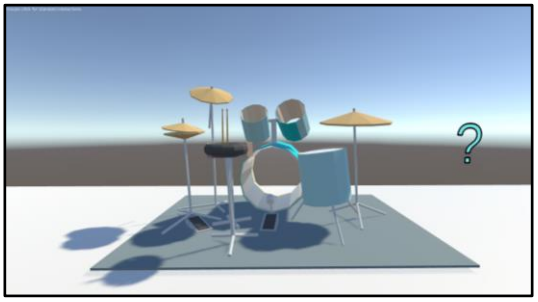

Figure 18 Drum kit

4 Overall methodology

In terms of methodology I researched many different kinds that suited me and suited the "openness" of the project. I then came upon the Kanban methodology[20]. "Kanban" is a Japanese term that in English means signboard. This is a lean methodology to improve and manage work.
I used the service Trello [21] to help me visualise this "signboard" by keeping the structure that Kanban should follow.

This structure is almost a left to right progress wall, left being a to research and to do when the most right side is a done with in between being the levels of progress obtained.

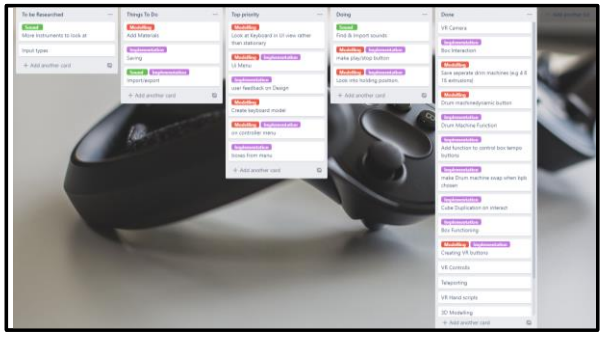

Figure 19 Trello Board

User Evaluations
ethics approved by universities computing ethics committee.

Regarding feedback from the user, we are going to use an iterative system that requires two sets of user feedback. The first set of user feedback is in the form of a design evaluation. This is to evaluate the first prototype made and for the users to give a sense of unbiased direction via the form of a System Usability Scale form and a short discussion.

The second Evaluation is a final evaluation. This is to be compared to the first set of feedback to see if the final product was able to improve upon the users first set of feedback, and also give valuable comments and a unique insight into how the system would be to use from the perspective as a user.

Unity
For a game engine to create the VR environment I chose unity[22] as it is the most widely used VR development platform[23] additionally having 91% of HoloLens[24] experiences being made in unity itself. paired with the fact that I have some experience creating a few games in unity in my spare time and in previous university classes.

Unity boasts many features that seem to be geared towards their support for VR/AR production. A few of these are: Extremely High frame rates thanks to a highly optimized stereoscopic rendering pipeline. Extensibility to allow any 3rd party hardware manufacturer to develop their own plugins to create an impressive experience for all devices[25].

Poly Tool kit
Googles "Poly"[26] is a website where users distribute and gather 3D objects that they have created, many with VR and Augmented Reality in mind. I used Googles "blocks" [27] which is connected to poly to create a lot of my models while actually in VR myself, painting in a 3D immersive environment.

Figure 20 Painting in Google Blocks

Unity has google poly integration through an asset that you can download for free on the asset store.

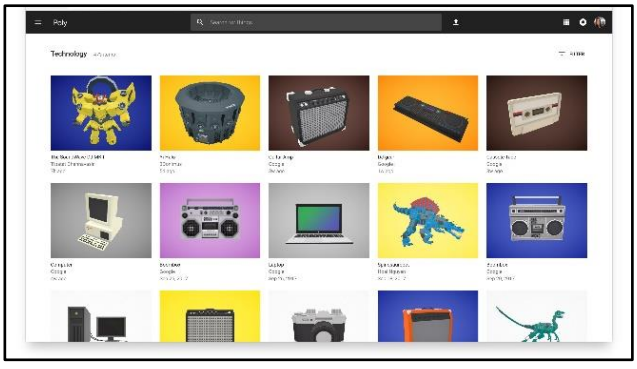

Figure 21 Google poly browse menu

Steam VR + ALVR sideload

SteamVR is the popular Video Game distribution service Steam's[3] attempt at hosting integration for Virtual Reality functionality.

Using SteamVR integration so that no matter what hardware that is used as long as it is supported by SteamVR.

Due to the COVID-19 Situation I had to wirelessly work in a small space so I had to acquire an oculus quest from the computing department which had have some software side loaded onto it in order to get it to connect to my PC as the cable that I had was not long enough to be directly linked.

This software was ALVR(air light VR) [28] This software is an open source remote VR display for wireless VR headsets to use SteamVR.

ALVR streams the VR display output from the PC to your wireless device over Wi-Fi.

5 Hardware

There is a massive number of headsets that are currently available that would have been suitable to use for this project. Thankfully, my project was focused around SteamVR [17] meaning that as long as they support the headset it would be fine.

The university's computing building has a dedicated VR Machine that was equipped with an HTC Vive setup.
The HTC VIVE is a product that was developed by HTC[8] and Valve[29] it is known as one of the two most widely known headsets, the other being the Oculus Rift. These were the two commercially available headsets whenever the technology first started to boom.

The HTC VIVE headset uses a 90HZ refresh rate with a 110-degree field of view. There are two OLED[30] panels one for each eye, each having a display resolution of 1080x1200.[31] Using this setup will keep users more immersed and reduce motion sickness.[32]

The Vive comes with Base stations that are known as the Lighthouse tracking system.[33] These bases emit infrared pulses at 60 pulses per second that are then picked up by the headset and controllers[34]

Finally, the controllers for the vive include multiple inputs attempting to recreate real life interaction methods. There is a ring at the top of the controller holding 24 infrared sensors that detect the base stations so that the system can detect the location of the controller.

As stated previously due to the COVID-19 Pandemic I was not granted access to the machine again, which caused some hiccups. I was able to get a replacement oculus quest [43] a fully mobile headset that I was able to sideload a Wi-Fi server connection service [28] to my main PC that let me access steamVR wirelessly.

Oculus Quest (All the apk + adb)

The Oculus Quest was revealed at an oculus conference in 2016. When Facebook CEO Mark Zuckerberg revealed that there was a standalone VR headset codenamed "Santa Cruz"[35], this was then later released as the Quest.

The Quest headset uses two diamond pentile OLED displays [36] each with an individual resolution of 1440x1600, higher than the competitor the HTC Vive, however it has a lower refresh rate at 72hz opposed to the VIVES 90hz.
This will feel slightly less smooth when turning and having engaging movements along with increased risk of motion sickness. That being said the higher resolution could be easier on the eyes and reduce eye strain.

Figure 22 Oculus rift headset

The Oculus Quest tracks using the Oculus insight, this is comprised of 4 cameras that are on the headset that are used to spatially track. This is what makes the headset so mobile, as it doesn't require a dedicated space with the "lighthouse" configuration that the VIVE Requires.

The controllers on the Quest use a smaller controller with inputs on the inside of the ring and a smaller handle. The ring, like most VR Controllers including the VIVE hosts infrared sensors that are to be detected by the system on the top of the controller. This serves the purpose of making the rings visible to the tracking cameras in the headset[37]

Figure 23 oculus quest controller

This was perfect for me; however, it could not connect to SteamVR to use Unity without any additional programs installed. That is when I Sideloaded the Air light VR software to host a server between my headset and Computer to stream the sound and video from the computer to the headset wirelessly.

There is an alternative however called the Oculus Link.[38] Three years after the quest was announced they announced the Link, this technology allows the quest to be tethered to a PC via regular USB-C cable to run PC VR (SteamVR). However, this in my situation was not ideal, as I did not have the cable and needed the experience to be wireless in my surrounding area.

6 Initial ideas

Initially, when I was assigned this project, I had a few things in mind. I was heavily influenced by past games such as Wii Music in the aspect of pick up and play whatever you want. However, I wanted to give more than just throwing an instrument at the user. This led me to wanting to implement some education on music and also much more functionality like a DAW (digital audio workstation).

When looking at the drums for the project, I thought the first place I should start was to make a drum machine. In my head this made the most sense as it acts exactly like a DAW does with its "Pattern" function, but also when it comes to programming it sounded like something that was very achievable.

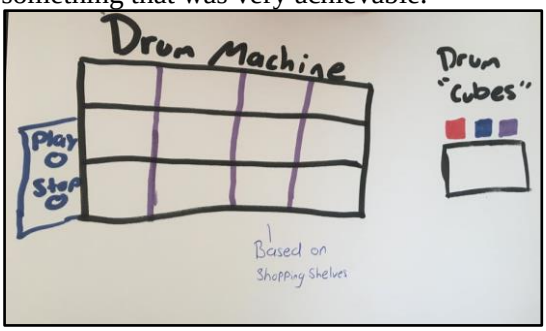

Figure 24 Drum machine sketch

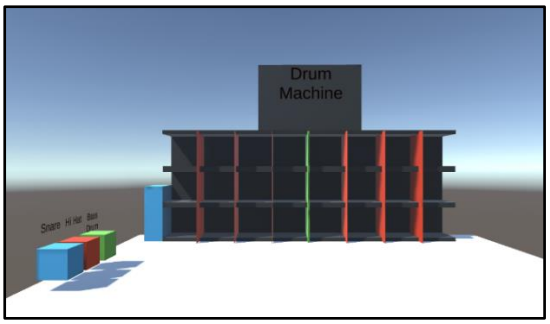

Figure 25 Drum machine

When it came to the "drum boxes" to put into the drum machine I had them on top of a table that would infinitely produce them as you picked up your chosen drum.

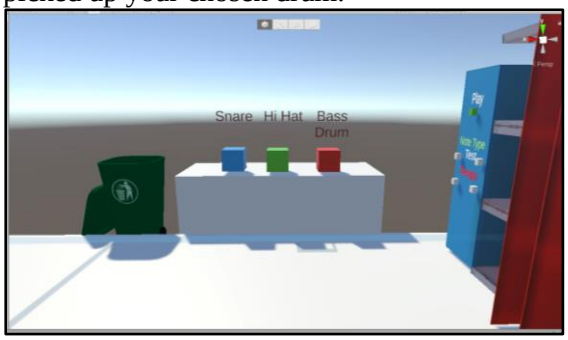

Figure 26 Drum cube table

However, this was terribly inefficient as you would have to walk the whole way to the other end for each drum and it would take a long time and be extremely tedious to the user.

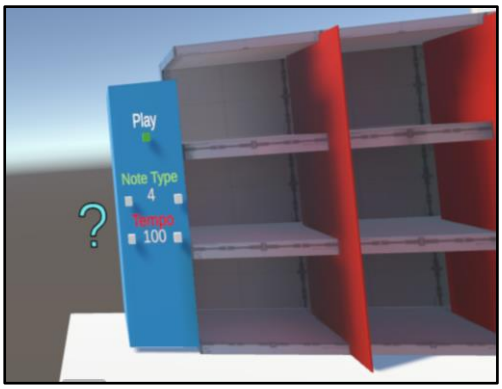

Figure 27 Drum machine control block

When the user touches this question mark in this context it will detect what type of notes have been selected on the box (quarter notes, eighth notes etc.) and then animate a little menu that shows them all of the information about that type of note along with some type of infographic photo.[figure 28&29]

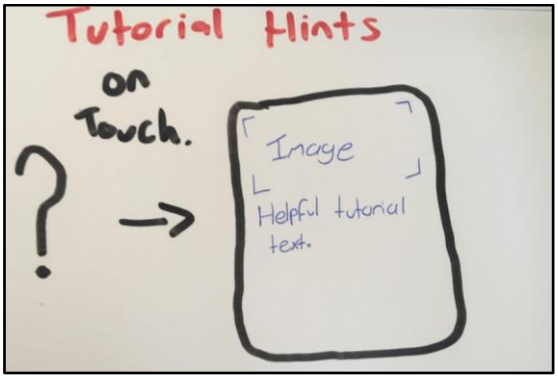

Figure 28 Tutorial hint sketch

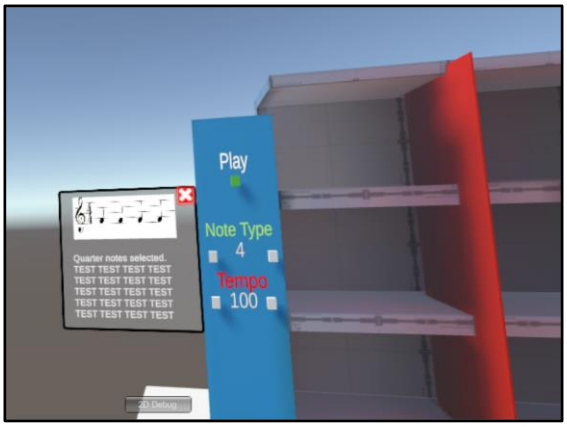

Figure 29 Tutorial hint window

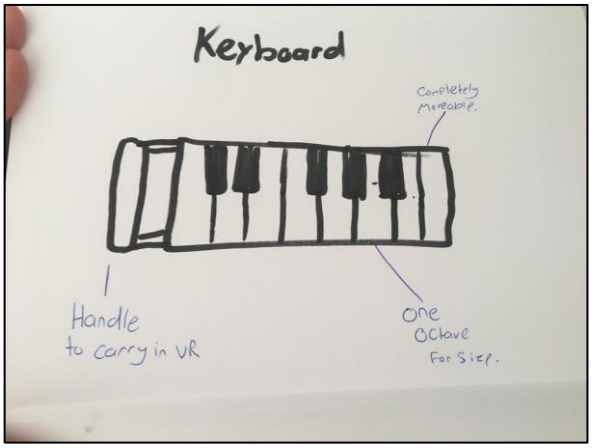

Figure 30 Keyboard sketch

The idea is for a keyboard made out of individual moving keys on a rectangular backplate, with a handle so that the user can carry it around with them.
The keys will be free moving to a certain degree, registering when in its most down position and most up position to make the sound.

7 Survey

Participants

The survey hosted 26 responses with 2 being excluded due to invalid answers.

materials

The surveys questions were split into a few sections, these were:

- Experience in VR
- Experience with Music
- Preference on software's direction
- Priority of features

Method

I created the survey using the university approved Jisc online surveys[39]. This was then distributed via university & music groups through email and social media. I then waited a month to give users the time to fill it out and spread the word to other people who may be interested in completing the survey.

Results

Do / Have you played any Musical instruments before?

When asked what instruments they have played, the large majority were spread among 4 groups. Drums, Strings, Keys and wind. Out of these, 3 can be integrated into VR easily using the inputs from the controllers, for instance playing drums in VR is more or less the same as in real life just with less feedback. This led me to have a main focus on getting drums, keyboard and a guitar playable within my music suite.

When asking peoples experience and use of VR

18/24 had used VR before, this was a surprise as I assumed less than half of people asked to have experienced VR before, this showed me that VR is becoming much easier to obtain. I followed these questions asking for the level of experience that they have with VR.
The levels of experience were

No Experience 5 (20.8%)
Used VR a handful of times 10 (41.7%)
Have experience but do not own device 7 (29.2%)
Have access to VR device 2 (8.3%)
Frequent VR User 0

This shows that most users have used someone else's device or a VR device that was set up in an interactive environment. These answers shocked me given the amount of people that had used VR before I expected more to have access to their own device.

When asked if you were to play music in VR what feature would you want to see?

Although many of the answers were vastly different, they all had a similar background.

Whilst many asked for drums there was a large request for realistic controls and feedbacks. As well as learning things about music. This was able to give me an idea to base my game off. First thing I would do is to create an easy drum machine to create beats easily while getting the user used to VR controls.

When asked Would you prefer a music VR software to be learning based or pure music creation?

Most people leaned towards 50-50 but on average there was a 30-70 in favour of pure music creation. This has led me to create more of a music suite. As if the user has walked into a music studio and has free reign to do whatever they want.

After this they were given a "Scale of importance" for different features I had thought of. These being:

Drum kit
top priority: 66.7%
Second priority: 16.7%
Not as important:16.7%
Could be left out: 0%

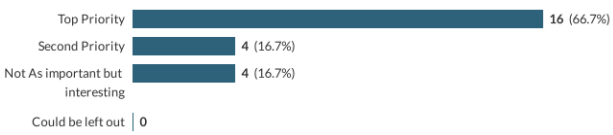

Figure 31 Drum kit Survey Results

The Drum kit as a feature has the highest interest among all of the participants, with the majority calling it a top priority and the remaining saying that it was at least interesting as a prospect. With 0 participants saying that it could be left out. This is what steered the decision of the drum machine being the first prototype to be added.

Keyboard
top priority: 50%
Second priority: 33.3%
Not as important: 16.7%
Could be left out: 0

Like the drums, the keyboard also had an extremely high rate of interest with the majority voting it to be a top priority and the remaining exclaiming that it was at least important. The fact that there is 0 people that think that the feature could be left out really points out which features are deemed vital in a game about music creation.

Live recording
top priority: 29.2%
Second priority: 45.8%
Not as important: 25%
Could be left out:0

Live recording was expected to be very high on the priority list, however when the majority of participants voted it as a second priority it was understandable. People are always going to want to make sure that the objects that they are interacting with work well before adding features that are designed around their functions. For example, who would want to record a broken drum kit that does not work?

Importing
top priority:17.4%
Second priority:52.2%
Not as important:26.1%
Could be left out:4.3%

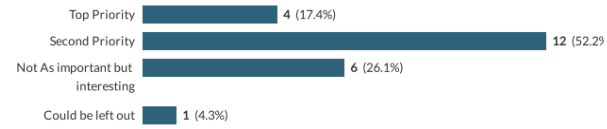

Figure 32 Importing Survey Results

The results for exporting were almost what was expected; however, we did not expect as many people to say that it was not important or could be left out. A majority second priority is no shock, however having 30.4% of participants do not consider it as a priority in any way was unexpected.

Distortion/filters
top priority:4.2%
Second priority:29.2%
Not as important:41.7%
Could be left out:25%

Figure 33 Distortion & Filter Survey Results

Adding Distortion or filters had the worst reception of any of the other proposed features, figure graph this graph shows just how one sided the votes were with an extreme decline and only one participant voting for it to be a top priority. This gave us confidence that we can save this idea until the end as an additive if time constraints are exceeded.

learning tools
top priority:16.7%
Second priority:41.7%
Not as important:37.5%
Could be left out:4.2%

Participants were not keen on learning tools as much as they wanted to see drums, or a keyboard implemented into the system. This was very helpful to solidify that the system should be geared more toward musical exploration than an educational tool. With a total of 79.2% of participants reporting that it is either a second thought or simply is not as important as other features.

These results gave me clear goals to aim for and helped me figure out just what I should prioritise. This led me to start creation on a drum machine that users could easily use to make beats in a fun and interactive way using VR.

These results also showed me that some features just might not be needed in VR for instance, a distortion/filter system had a quarter of users who were asked say that it could be left out, with a further 41% of users say that it isn't important. Without guiding answers like this I would have wasted time

focusing on these finite details whenever I could be spending my time on the more core and vital features.

8 Design Evaluation

The first evaluation that I had to carry out was a questionnaire after letting the users have an interaction with the main function of the program at the time (the drum machine).

I then gave the users a questionnaire. Answering questions on a one to five scale, one being strongly disagree, five being strongly Agree, the following are the questions and the average answers among users.

These questions were:

1. **I think that I would like to use Music in VR frequently**

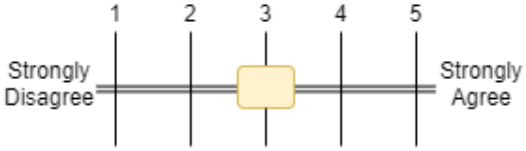

Figure 34 User Feedback Statement 1 Result

This question was asked to gage how the system impacts a user's will to come back and play it. If the system leaves the user wanting more than it is a good signifier that it has likeable qualities and has good game direction. This answer tells us that the users found that they may replay it, but they wouldn't necessarily agree that they would like to use it frequently. Having an answer in the middle is good as when the next evaluation is carried out, we can see if we were able to sway their opinion in a way that is for the better.

2. **I found Music in VR unnecessarily complex**

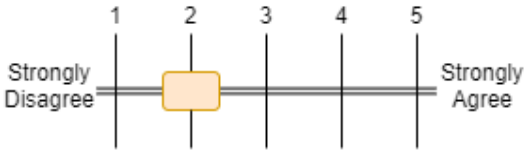

Figure 35 User Feedback Statement 2 Result

The users did not agree that they found the system complex. This is a big win as the feature that they tested *(Drum machine)* was one of the most complex features that are to be implemented into the system. The aim is to get the users to vote a 1 in the final evaluation after they have used a more finalised build.

3. **I thought Music in VR was easy to use**

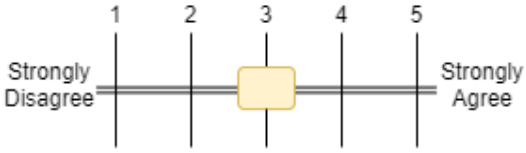

Figure 36 User Feedback Statement 3 Result

Once again, the users shot straight in the middle with their average answer of 3. This is helpful for the end of the project to refer back to, however at this point of reflection it shows that the users on average did not find the system easy to use. This is a problem, when it comes to this project and VR in general, I believe easy to use controls and familiarity aid immersion and create a greater experience overall. In the final evaluation I am hoping for this answer to be a 4 or 5 to show that the users agree that the system is easy to use.

4. **I think that I would need the support of a technical person to be able to use Music in VR**

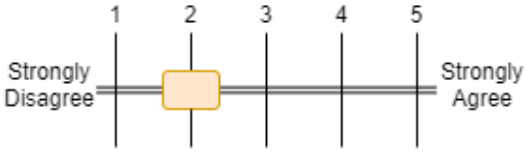

Figure 37 User Feedback Statement 4 Result

The answer to this statement is acceptable and where I hope that it would be. However, I aim to keep or improve this average outcome as the last thing that we want is for people to feel overwhelmed and need help to use the system.

5. **I found the various functions in Music in VR were well integrated**

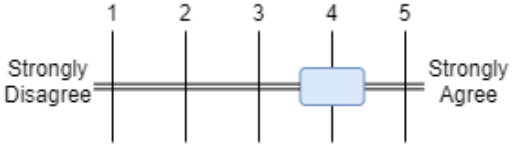

Figure 38 User Feedback Statement 5 Result

Integration is key when it comes to creating a system that is based on real life movements, as well as having instruments to be constantly adapted. The user must feel like everything fits

and works correctly or immersion could take a hit.

6. **I thought there was too much inconsistency in Music in VR.**

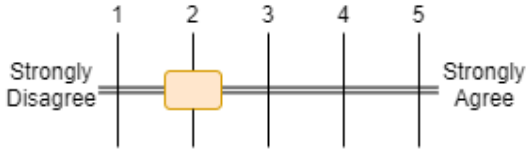

Figure 39 User Feedback Statement 6 Result

Inconsistency, like integration are vital when it comes to keeping the user engaged in the virtual immersion and exploration. If you lose the users focus, the user is very likely to lose interest and not use the system anymore. The users have said that they disagree that they think there is too much inconsistency which is a very positive note, however with the final evaluation I am hoping that we are able to get that to a 1 by making sure that everything is the same art style and functions using the same controls and behaviours.

7. **I would imagine that most people would learn to use Music in VR very quickly.**

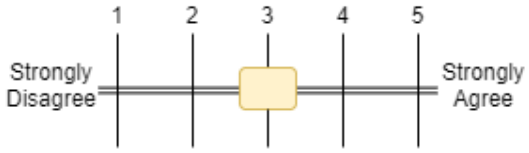

Figure 40 User Feedback Statement 7 Result

This question is to be analysed with question 2 as they both ensure that the user has an easy time with learning and not getting confused with the system. Once again, the users have voted on average a 3. This signifies that they do not necessarily agree or disagree, this is something that we want to change. One of the main aims of the system is ease of use for the user. The user not being able to learn how to use it quickly is a large issue as the user is to explore rather than spend their time learning the functions of the system.

8. **I found Music in VR very cumbersome (awkward) to use**

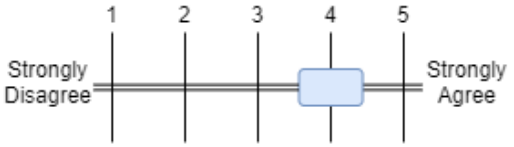

Figure 41 User Feedback Statement 8 Result

Question 8 stems into worries that the user may be overwhelmed with the sheer amount of interactable objects there may be in the system, or that these interactable objects may not function in their intended way. Unfortunately, the users voted for a 4 (agree) overall that the system was cumbersome to use. Some users felt like the way that we had set up the drum machine with the boxes on a table was too clumsy and could do with a lot of work. This is a very disappointing result however very valuable as it tells us where we need to work for the next evaluation.

9. **I felt very confident using Music in VR**

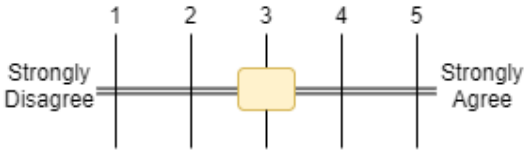

Figure 42 User Feedback Statement 9 Result

Confidence with the system is something that some users will have more than others, however making sure that users feel like the software is not intimidating and easily useable is a large goal. The participants on average said that they neither agree nor disagreed with a rating of 3. By the end of the final evaluation we will work towards bringing this to a 5 (strongly agree) as a user being confident with using the software and VR is something we wish to encourage via the system.

10. **I needed to learn a lot of things before I could get going with Music in VR.**

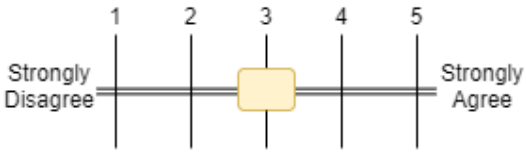

Figure 43 User Feedback Statement 10 Result

Our system tries to focus on the user's exploration to be their main educational tool.

The user's voting 3 on this statement is not surprising as the feature that was shown looks daunting at first. This has started thoughts on how we can make features in the game explained better and give subtle directions without flat out telling the user what to do.

Additional Comments were as follows:
"Going from the instrument boxes to the machine looked very tedious, and it took a lot of time."

"Was very immersive, however the boxes were quite hard to work with when bringing them the whole way across the area."
These were very accurate comments, one that I didn't think about too much while I was testing. It is this comment that led me to make the change [figure 44] so that the user did not have to keep teleporting back and forth.

What I took away from these was that my design prototype had good direction but was not out standing in its functionality. For instance, on question 8 the average answer was leaning towards strongly agreeing with the product being very awkward.

9 New ideas

Watch Menu

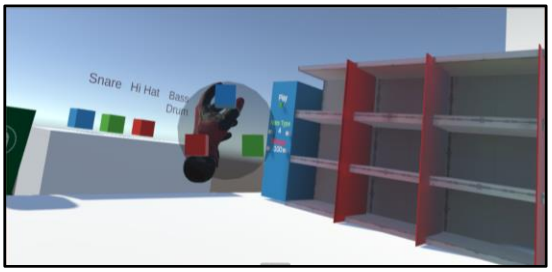

Figure 44 Watch clock

After the feedback from the design evaluation I created a "watch menu" [figure 44] as I call it, a menu that rests on the VR hand like looking at a watch, this has one of each drum that you can spawn the boxes from. It makes a lot more sense as it cuts out constant travel and you can do each beat of the drum machine as you go along instead of stopping and starting.

Real life Drumkit

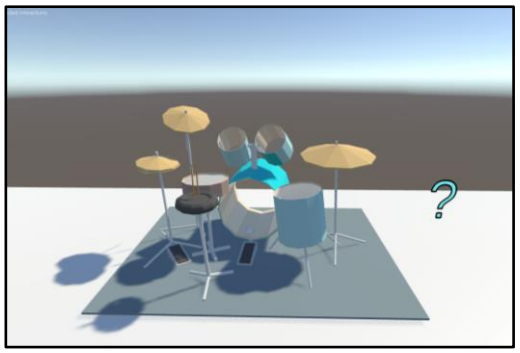

Figure 45 Full VR Drum kit

After the creation of the drum machine I found myself exploring the creation of interaction inspired by the real-world action. A drum kit is a perfect example of this, the collision of the user holding a stick onto different areas of a 3D modelled drumkit.

Recycling bin

Figure 46 VR Recycling Bin

After cluttering the area with boxes and not being able to get rid of the spare drums, I decided to make a deleting mechanism that would look nice as a recycling bin.
This led me to searching throughout the internet for 3D models of bins, fireplaces and even skips to try and find a model that would fit the aesthetic of the game but also be functional. That is when I found this small green recycling bin that I was able to take the lid off so that it was open to receive unwanted drum boxes.

Guitar

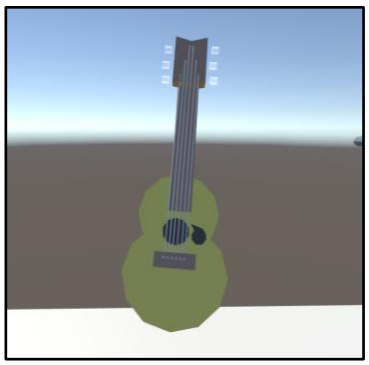

Figure 47 VR Guitar

The survey results came up with Strings and guitars as one of the most requested after keyboards. Once I was able to finish the foundations of the drum machine and drum kit, I started to focus on expanding the number of instruments that were in the Virtual Environment. I was able to find a 3D model of a small classical guitar that I could begin to work with to make functional.

Keyboard

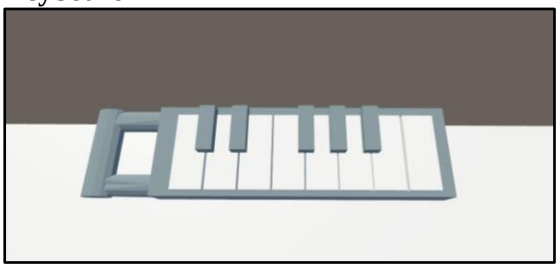

Figure 48 VR Keyboard

The Keyboards invention a was another idea that I had an initial idea of, however adapted it when I heard the feedback. I had a focus to make it more mobile rather than stationary like the drumkit. If the user is able to have more interactions, I figured that it would aid immersion for the users.

9.1 User Experience in VR

Making sure my project focused on the user's point of view during the design process was a vital piece of my planning an implementation.

UX design for VR is not as straightforward as it might seem, in real world UX the user interacts via mice, touch screens etc. But in VR there are no similar controls as everything in the world is rendered around you. The user also is inside a virtual environment which brings different VR design problems and details such as:

Depth or distance as a 3rd Dimension
Larger field of view and 360 degrees world
How to effectively use spatial sound

When designing User interface and menus for the Virtual world, you have to think about how ergonomics differ in VR than from the normal world. If not taken into consideration users will experience discomfort and nausea. Mike Alger had a study that depicts the limits for zones and where to place content around the user.[40]

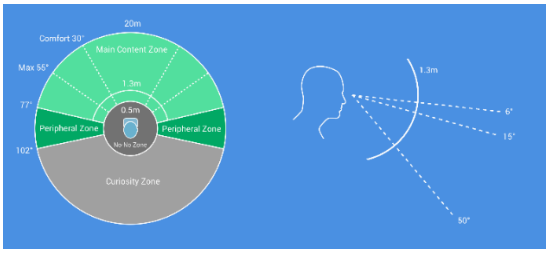

Figure 49 Mike Alger VR UX Zones

This depiction comes with certain "zones" starting with the "no-no zone" this is anything within a 0.5m radius from the user. There should never be any permanent content to interact with in this zone, of course there are exceptions, but these should be temporary and evaluated specifically to each case.

The "main content zone" area is the most comfortable area for a user to see and interact with, users do not need to interact their head too much in order to see this area as it is between 30 and 55 degrees, this combined with the devices field of view gives users an area where they can rotate their head and see elements.

The peripheral Zones are areas of less interest, these areas are for items that are not necessary but could be of some user or interest.

Finally, there is the curiosity zone, this requires the user to turn their body to see the area, this should not be used for any permanent items, unless you wish to reward the user for exploration.

10 Implementation

This section is going to explain and show how the system functions, the ideas behind the features and the code that puts it all together.

I coded this project using C# using Unity & steam VR libraries. Unity works by having game objects and giving them attributes for example the physical models and gravity values. Scripts attach to these objects in the same way.

Google Poly
For the 3D modelling I Used Google Poly and Google Blocks, these are 3D VR modelling software's released by google. You use Blocks to model in VR which is how the keyboard was made. An alternative to that is to use Google Poly which has a unity downloadable asset where you can "browse" the catalogue uploaded by other users. This is how I acquired the guitar and drumkit models. The models used in this project were cleared by the creators to be used in the project.

ALVR & Oculus Quest
At the time of development, the oculus quest did not have much wireless support for Pc connections, it functioned as a standalone VR entertainment device. This sparked my investigation into software I could use to connect the two wirelessly over WIFI. Luckily, there was a GIT repository called ALVR (Air Light Virtual Reality) that did just this.
ALVR had to be side loaded via my PC using Windows PowerShell [41] and the ADB [42] (android debug bridge). Androids ADB is a versatile command-line tool that lets a PC connect and communicate with a device. This allows users to install software onto devices that would otherwise be unauthorized.

Using this method, I was able to host a virtual server on ALVR and stream my unity project from my computer to the quest, while simultaneously streaming my inputs and outputs back to my PC from the quest.

Attaching to user's hand
Attaching to the user's hand is one of the most important things in virtual reality. Without the ability to pick things up it removes so much immersion and familiarity when it comes to the use and feel of objects.

```
private void HandHoverUpdate(Hand hand)
{
 GrabTypes grabType = hand.GetGrabStarting();
bool isGrabEnding=hand.IsGrabEnding(gameObject);

if(interactable.attachedToHand == null &&
grabType != GrabTypes.None)
{
Attachpoint =
hand.transform.Find("ObjectAttachmentPoint").game
Object;

  if (gameObject.tag == "keyboard")
{
  attachpoint.transform.localPosition =
  new Vector3(0.03f, 0f, -0.12f);

  attachpoint.transform.localRotation =
  Quaternion.Euler(0, 80, 0);
}
```

The figure above shows what happens if you grip when hovering over the keyboard. The variable object attachment point is a small area attached to the hand. This is needed as different objects need to be turned/facing different positions on a local axis from the user.

An example of this is the keyboard facing the user but the guitar needing to face away from the user. Another feature of the Hand attachment script is to duplicate a drum cube from the hand menu, resize it and make it a child of the scene instead of the hand so that it will freely move.

```
else if(gameObject.name == "HiHatCube" &&
respawner == true)
{
 pos = BoxPos;
 var newHat =
 (GameObject)Instantiate(Box,pos,
 Quaternion.identity);

 newHat.transform.parent =
 lefthandpoint.transform;

 newHat.name = "HiHatCube";

 Box.transform.parent = null;

 Box.transform.rotation =
 Quaternion.identity;

 Box.transform.localScale =
 new Vector3(0.3f, 0.3f, 0.3f);
}
```

Drum Machine
Storing all my active in drum machine Collider boxes into an array and making the index null as they are taken out. This was very complicated and created a lot of duplication errors since the object in its held and dropped state are different, triggering the collider twice. I spent a long time rewriting my code to accommodate these changes, but the best fix that I could find made a very large array as it nullified previous fields and kept moving on for instance: if you put a bass drum in first, a snare second and then a bass drum again. As

you take the first bass drum out, it would nullify the first index. Meaning it would start with an empty space which is terribly inefficient.

I fixed this problem by putting them all into a list.

```
private void OnTriggerEnter(Collider other)
{
   detectCheck = other.gameObject;

if (detectCheck.gameObject.tag == "drum")

{
  detectedDrum.Add(detectCheck.
  gameObject);

  detectedDrum[i].GetComponent
  <PlayDetected>().playSound();


 return;
}
```

```
private void OnTriggerExit(Collider otherexit)
{
 for (j=0; j<listlength;j++)
// for the entire list
 {
  if(otherexit.gameObject ==
  detectedDrum[j].gameObject)
// if the exiting object is in the list
   {
   detectedDrum.RemoveAt(j);//remove it
   }
 }
}
```

This helped with my indexing issue. As when it found a match, it would just remove that list index rather than nullifying an array index and moving on.

Once the game objects are in a list, each of them has a small playSound Script that will play an Audio Source that is attached to the object. This is the sound that makes it a specific drum. When the user presses “Play” on the control box it calls the function PlaySequences to read through all of the elements on each list, via the script PlayLoop this sequence script the function simply scans the list and plays the sound of all the game objects that are inside of the list at once. Loop is then played, then moved to the next collider (beat in the bar) after a wait of the tempo time.

```
public void PlaySequences()
   {
     StartCoroutine(PlayDetectors());
   }

public IEnumerator PlayDetectors()
{
 yield return new
 WaitForSeconds(0.3f);
 btnnoise.Play();

  if (bpbchoiceint == 4)
    {
    for (stop = 0; stop < 4; stop++)
     {
      Detector[stop].GetComponent
     <DrumMachineDetect>().PlayLoop();
       yield return new
       WaitForSeconds(time);
     }
    }

  else if (bpbchoiceint == 8)
  {
    for (stop = 4; stop < 12; stop++)
   {
    Detector[stop].GetComponent
    <DrumMachineDetect>().PlayLoop();
            yield return new
     WaitForSeconds(time);
    }
   }

  else if (bpbchoiceint == 16)
  {
    for (stop = 12; stop < 28; stop++)
     {
      Detector[stop].GetComponent
     <DrumMachineDetect>().PlayLoop();
     yield return new
     WaitForSeconds(time);
     }
  }
 }
```

Drum Kit

My main focus of thinking for the drum kit was to play a sound held in an AudioSource component that were held in “contact cylinders” [figure 50] that were hidden and placed on top of each part of the drum kit

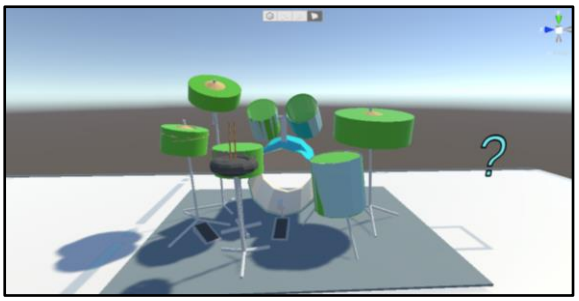

Figure 50 VR Drum Kit Collider boxes

Whenever the user picks up the sticks and contacts any of the hidden cylinders with those sticks it trigger an event to play the sound.

```
private void OnTriggerEnter(Collider other)
{
 detectCheck = other.gameObject;
 if (detectCheck.gameObject.tag == "stick")
  {
    Debug.Log("working");
    soundfile.Play();
  }
}
```

Previously, I had used a separate method that detected the solid object of the drumkit. However. It was very hard to distinguish what was hitting where, for instance if your hand hit the drum it would make the sound. This caused many accidental sounds and made the game feel as if it was not working as intended.

Keyboard

Using google poly I fashioned a keyboard out of a few keys and put them together with unity.

The idea behind the keyboard is very simple, they are able to move -0.01 on the Y axis, once in the most down position it will call for the sound to be played.

```
public void playSound ()
   {
      soundfile.volume = 1f;
      soundfile.Play();
   }
```

After the button is then in the starting position stop sound is called, this starts the StartFade function, this will fade out the volume incrementally with time.

```
public void stopSound()
   {
      StartCoroutine(StartFade(soundfile, targetVolume));
   }


public IEnumerator StartFade(AudioSource soundfile, float
targetVolume)
{
//loop volume down -.05 every 0.05 sec
for (soundfile.volume = 1f; soundfile.volume>0f; i += 0.05f)
  {
soundfile.volume = soundfile.volume - 0.05f;
yield return new WaitForSeconds(0.2f);
  }

  if (soundfile.volume == 0f)
  {
      yield break;
  }

}
```

Guitar

The guitar functions with 3 colliders that each hold a different chord. As you pull the trigger with your right hand (to simulate strumming) it will detect if the left hand is in contact with one of the colliders. The system will then play the chord.

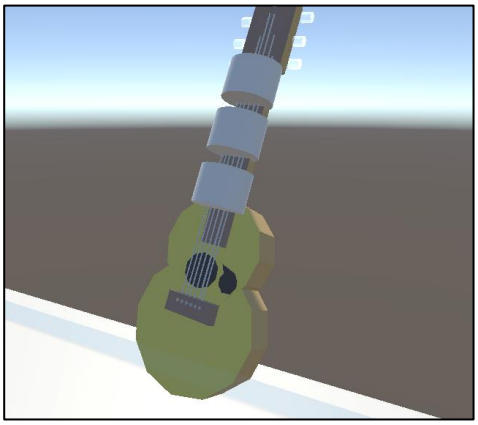

Figure 51 VR Guitar Chord Collider Boxes

The code is quite straight forward, each collider (fret1, fret2, fret3) has a Boolean quality called isfretpress. This Boolean gets changed to true when there is a hand colliding into it.

```
void Update()
   {
isguitargrab =
guitar.GetComponent<SimpleAttach>().guitargrab;

isfret1press =
fret1.GetComponent<detectguitar>().isfretpress;

isfret2press =
fret2.GetComponent<detectguitar>().isfretpress;
```

```
isfret3press =
fret3.GetComponent<detectguitar>().isfretpress;

if (isguitargrab == true)
  {
if
(SteamVR_Actions._default.GrabPinch.GetStateDow
n(SteamVR_Input_Sources.RightHand))
    {
      Debug.Log("trigger press");
       if (isfret3press == true)
       {
         chord3.Play();
        }
       else if (isfret2press == true)
       {
         chord2.Play();
       }
       else if (isfret1press == true)
       {
         chord1.Play();
       }
     }
```

The script then detects when SteamVR detects a grabpinch (the name for a trigger press) and filters through which of the frets are pressed, checking the higher chords first as on a guitar if you press a high and low note, only the low note will resonate. To simulate this if you have two frets colliding at once, it will only play the higher fret.

Recycling Bin

Figure 52 VR Recycling Bin

The recycle bin was created once I spawned too many drum cubes for the drum machine and wanted to de-clutter. So I implemented this bin model from google poly. The inside of the bin has a collider that once it detects a drum will delete the game object from the scene.

```
private void OnTriggerEnter(Collider other)
 {
  tobeDeleted = other.gameObject;
  if (tobeDeleted.tag =="drum")
   {
    Destroy(tobeDeleted.gameObject);
   }
 }
```

11 Final Evaluation

The Final evaluation was a and a short discussion after asking the users to complete a series of tasks.

After they completed the tasks, they were asked to fill the same system usability scale form that they filled before to see if improvements had been made overall. These questions are on a one to five scale, one being strongly disagree, five being strongly Agree, the following are the questions and the average answers among users.

The diagrams below are to show the change in answer from the previous SUS. The white circle indicates where the previous answer was, and the coloured brick indicates the new SUS outcome.

1. **I think that I would like to use Music in VR frequently**

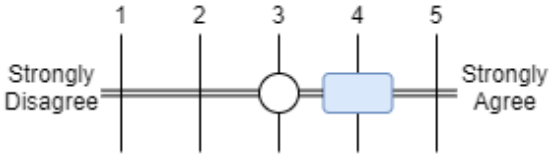

Figure 53 Final Evaluation Statement 1 Results

This statement has changed from a rather indecisive outcome to an agreement that the user would use the system frequently. This is a large improvement as we want to continue to keep engagement with the user so that they are more likely to keep exploring the possibilities of music creation in Virtual Reality.

2. **I found Music in VR unnecessarily complex**

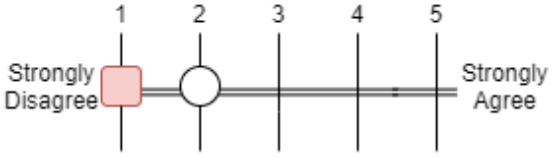

Figure 54 Final Evaluation Statement 2 Results

The previous answer to this statement was a 2, a Standard disagree. After the revisions made to the complexity of the system users on average strongly disagree with the statement. This means that the changes, for instance the

drum watch menu had an impact on how the user was able to view the complexity of the system.

3. **I thought Music in VR was easy to use**

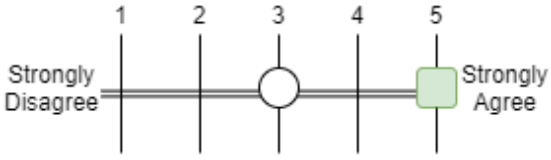

Figure 55 Final Evaluation Statement 3 Results

The first user evaluation on average had this statement as a 3, a middle of the road answer about the ease of use of the system. This is a huge goal for the system and one of the main aims overall. After using the Final build, the Users on average strongly agreed that the system was easy to use. This was due to helpful hints and control changes that were made to make sure that the user had the most painless time trying to work out what to do and then actually carry out those actions.

4. **I think that I would need the support of a technical person to be able to use Music in VR**

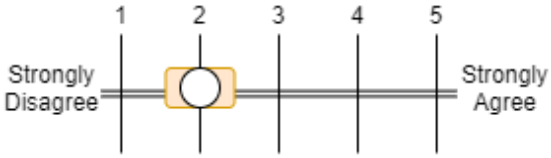

Figure 56 Final Evaluation Statement 4 Results

This was the only statement in the entire questionnaire that stayed with the same answer. This was somewhat a shock. Some people view Virtual Reality to be a hugely technical task and are afraid to tackle its use alone.

5. **I found the various functions in Music in VR were well integrated**

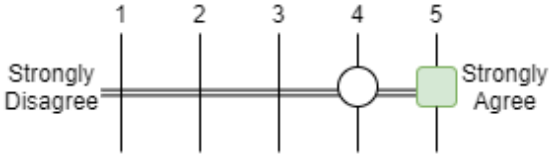

Figure 57 Final Evaluation Statement 5 Results

6. **I thought there was too much inconsistency in Music in VR.**

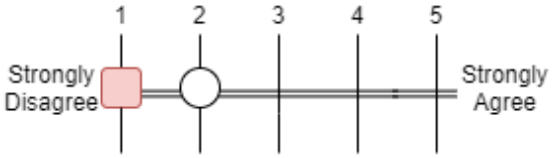

Figure 58 Final Evaluation Statement 6 Results

Question 5 changed from 4 to 5, meaning the entire majority strongly agreed that it was well integrated, Question 6 follows this same line of questioning as it asks: *I thought there was too much inconsistency in Music in VR* This too went from disagree to the entire majority voting Strongly disagree. These outcomes show me that the changes to the system to ensure that it was smooth a consistent with no bugs was a massive success as the entire feedback group agrees that it has changed for the better.

7. **I would imagine that most people would learn to use Music in VR very quickly.**

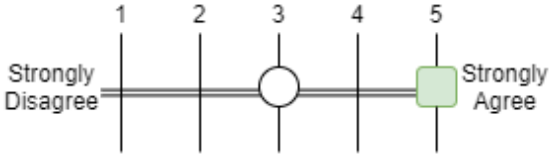

Figure 59 Final Evaluation Statement 7 Results

This was the only outcome that was a shock was that users thinking that they need the support of a technical person to use the system stayed the same, according to question 4. Personally, I was expecting the answer to shift to a strongly disagree, but it stayed at a 2, meaning that some users still think that they may need to have someone technical near them to use the system. I believe that this is aimed directly at VR as a whole and not the system directly as Virtual Reality has a stigma around it that it is difficult to set up/function.

8. **I found Music in VR very cumbersome (awkward) to use**

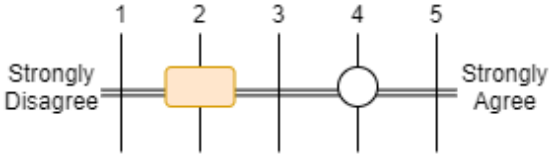

Figure 60 Final Evaluation Statement 8 Results

Question 3 & 8 deal with the issues that were previously apparent with the first design evaluation, mostly being geared towards ease of use. Question 3 asks if they thought the system was easy to use. The answer went from a middle ground of 3 straight to a strongly agree rating of 5, this indicates that the ease of use from the user's perspective has changed drastically. Similarly, with question 8, I ask if the system is cumbersome or awkward to use. The users on average voted 4 which would be agreeing with the statement. After they used the final system this shrunk to a 2 signifying a disagreement.

9. **I felt very confident using Music in VR**

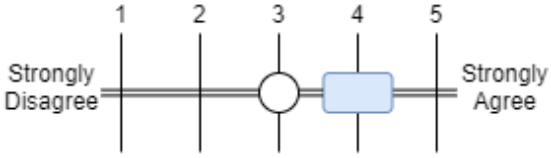

Figure 61 Final Evaluation Statement 9 Results

10. **I needed to learn a lot of things before I could get going with Music in VR**.

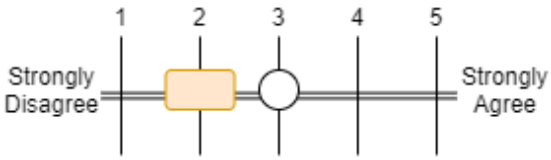

Figure 62 Final Evaluation Statement 10 Results

Statements 9 & 10 both were aimed at how the user felt on a first impression with the new system when it came to confidence of use and also how easy it would be to gain that confidence. Both of these questions shifted by one point in the positive direction, statement 9 going from a rating of 3 to 4 and statement 5 going from a 3 to a 2.

Additional Comments were as follows:
"Comparing my first experience with VR music to the final, I can see vast improvements. How everything is used is much clearer cut, and the screen metaphors such as the bin and question mark help guide the user to the functions of these things. It is also more user friendly as there is more information available on screen for the user to access. Having the music boxes attached to the left hand also negated the tedious movement that was previously there."

"Very much a fan of the drum added feature, very cool app and would be so useful to help some folk make music, very straightforward and very intuitive"

"Overall, really impressive stuff, especially the drums that seemed to be played very naturally and easily. Personally, I'm not a huge fan of VR but if I was it would be something I would love to use. The music theory information is also very useful for people that may not know much about that kind of stuff."

These results showed a stronger opinion on almost every answer after being exposed to the changes that had been made to the system. The circles were almost exclusively in the middle with no strong opinions.

Question 5,2,6 and 7's results made it abundantly clear that the changes that were made after the design have made the system much easier to grasp music and VR.

Question 2 and 7 were asked to ensure that the users would have an easy time using and learning about VR and music. These questions were Vital as they let me know if I was on the right track to success in my project. Question 2 asked about the statement: *I found Music in VR unnecessarily complex*. The group disagreed with this statement but did not strongly disagree meaning that there was room for improvement. With that answer I aimed to make the system as simple with no need for explanation as possible. After the changes that I made to the systems to make them easier to use the groups answer came out as a majority 1, a strong disagreement.

Finally, the comments were extremely positive. The majority mentioning the controls coming naturally and the ease of use for the system. Comments also mentioned being pleased with the addition of features, the most common being the physical drum kit. The users enjoyed the real feel and how smooth the kit seemed to function. A couple users mentioned about how they are not a big fan of VR in general. However, when the system was interacted with, they seemed to have a great time.

12 Conclusion

This projects aim was to explore the possibility and limits of music creation in a virtual reality environment whilst aiding the knowledge of users who do not know much about music creation and Virtual Reality.

In conclusion the system created succeeded in the criteria that I had set for it. The project was carried out with the user in mind throughout, with the ease of use, familiar controls and ability to freely explore the possibilities of creating music in VR at the forefront. While these mindsets were met, In the future I would hope to have a focus on creation of full songs rather than playing music live. Hopefully, VR as a technology gets pushed further and applications exploring the possibility of creation within a virtual environment such as this system and google blocks become widely available.

Acknowledgements

A huge thanks to my supervisor, Dr Rachel Menzies, for extensive help during the entirety of the project. Mahamadou Niakaté for sorting me out with a laptop at the start of the year and even further once the COVID-19 Pandemic struck and shut down the university, in his own time came to deliver my an oculus quest to continue my development in VR.
The university of Dundee for providing me with the personal space and equipment to develop in Virtual Reality comfortably.
Finally all of the users who participated in the survey and user evaluations of the system.

COVID-19 Statement

Covid-19 directly impacted this project with the denial of dedicated space, equipment and meetings being cancelled & stripped away from me. Not only that but extreme stress from family members contracting the virus & extremely at-risk family members whilst I am locked out of my home country. For a full report see appendix D.

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Appendices

A-Design Sketches

- A1 – Drum Machine Sketch
- A2 – Tutorial Hint Sketch
- A3 - Keyboard Sketch

B-Ethics Documentation

- B1 – Focus Group Guide
- B2 – Demographics
- B3 – Participant Information Sheet
- B4 – Checklist 1
- B5 – Checklist 2
- B6 – Non Clinical research form
- B7 – Survey Questions
- B8 – Informed Consent form

C-User Evaluations

- C1 – VR SUS form
- C2 – User Evaluation results
- C3 – Design Evaluation Video
- C4 – Final Evaluation Video

D- Covid Statement

E- Trello Board

F- Source Code & Unity Files.