The Creation of a Musical Instrument Within a Virtual Space for Education.

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Abstract

During COVID-19, many sectors around the globe shut down to stop the spread. One of these sectors was education. This forced schools to find new ways to instruct their students, so they are not left without an education. This project will investigate if a musical instrument created for a virtual reality space can be used in education to teach students about music by researching past academic literature to find gaps, developing a musical instrument for the virtual reality medium, and having participants test the artefact to answer the question addressed.

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1 Introduction

Although it feels like the world is slowly going back to the way it was before the COVID-19 pandemic, the virus is still active, so people/businesses have had to find new methods to accomplish their day-to-day tasks while reducing the risk of transmission. One of these methods is using virtual reality technology. As of 2021, the global virtual reality market is valued at 21.83 billion dollars with an expected compound annual growth rate to increase by 15% from 2022 to 2030 as stated by Grand View Research (2022).

One of the industries that are starting to adopt the virtual reality technology is education. A study by Mateen and Kan (2020) demonstrated the use of virtual reality in education by creating a simulation where medical students were able to enter a virtual clinical environment to perform anatomy on subjects. It was discovered that students who were exposed to virtual reality simulations performed higher than students who used traditional methods. Furthermore, if both traditional methods and virtual reality were mixed, the students would be able to further their knowledge.

Of course, the medical field is not the only area where virtual reality can be used. Institutions around the world could benefit from the use of virtual reality for any course. This is where main the main idea for the project comes into play. Knowing that virtual reality can be used to advance the students' knowledge, what if virtual reality could be used in the study field of music.

In the project proposal, it was stated that the aim of the project was to develop an artefact which would allow users to create and play music which in theory, would improve the user's knowledge about music theory without having to buy or pick up an instrument. The aim of the project has stayed the same with the following objectives being unchanged:

1. Conduct background research in music theory to create a virtual reality instrument

2. Conduct research on virtual reality development elements to create a virtual reality program.

3. Evaluate the efficiency of the software with user testing by testing users with diverse levels of musical ability

The following paper will discuss the creation and the evaluation of LaserHarp VR, an artifact created which improves on the standard laser harp and turns it into a virtual reality musical instrument taking advantage of the virtual reality medium which would be impossible in real life.

2 Literature Review

Although there are numerous advantages to studying a musical instrument, the negatives may exceed the rewards for some people. The expense is the primary reason for not wanting to study an instrument. Depending on the instrument, things like the cost of a music teacher, the instrument, and the learning materials might be quite costly (Andreas, undated). Musicians may not have enough space for instruments such as pianos, which take up a lot of room.
The difficulties of owning an instrument can be eliminated via virtual reality. With features like Oculus Guardian on the Oculus Quest 2, the user can specify boundaries based on the space available (Meta Quest, undated). Furthermore, with the decreasing cost of virtual reality headsets (Marr, 2020), purchasing a virtual reality headset may wind up being less expensive than purchasing an instrument. This could imply that even if the user loses interest in the musical instrument, the headset still offers a variety of options. This is beneficial to both parents and schools because it saves money on equipment.

1.1 Limitations of Virtual Reality

One of the most common issues when designing a virtual reality musical instrument is the challenge of accurately depicting a hand with finger movement. This means that some instruments that need finger movement, such as the guitar, will not work effectively in a virtual reality environment (Andronache et al., 2020). Mäki-Patola (2005) came to a similar conclusion, claiming that recreating an existing instrument would not produce fascinating results, thereby alienating musicians who are accustomed to playing traditional instruments. Although firms such as UltraLeap are making strides in haptic feedback technology by using ultrasounds to bring a virtual touch to life, these are either too expensive or unavailable (Ultraleap, undated).
Instead, it is suggested that instruments be created solely for the virtual reality medium. This opens options such as visualization that would not be possible in real life. Although haptic feedback can help the user, visuals can also help and provide real-time information about what they're doing (Mäki-Patola et al., 2005). The design of a laser harp for the virtual reality medium is covered in an essay by Andronache (2005). The instrument was built with eight lasers to represent an octave (8 musical notes). Although this is a popular option and simple to learn, the lack of sharps, flats and other octaves can limit the user's inventiveness and potential. Beginners and professional musicians alike can benefit from the software's wide range of notes and octaves. This would allow for skill advancement, such as when a beginner learns the basic octave and then introduces other notes to increase their musical understanding.

1.2 Multiplayer within virtual reality

With the recent outbreak of the COVID-19 pandemic, 1.6 billion students in over 200 nations were forced to miss school (Pokhrel and Chhetri, 2021). Teachers had to use a variety of methods to educate their students in the absence of schooling. Online learning proved to be the most effective method of keeping pupils educated (Schools & Academies Show, 2020). Although online education has proven to be helpful, it is lacking in one area: sociability. Students gain skills, behaviour patterns, ideas, and values that are necessary for successful functioning in society through socialization (Kuczynski, 2012). Orel and Guna (2018) examine the social involvement between users in the metaverse in their study. It was concluded that because of the perceived self-control in the digital realm, there was a higher level of contact with other peers and environments.
Serafin et al. (2016) published an essay with nine design guidelines to aid in the construction of virtual reality musical instruments. As virtual reality has been a one-person experience, Principle 9 advocates making the instrument a social experience where users may create, share, and play together. 4 separate virtual reality instruments were produced in the study by Çamcı et al (2020), which focused on the single-player experience rather than a social one. Making the project multiplayer allows users to interact with one another while playing and teaching one other. This would be beneficial in situations such as lessons, where a virtual environment may offer a social presence for people who want to develop their musical talents while playing with peers who are in another area (Serafin et al, 2017).

1.3 Customization

As previously shown, Andronache (2005)'s laser harp has a predefined amount of notes. Although this is beneficial for beginners because there are fewer notes to learn, more accomplished musicians who want more may find it annoying. Adding customization to the solution is one method to solve this problem. Adding functional customization allows for changes in the functionality, appearance, or usability of the program by allowing the user to make decisions that increase its personal relevance (Turkay and Adinolf, 2015). Using cosmetic customization, the user can customize the colour of the laser beams or the projector itself which could lead to positive player enjoyment without changing the mechanics of the program (Turkay and Adinolf, 2015).

Allowing the user to select notes while implementing functional customization can be done by keeping a selection of notes from each octave that can be assigned to the laser of their choosing via the menu when a projector is selected. A menu that allows the user to construct projectors would be useful because it would allow them to assign notes and create their own instrument configuration. The user can give colours to the projectors or the beams themselves to provide cosmetic modification. Beginners may find it helpful to assign each projector a distinct colour, while more skilled users may prefer to allocate colours based on octaves.

3 Methodology

3.1 Project Management

As mentioned by Heerkens (2002), project management reviews the steps in organizing and managing projects where topics such as building realistic schedules and measuring the success and failure of the project. When looking into the project in more detail, it was possible to split it into three different sections. The first section was doing some research into existing projects and other material that would aid in the creation of the artefact. The second stage was developing the artefact and the third stage was having a user testing study using the artefact to see if it conducts the desired tasks.

Within each of the section, there are smaller tasks that need to be completed so project management is crucial to make sure everything is completed in time to avoid failure. This project used a variety of different techniques to make sure the project would be completed in time.

3.1.1 Gantt Chart

When completing the project proposal, a Gantt chart was created which highlighted tasks that needed completing against a timeline set for each of the tasks. Having a Gantt chart allows for a comparison of how the progress on the project is going against what was originally planned. For this project, the Gantt chart was used to give a more overall structure to what topic should be done now, so for example when to start an assignment and how long the assignments should take to be completed or how much time should be spent researching.

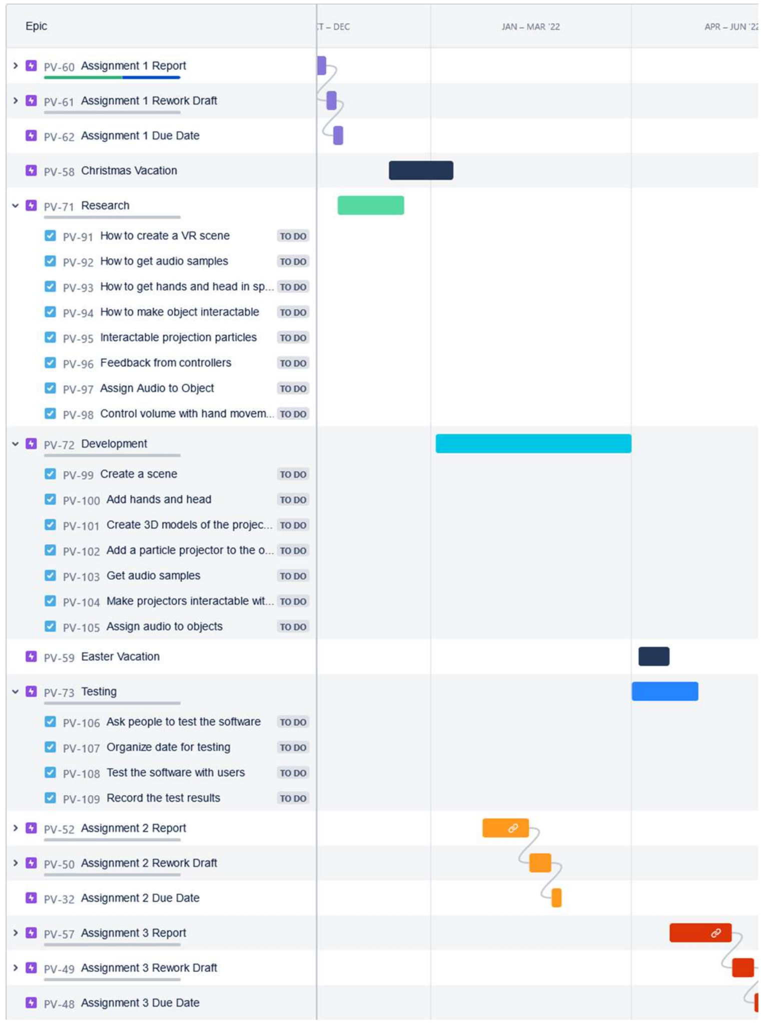

Figure 1 – Gantt Chart for the project

3.1.2 Kanban

Similarly, to the Gantt chart, a Kanban was created which allowed for the identification of what tasks there are in the project and to keep the progress of what is currently being worked on or finished. While the Gantt chart is used to keep a track of time on the overall project, Kanban keeps track of all the tasks within the individual sections of the project. For example, during development, a track of different functionality is kept which shows what functionality is currently in development and what still needs completing. This was extremely useful in the project as keeping a track of the functions while developing meant that time was not wasted trying to figure out what to create next. Furthermore, if time constraints meant that functions had to be removed, using the Kanban, it can be determined what functions are not in development and would take too much time.

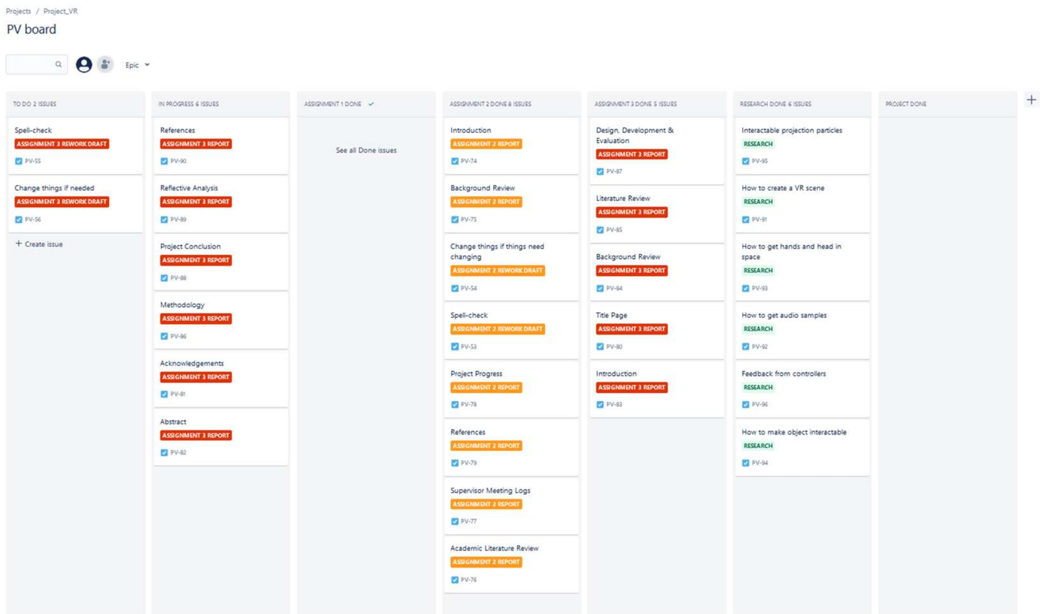

Figure 2 - Kanban for the project

3.1.3 Risk assessment

In the project proposal, a risk assessment was created. Risk assessments are important in project management as identifying the risks which might cause the project not to be completed in time would allow for reduction of the risks. Unfortunately, the risk assessment created was not used as the original risk assessment focused on the risks that would affect the participants rather than the actual project itself.

3.1.4 Supervisor meetings

During the project, weekly supervisor meetings were planned to discuss how the project is progressing and if there are any questions. This was found to be extremely helpful as having weekly meetings meant that goals had to be completed so a discussion could be made each week. This led to goals being completed more frequently. If there were no weekly meetings, the progression of the development would have been slower as the meetings made sure work was being done.

3.2 Software Development

Software development is a process by which a software project is completed or developed through the well-defined processes or stages (Chandra, 2015). When developing the software, the main software development methodology used was scrum. The reason for the usage of scrum methodology was since software development is so unpredictable where many elements of the project could change either based on time or the complexity, scrum would allow for the development of different functionality that have different requirements while giving flexible requirements selection during sprints (Srivastava et al, 2017)

Using a Kanban as mentioned in in project management, it was easier to plan the elements and features required to make the project successful which would then lead into a sprint. Within the sprint, the individual tasks identified in the plan were then created and tested to see if they work as they should do. This made the development easier as time constrains caused by other assignments and personal events left the project not being completed. So, scrum made sure that even with the time constraints, functions of the project would still be completed.

3.3 Toolsets and Machine Environments

During the development of the project, a variety of tools and hardware were used for software development and project management. This section of the report will cover all the tools used and make comparisons to other tools that could have been used for the development.

3.3.1 Blender

To create the 3D model for the projector, a program called Blender was used. The reason for this is because Blender is an open-source tool used for modelling, rendering, animation, and anything else related to 3D computer graphics (Alecu, 2010). With Blender being open source, it was free to use so no money had to be spent and because of the software being free, it has an active online community that provide assets and tutorials on how to use the software.

Although other software like Maxon's Cinema 4D exist and achieve similar objectives, they are not free and cost £55.10 a month if paid annually or £94.80 a month (Maxon, 2022). Since only one 3D model needed to be created for the projector, Blender was the best choice.

3.3.2 Photopea

Photopea is an online image editor which allows for multiple tasks to be done ranging from simple tasks like resizing an image up to more complex tasks like creating illustrations (Photopea, 2022). During the development of the project, Photopea was used to create materials for the game like the floor texture and the masks used for the laser.

The main reasons for the usage of Photopea was that it was free to use, the portability aspect of being able to use it without downloading any software and supporting a variety of file formats made it a versatile tool. Adobes photoshop was considered but just like Maxon's Cinema 4D, Adobe Photoshop requires a subscription service which would cost £9.98 per month (Adobe, 2022). Within the project, only a couple of assets needed to be created so Photopea worked simply fine.

3.3.3 Unity

As stated by Zamojc (2012), Unity 3D is a powerful cross-platform 3D games engine which allows for the creation of 3D games or application for a variety of devices by using a user-friendly environment. By being free to use and having an active community where other content creators provide assets which can be reused within different projects to ones needs (Jerald et al., 2014). There is other software that could have been used like Unreal Engine 4 but in the end, Unity was chosen for the fact that Unity has a larger community where on Unity3D's forum, there are over 6100 dedicated topics on VR development while Unreal Engine's forum only has 4600 threads (Circuit Stream, 2022).

3.3.4 Visual Studio 2022

When developing the artefact with Unity, the main programming language used was C#. Visual Studio 2022 allowed for the creation and the editing of scripts while giving syntax errors and highlight functionality thanks to the cross-support between Visual Studio and Unity.

While JetBrains Rider was considered as the IDE of choice when creating the artefact for the extensibility which would support Unity, Visual Studios 2022 was chosen as it was free to use with the university account while JetBrains Rider had a subscription service (JetBrains, 2022).

3.3.5 Oculus Quest 2

The Oculus Quest 2 is an all-in-one headset that is filled with hundreds of unique experiences (Meta, 2022). The Quest 2 allows for the headset to be used by itself or be connected to a computer, and with recent updates adding support for Air Link which adds a way to connect the headset to a PC through Wi-Fi, more functionality keeps getting added.

While other headsets like the Oculus Rift and the HTC Vive exist, the ease of not needing a cable or other external sensors needing installing make the Oculus Quest 2 easy to use without having to set anything up which speeds up the process of development and testing.

3.3.6 Pinterest

When designing the artefact, Pinterest was used to create a mood board which would be useful to generate ideas on how the project should look. Pinterest allows for sharing of ideas in the form of images which then can be pinned to a board (Meng, 2019).

Like Pinterest, PureRef was considered as it allowed for adding reference images into one place with features like notes helping in the organization of the images (PureRef, 2022). Pinterest was used over PureRef because Pinterest allowed for the search of different images within the website which makes it easier finding reference images.

3.3.7 Github

To keep the artefact accessible, GitHub was used as it allowed for the code to be hosted for free with unlimited repositories (GitHub, 2022). OneDrive could have been used as with the university account, 1TB of storage can be used to store projects like this. GitHub keeps a track of all the commits within the repository which means if there was something to go wrong within the artefact, a backup would be available for download. This was the main reason for choosing GitHub.

3.3.8 Atlassian Jira

A study done by (Filion et al., 2017) refers to Jira as a work item tracker which is used to track bugs and tasks that a project might have. Using Jira, it was possible to create Kanban's and Gantt Charts for the project which would aid in project management. Microsoft excel could have been used to create these project management tools but the automated system of Jira makes it easier to keep a track of tasks needing to be completed or to evaluate the time management of the project.

3.3 Research Methods

Williams (2007) say that research is a process of collecting, analysing, and interpreting data to understand a phenomenon. Research methods can be split into two distinct categories, qualitative research, and quantitative research. To answer the question addressed, both qualitative and quantitative methods have been used. With the question in mind, two different tests can be used to answer if the artefact can be used withing education.

Using quantitative research, a system usability scale can be created to find out how usable the system by collecting the raw individual survey ratings across all the testers of the artefact and converting it into a single SUS score based on Brooke's standard scoring method (McLellan et al., 2012). The results from the system usability scale will find if the artefact has a high usability score as if the system were to be used in education, it would have to be simple enough to use for anyone.

On the other hand, the collection of qualitative data will be done by an interview where questions about the artefact they have tried out will be asked. While the system usability score will tell how usable the artefact is, having an interview will give more insight into each feature of the artefact ranging from positive feedback to more negative feedback which could be used to improve the artefact further.

4 Software Development Projects

4.1 Requirements elicitation, collection, and analysis

At the beginning of the project, many different ideas were created which would set the course of the artefact. The main theme that was certain was creating a program in virtual reality and having it relate to music. During the first handful of supervisor meetings, research into existing virtual reality musical programs was done to aid in idea making. Concepts like a virtual reality guitar and piano were first suggested, but the complexity of a guitar would be seemed too complicated to recreate while instruments like a piano have already been created.

This inspired the concept of creating a unique virtual reality musical instrument. When trying to find realistic examples of instruments that exist in real life that would be great for the context in virtual reality, an instrument that had the most potential was the laser harp. The laser harp is a musical instrument that has several laser beams which if are interrupted, produce sound (Laser Harp Controller, undated).

Figure 3- A user using the laser harp (Laser Harp Controller, undated).

Once the base musical instrument was found, ideas on how to convert it into a virtual reality experience started. At the end, the concept of individual lasers that the user would be able to move and place wherever they feel was developed.

4.2 Design

When the design period started, an early concept of the artifact was created by drawing the main idea. Different ideas for the projectors that would have the laser beam were explored like what shape should the projector be. Ideas like spheres, cubes and even rings were considered. Other things like different layouts of the projectors were considered to see different ideas of how a user might interact with the artifact.

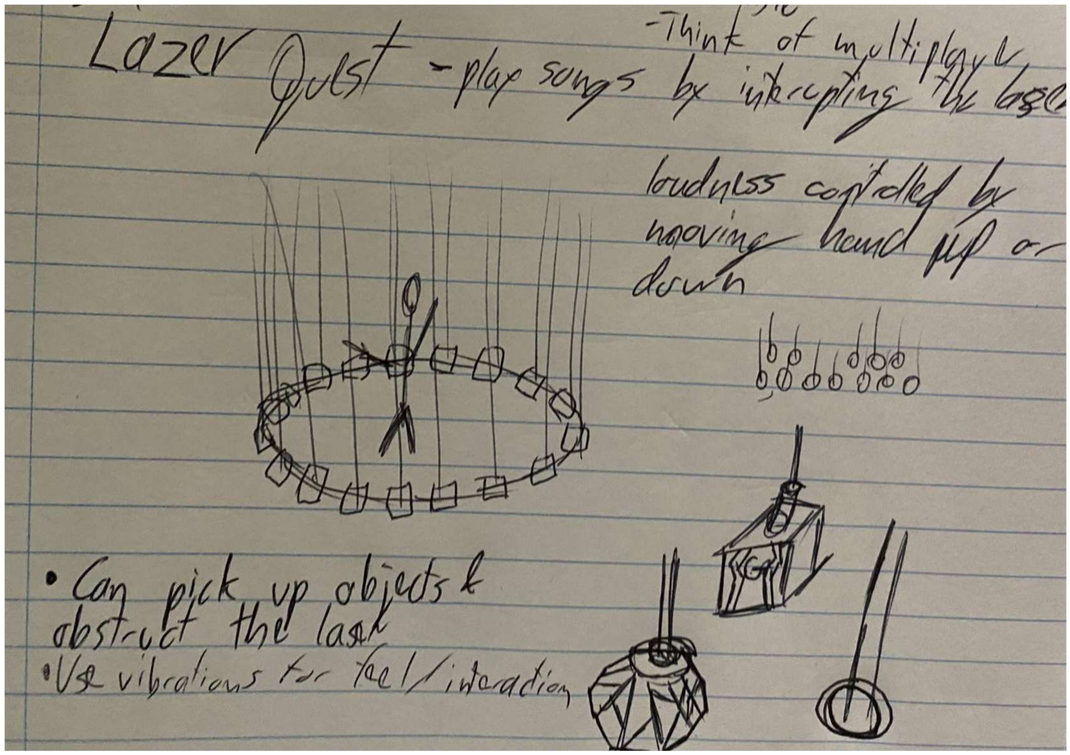

Figure 4 – Early concept art of the artefact.

Once the concept art was created, it was possible to find the main objects that would create the projectors. These were the projector itself, the laser, and the environment that the user would be within. This allowed for a mood board to be created which can be used for inspiration. Using Pinterest, different images were pinned which felt the most fitting for the artifact. Just like the concept art, different ideas for the environment, lasers and projectors were developed.

At the end of the design period, it was decided to create an artifact which resembled the aesthetic of 80's synth since the main theme is lasers. Now that the main theme has been designed, most of the design for the projector and the laser was developed as the artifact was being made.

4.3 Building / coding

After the design of the artifact was created, it was time to create the actual artifact. To get started, my supervisor was generous to supply a virtual reality template withing Unity which was used as part of the Virtual Reality Module. This template came with premade elements like an XR Rig which allows for the virtual reality headset to see and interact with the objects within the scene and multiple objects which the user can pick up and interact with. The template was a good steppingstone as it was then studied to see how the interaction between the program and the headset works.

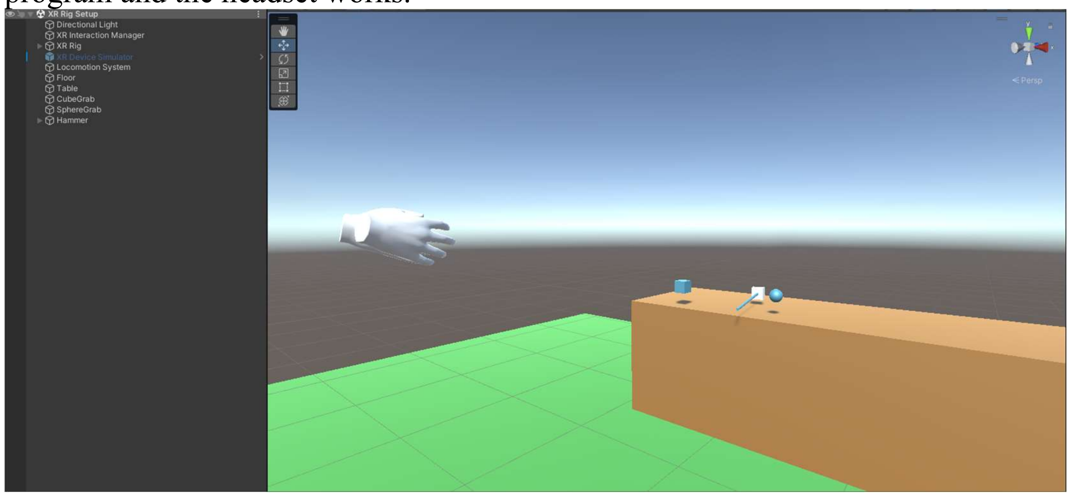

Figure 5 – The Virtual Reality template.

Using the template, it was possible to expand on it and create the artifact. When changing the template, two main elements were changed within. The first element that had to be changed were the packages. These allow for extra functionality that can be used within the game. The template unfortunately had outdated plugins, mainly the XR interaction toolkit which is the essential plugin to allow for virtual reality support.

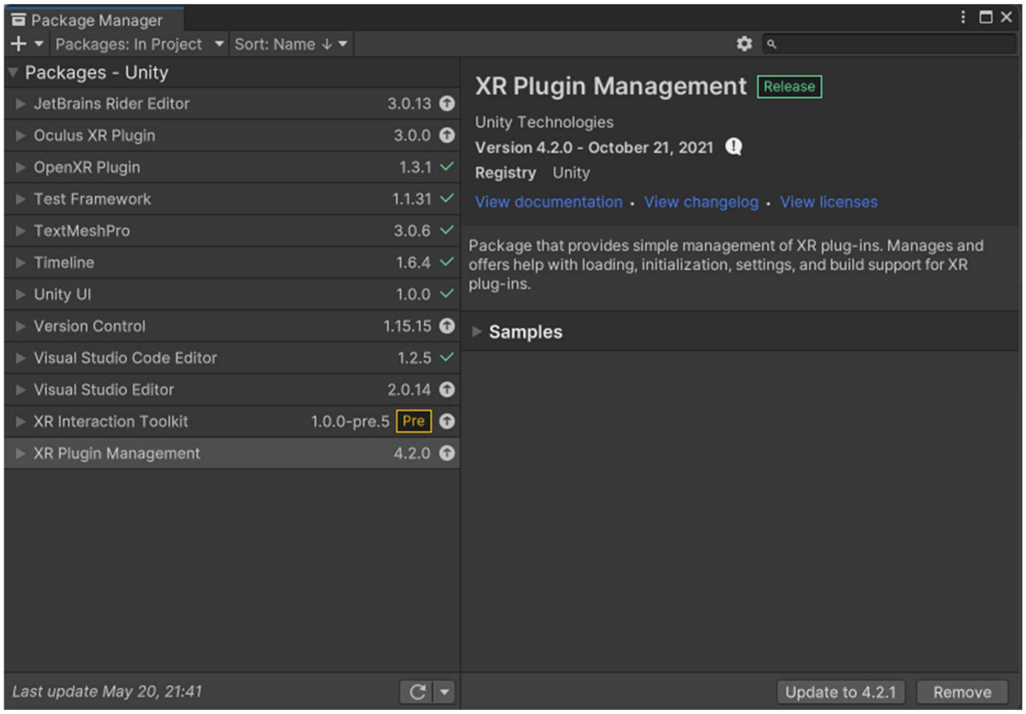

Figure 6 – The templates package manager

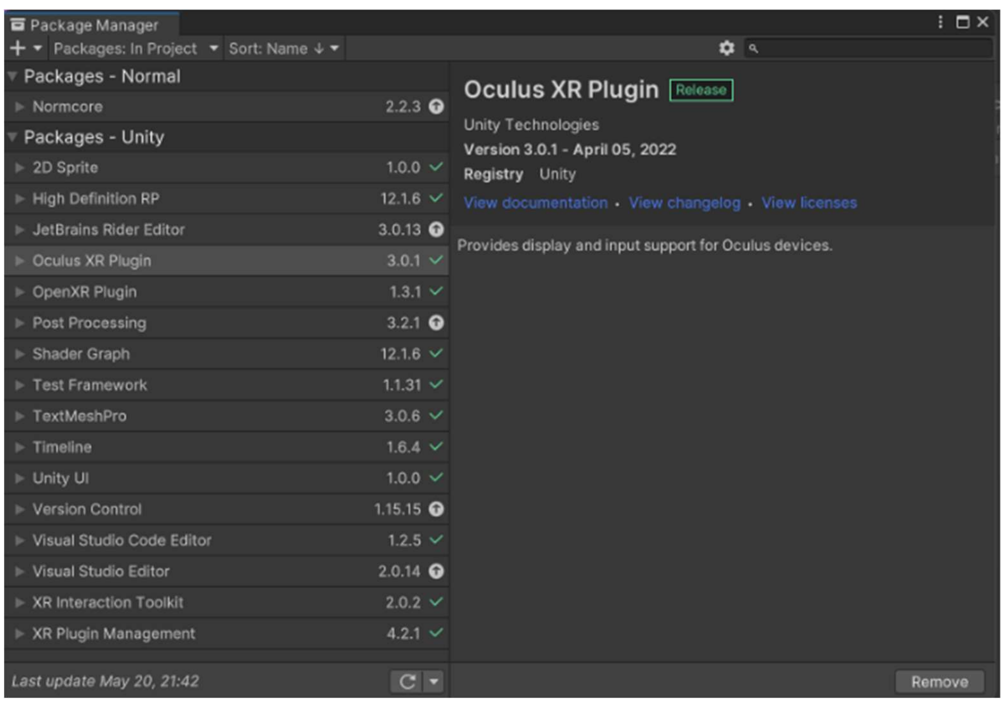

Figure 7 – Final template package manager

Once the package was updated, the XR Rig lost the animations in the hands which had to be fixed. The main reason for this was that with the new update, the XR Rig became obsolete and was replaced with a new system called XR Origin. The only difference in the two systems is the name so adjusting the artifact to work with XR Origin was simple enough. All there was to do was add the XR Origin to the scene and importing the hand models from the XR Rig template into the XR Origin model. Further into the development into the artefact, the hands for the XR Origin were changed into physical hands to aid in the interactions within the program. A video guide by Valem Tutorials (2022) on how to make physical hands was used as a prefab for hands with colliders was provided which make the interactions feel more realistic.

A feature that allowed the user to switch a ray cast interaction mode and a direct interaction mode was also implemented. Although both systems exist within the XR Interaction Toolkit, only one system can be assigned as the main interaction mode. While developing the artefact, it was desired to use the ray cast interactor to interreact with the UI elements while a direct interactor would be used to interact with the projectors and the lasers. This is because the line renderer laser from the ray interactor would get in the way when interacting with the lasers which might be frustrating to some players. A tutorial by VR with Andrew (2021) showed how both systems could be implemented. With some modifications, it was possible to switch between the two systems with a click of button using the Input System.

The second modification to the template was changing the rendering pipeline. In Unity, there are 4 main rendering pipelines that a user can choose from. The main rendering pipeline is the built-in rendering pipeline that automatically gets assigned to every project automatically. The other 3 rendering pipelines are as followed:

Table 1: A table describing different rendering pipelines

Name of rendering pipeline	**Description**
Scriptable Render Pipeline	This pipeline allows developers to customize or create their own rendering systems.
Universal Render Pipeline	This pipeline allows developers to use powerful graphical tools while being optimized for many different systems (e.g., Mobile Phones, consoles etc.)
High-Definition Render Pipeline	This pipeline allows developers to take advantage of powerful hardware to achieve powerful visuals.

(Unity, 2022a)

While the template came with the built-in rendering pipeline, it was decided to use the high-definition render pipeline as this would have allowed for better looking visuals. Another reason was that at the time of creating the laser, it was thought that to use a package called shader graph to create the laser, the high-definition render pipeline had to be used. This was later found to be false. Now that the packages were updated and the rendering pipeline was changed, it was time to create the artifact. The next part of this report will be split into the key features of the artifact.

4.3.1 Projector

The creation of the projector model was uncomplicated. Using Blender, a simple icosphere model was added which then had a wireframe modifier added. With some parameters changed, the modifier gave the icosphere a hollow effect which would allow for some nice glow visual effects to be added. Unity supports blender files so saving the model and importing the file into unity allowed for an instant access to the model within Unity.

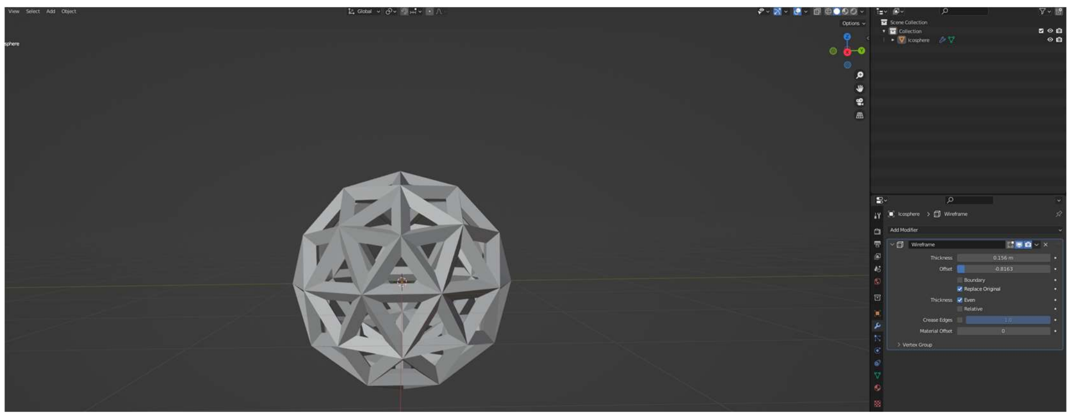

Figure 8 – The model for the projector inside Blender.

4.3.2 Laser

Once the model was created, it was time to make the laser where the user could interact with to produce a sound. There were two main parts when creating the laser. The first was the visual look of the laser while the second part was the functionality of the laser.

When it comes to the functionality of the laser, a script was created which houses all the elements for the laser. A tutorial by Marcos Schultz (2015) taught how to make a script to make an interactable laser. This was used as the starting point since it supplied a great starting point which can be modified and improved on. The script first created variables needed for the laser like the colour of the laser and the projector, the length, the collision light to make the laser more interactive and the audio source which will play the note.

When the program gets started, an audio source, a line renderer and collision light us automatically added. In this instance, a line renderer is used to render the laser as it has support for shader graph materials (this will be discussed further on in the report). Once everything is added, a ray cast is then created inside the update function. This was the main function used as this allowed for the detection of the hands interacting with the laser. The ray cast sends out an invisible laser which would report any collision including the location of where the collision happened. With the location of the hit, the line renderer length can be changed into the collision location which makes it have an effect of the laser being interrupted by the hand even though all that is happening is the line renderer length being changed. Furthermore, if a collision happens, the audio source is then played which outputs the musical note from the synth. The code can be seen in Appendix 1.

The visual of the laser was created using a resource called Shader Graph which allows for the creation of visual shaders in real-time (Unity, 2022b). A video guide by Gabriel Aguiar Prod demonstrated how to use the functionality of shader graph to create a laser beam. This tutorial was then used to create a laser beam shader for the artifact which was applied to the line renderer.

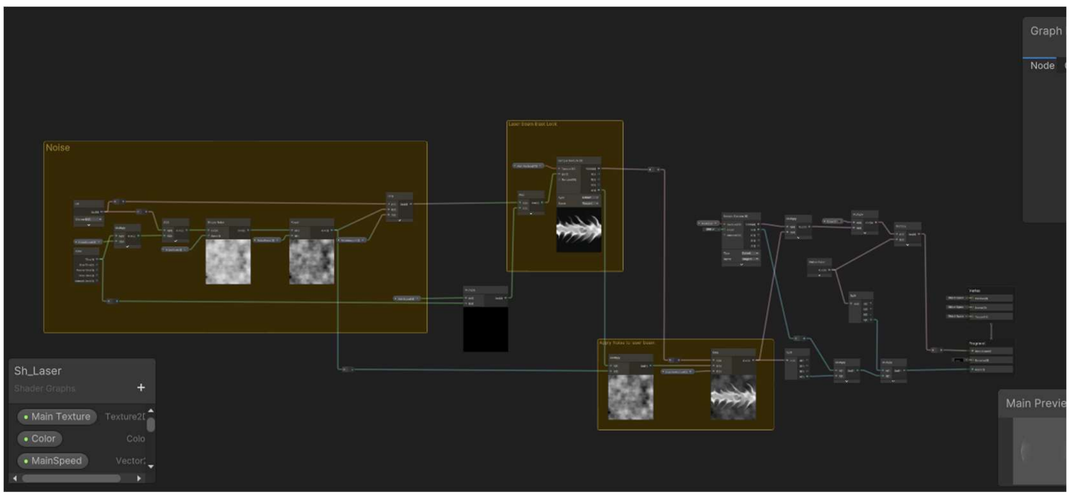

Figure 9 – The shader graph for the laser beam.

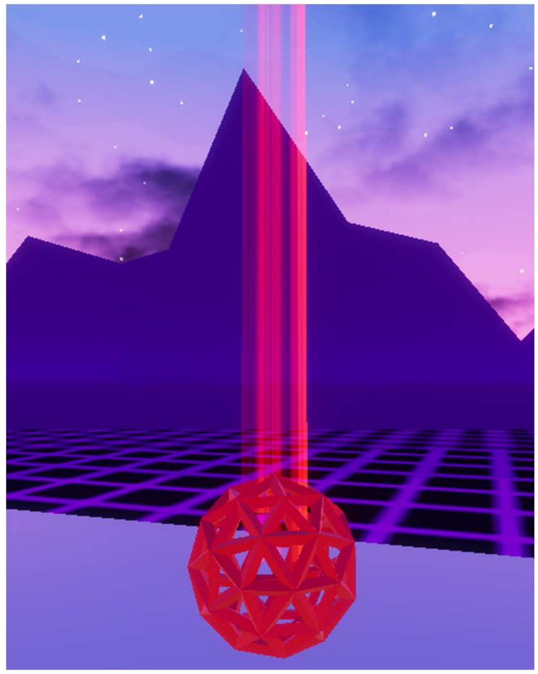

Figure 10 - The projector with the laser

4.3.3 Synth

Just like the functionality for the laser, most of the functionality for the synth comes from a script which was demonstrated in a tutorial by Dano Kablamo (2017). The code had the basics of what was needed for the artifact, so few modifications had to be done. The code written consists of two main elements. In the start function, an array is filled with frequencies that represent a note. To find the frequencies required for the notes, the website physics of music provided a table of different notes with the corresponding frequencies (Physics of Music – Notes, 2022). The OnAudioFilterRead function creates the actual sine wave which is used for producing the soundwave that gets played. The code can be seen in Appendix 2.

Extra functionality has been done in the form of a switch script. This script allows the user to assign notes from the array to a projector through UI. The functionality for the switching code was inspired by Grafik dev (2021) where the code changed UI images. Once the switch script was done, the synth script was added to the laser script which allowed the laser script to access the filter sine wave created.

4.3.4 Environment

To create the environment, a terrain was added which would function as the floor for the player to stand on. Using the terrain tools, it was possible to add some details like hills in the background using the raise or lower the terrain tool. A texture created in Photopea was then added to the terrain to give the ground a Tron/80's feel.

For the skybox, an asset called FREE Skybox Extended Shader from the Unity Asset Store was used which were applied to the sky and fog volume game object to create clouds and the stars (BOXOPHOBIC, 2022). To get the purple colours in the environment, parameters within the sky and fog volume were changed with most of the colours being turned into purple.

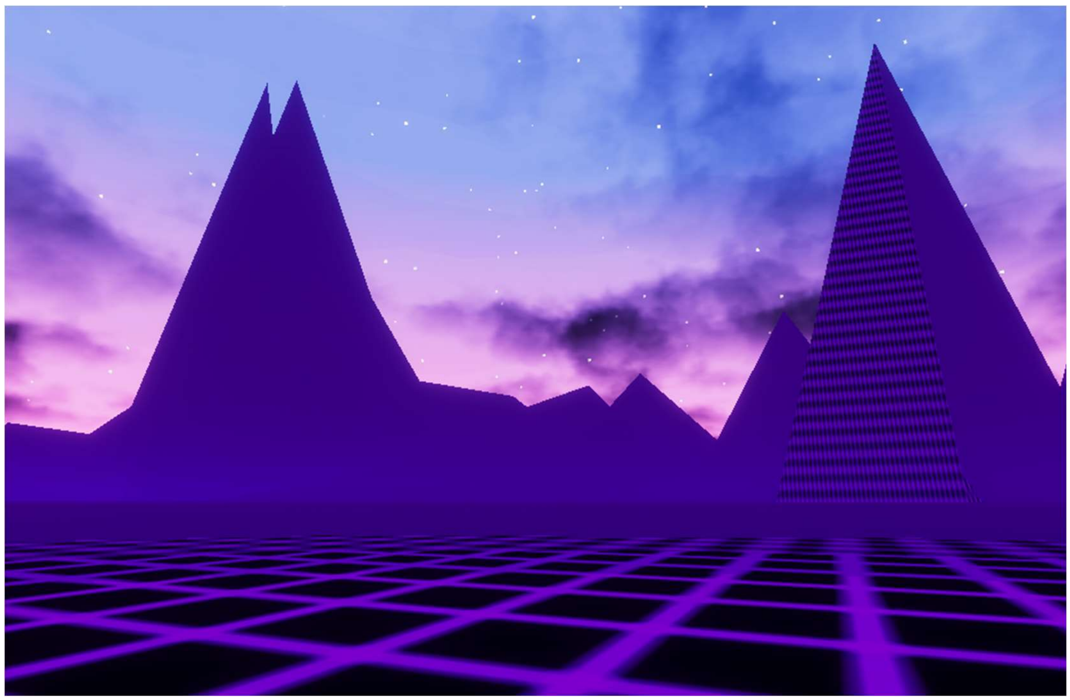

Figure 11 – The environment

4.3.5 UI

In the artifact, there are 3 main UI systems that serve a different purpose. The first UI was the simplest to create, that being the main menu UI. The Main Menu consists of a logo made in Photopea and 4 buttons. The first 3 buttons change the scene based on what the user has chosen to play with (Single player, Demo or Multiplayer). A script is attached to the buttons which allow for the change of scene based on the index of the scene managed within the build settings. The last button is an exit button which quits the application. Just like the other buttons, the quit functionality has been done through a script.

Figure 12 – The main menu

The second UI comes in the form of a wrist UI. This allows the user to either generate extra projectors to play with or exit back to the main menu. Although the wrist UI works like the main menu UI, extra code had to implemented which would allow the user to open or close the menu. An online tutorial by Linkira Studios (2021) demonstrated how to create a wrist menu in Unity with the Unity Input System, the code from the tutorial was then modified to allow for the generation of the projectors within the scene.

Figure 13 – The wrist UI menu

The final third UI is the customization menu for the projectors. Each projector has a customization menu assigned as a child, which allows each projector to be customized instead of all the projectors being customized by one menu. There are three main elements in the customization menu. The first two elements are the colour customization. With an asset called Flexible Color Picker from the Unity asset store, it was possible to implement a colour customization menu where the user can point at a gradient of colours which automatically assigns the chosen colour into either the laser or the projector (Ward Dehairs, 2022). To get the colour to change, it was possible to assign the flexible colour picker to the line renderer colours and the material through the laser script.

The next part of the customization menu came in a form of the note changing buttons. As mentioned in the synth section, the two buttons use the switch script which allow for the change of the note by incrementing or decrementing the index value which gets assigned to the frequency array. To let the user know which note is currently selected, a string array of note names was created which is the same size as the frequency array. Each value from the note array corresponds to the frequency array so if a note is changed, a separate index for the note name array is incremented or decremented which is then displayed to the user.

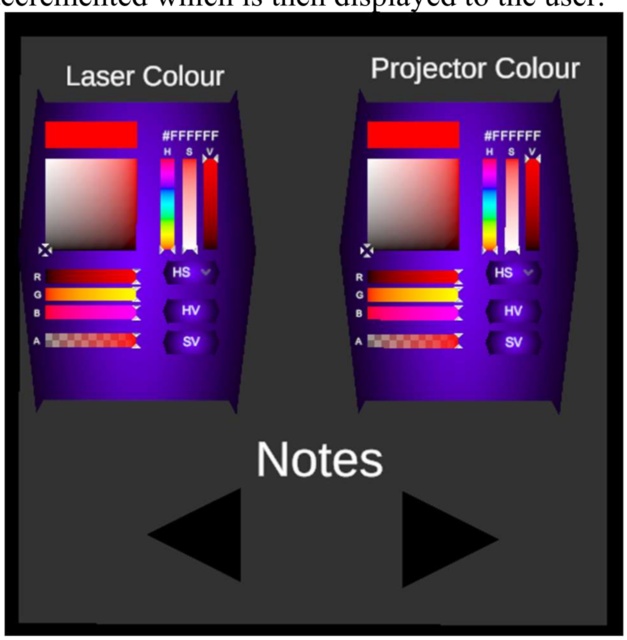

Figure 14 – The customization menu

4.3.6 Multiplayer

Although at the beginning the multiplayer functionality was one of the major features that was decided on, further into the development it was decided to focus on the single player aspect more. When the single player functionality was done, multiplayer was implemented using an asset called Normcore which allows for seamless multiplayer (Normcore., 2020). Once an account is created, normcore provides a prefab where if added to the scene, multiplayer works right out the box with voice chat. Although the multiplayer works, it was not tested properly as there was no access to a second headset.

4.4 Testing

When it comes to the testing of the artifact, the method used was a little unorthodox. This is because while developing the features of the artefact, if a feature did not work as intended, then it was developed further to make sure it works as desired. This was done from smaller bugs like missing a semi-colon within a script all the way to larger bugs like the VR hands not having animations.

Once the artifact was built correctly, a full playthrough was done to make sure all the functionality works and that there are no errors that might occur when a user assesses the program. If an error occurred, then the program went back into development and the issues were fixed. Then another playthrough was completed until everything worked correctly.

During the playthrough, each level was evaluated to see if everything loads correctly. All the levels share the same concept so similar tests were completed:

- Moving and looking around the scene
- Loading into the levels from the main menu
- UI interactions working
- Picking up and interacting with the projector
- Being able to customize and play melodies with the projectors.

4.5 Operation

Once the testing was done, the artefact was complete and ready for user testing. These are the final features within the artefact:

- A main menu where the user can select between 4 choices (Single player, Demo Level used for user testing, Multiplayer, and the exit button)
- Projector that shoots out a laser which a user can use to interact with by interrupting the laser. This would play a note from the synthesizer.
- A customization menu which allows the user to change the colour of the laser, the projector and assign a note to individual projectors
- Two different interaction modes for the hands (ray interactor or direct interactor) which the user can switch between with a click of the button on the controllers.

- A wrist UI menu which allows the user to go back to the main menu or spawn in more projectors.

5 Research

5.1 Participant recruitment

Since the Covid-19 regulations have been loosened, it was possible to acquire people to participate in in-person testing. When looking for participants to evaluate out the artefact, word of mouth was used. By asking people to participate in the research, they were able to ask other people to participate which allowed for more people. Since the artefact uses virtual reality technology, the tests would have to be in person which meant a risk assessment had to be filled in. The risk assessment can be seen in Appendix 3.

5.2 Evidence that ethical procedures have been followed

A participant information sheet and a consent form were created which were given to the participants. The participant information sheet explained to the participants the study that is being done, the information that will be collected and any other questions that they might have. If the participant read the information sheet and were more than happy to participate, then the consent form was filled in and both the researcher and the participant had a copy. The two forms can be seen in Appendix 4 & 5.

5.3 Study design

To answer the question that the project addresses, a series of tests had to be created. The main elements the tests had to answer is how easy it is to interreact with the system and if it can be used in education. It is important that the system is easy to use as if children who might have never used VR use the program, they might find it hard to interact with. Furthermore, it is important to find out if the users who evaluated the program think it can be used in education.

As stated in the research methods, two methods of gathering information were used. The first thing the tester would have to complete would be the system usability scale which will give insight into how easy it was to use the software. This will be followed by an interview where the questions asked will give more insight into the individual features within the artefact. Using these two methods should provide an answer as to if virtual reality instruments can be used in education.

5.4 A detailed description of the procedure

Before the participants were asked to come into Isaac Newton Building, a lab was set up with an Oculus Quest 2 and a laptop which contained both the system usability scale which the tester will be answering and the questions that will be asked during the interview.

The task created for testing was that the user would have to recreate the melody of twingle twinkle little star within the virtual reality environment by assigning notes to projectors and then playing the melody. Once the melody was recreated, the test would be stopped. In the testing level, 6 projectors were created to aid the user and, on the left, a UI interface with the instructions of what notes need to be assigned were given to the tester. All that the user had to do was assign the notes that were displayed on the left to the 6 projectors.

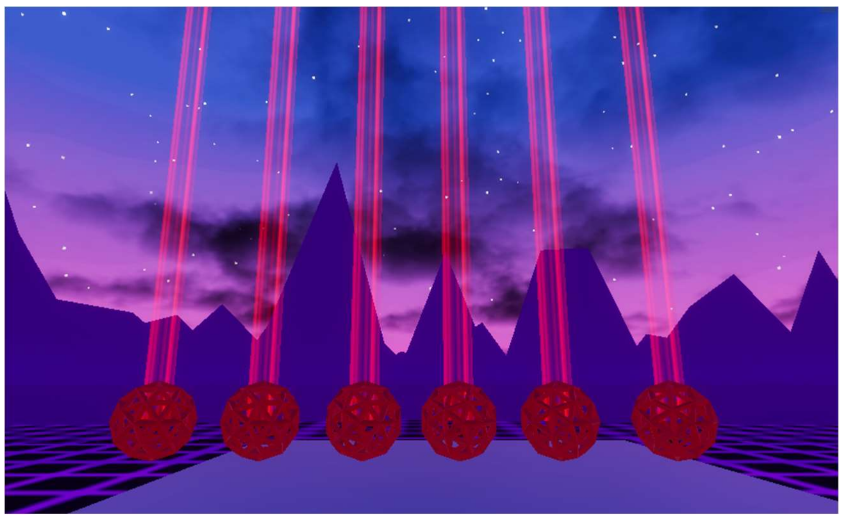

Figure 15 – The 6 projectors

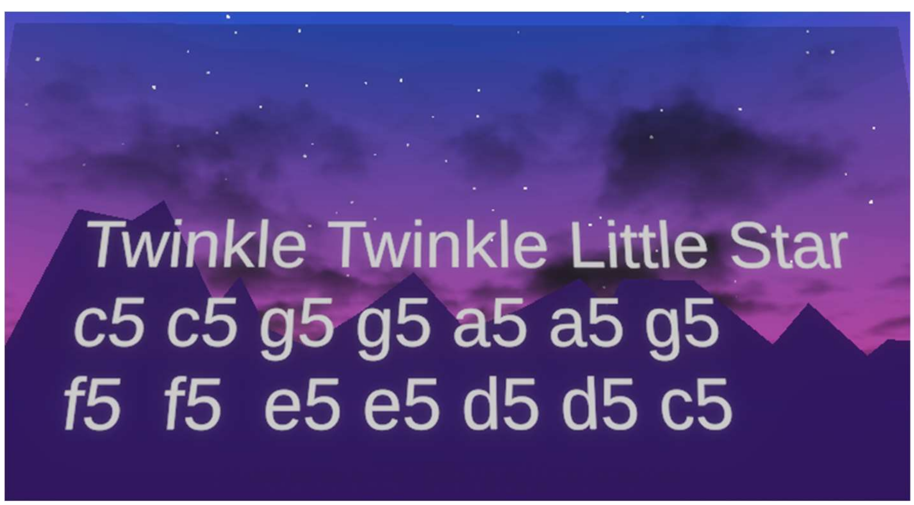

Figure 16 – The UI menu with instructions

Once everything was set up and assessed, participants were invited one by one to evaluate the artefact. An explanation of the task was given to the participant so they would know what to do and a quick explanation of the control scheme was given so they would know what button on the controllers does what. Once all the explanation was completed, the VR headset was cleaned to reduce the risk of spreading COVID-19 and the test was underway. The participant was also encouraged to be creative with the projectors, like customizing the colours or moving the projectors around. Once the participants were successful at recreating the melody, they were asked to fill in the system usability score which was then followed by an interview. Once the interview was completed, it was time to do the same test on another participant.

5.5 Results and Analysis of the results

In this section, the results from the system usability scale and the interview gathered from the 10 participants will be displayed and analysed. Both forms will be available within Appendix 6 & 7.

To figure out the results from the system usability scale, a SUS score had to be calculated. To calculate this, there are 3 stages:

1. Calculate X = Sum of all odd-numbered answers – 5
2. Calculate Y = 25 – Sum of all even-numbered answers
3. Calculate SUS Score = (X + Y) x 2.5

This process was done for all the 10 participants to acquire 10 different SUS scores. The SUS scores can then be interpreted to give an average SUS score which we can compare with the general guidelines to find how the artefact performed. To calculate the average SUS score, all the participants SUS scores were added together and divided by how many SUS scores there were. In this care, the maths was:
Average SUS score = (70+95+87.5+40+82.5+85+85+72.5+92.5+70) / 10

According to Klug (2017), an average SUS score is 68 so with the artefact receiving an average SUS score 78, the artefact created is above average with a grade of a B+. Having a score of 78 means that users found the usability better than average which is a good sign as if the program were used in education, this would mean the user would find it easy to use. This of course still leaves room for improvements as a desired score would be an A+ which has a numerical score range of 84.1 - 100.

When looking into the interview answers, most of the questions asked were more opinion based rather than fact based to gather some insight on what the participants thought. In total, there were 12 questions that were asked. The more important questions asked were 11 and 12 as they provide some insight into some problems that the participants might have encountered and solutions on how to fix them. On top of that, question 12 answers the main question raised. Here are some of the most frequent solutions that were raised:

Question 11 – If you could change one thing in this product, what would it be and why?

- "Add the notes that are selected underneath the projectors so you can see what notes you're playing"
- "Have a piece of text in front of the projector which shows what note is currently selected."
- "Probably to add more notes and add more things to play with (diverse types of sounds)"
- "Make the menus closer to the user"

The full question sheet with answers can be seen in Appendix 8

6 Conclusions

At the beginning of the project, the main question addressed was if it is possible to create a musical instrument within a virtual reality space which can be used in education. Furthermore, 3 main objectives were established:

- Conduct background research in music theory to create a virtual reality instrument
- Conduct research on virtual reality development elements to create a virtual reality program.
- Evaluate the efficiency of the software with user testing by testing users with diverse levels of musical ability

The first two objectives were achieved as written in the background and academic literature section where previous developments were studied to identify gaps within the research. The gaps identified influenced the development of the project making sure features such as customization were included and making a virtual reality instrument purely for the virtual reality medium.

Furthermore, the third objective was completed by having participants test out the program and acquiring the results from these tests. From the results and analysis section, it is clear to see that the data indicates that the artefact is easy to use for the user while also being educational, teaching the participants how certain notes can be used to create music, no matter how much musical experience the user has.

To conclude, although there are areas that could be improved upon to make the system even easier to use for the users, especially ones who might not have any virtual reality experience, the artefact accomplishes the tasks that were set and could be used in education to teach or allow the user to play/create music.

7 Reflective Analysis

Although the artefact accomplishes the desired tasks, further development could have been done to improve upon. When doing user testing, a lot of improvements were identified. The main improvement to the artefact would be a system where the note that is selected on the projector would be shown either under the projector or nearby. It was discovered that a lot of users struggled to remember which note was assigned to what projector, so it caused a lot of confusion. The only ways the user could remember the notes were either assigning colours to the projectors and the lasers to make the memorization easier or opening the customization menu to see which note is currently selected. This feature would have not been hard to implement as the script was already created within the customization menu.

Furthermore, participants found it hard to use the controls within the artefact. If the controls were not explained prior before testing, participants would have not been able to know what button does what. A help button could have been added which if the user clicked on, a UI interface highlighting the controllers and what button does what would have been super helpful in making the software easier to use without any prior knowledge.

Project management could have been used better while developing the artefact. On many occasions, work was not being done. Many things like other assignments slowed down the amount of work that could have been done. Furthermore, during the development of the artefact, I contracted COVID-19 which stopped the development of the artefact by almost 2 weeks. The Gantt chart created was then not followed. This meant the development overlapped by a couple of weeks so there was less time to work on the dissertation report. Development could have been started earlier so in case anything did happen, there would have been extra time allocated for these situations.

Even with the circumstances affecting the artefact and improvements needed, overall, I am really pleased with the artefact that has been created. During the participant testing, seeing users interacting with the artefact and recreating the melody was a satisfying feeling as it felt like the artefact did everything that I would have wanted it to do.

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9 Appendix

9.1 Appendix 1 - Laser Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;


public class Scr_Laser : MonoBehaviour
{
    //Variables for the colour pickers and material
    public FlexibleColorPicker laserfcp;
    public FlexibleColorPicker projectorfcp;
    public Material material;

    //Length and width of the laser
    public int Distance = 50;
    public float width = 0.02f;

    //A light which is added to the hit point
    private GameObject ColisionLight;
    private Vector3 lightPos;
    //The synth from the synth script and an audio source.
    private Synth synth;
    private AudioSource audioSource;


    void Start()
    {
        audioSource = gameObject.AddComponent<AudioSource>(); //Add an audio source which will output audio
        audioSource.playOnAwake = false; //Make sure audio doens't play when a projector is added
        synth = GetComponent<Synth>(); //Get the synth from the synth script

    Laserbeam();
    }

    // Update is called once per frame
    void Update()
    {
        //Get the line renderer and material of projector to allow for the customization of colour
        GetComponent<Renderer>().material.color = projectorfcp.color;
        GetComponent<LineRenderer>().startColor = laserfcp.color;
        GetComponent<LineRenderer>().endColor = laserfcp.color;

        Vector3 LaserEnd = transform.position + transform.up * Distance; //The length of the laser
        RaycastHit hit; //Define a raycast hit to find
        if (Physics.Raycast(transform.position, transform.up, out hit, Distance)) //If statement to see if the raycast has been hit
        {

            //Adjust the size of the line renderer based on the hit position
            GetComponent<LineRenderer>().SetPosition(0, transform.position);
            GetComponent<LineRenderer>().SetPosition(1, hit.point);
            ColisionLight.transform.position = (hit.point - lightPos); //adjust the location of the light

            synth.gain = synth.volume; //Set the gain / volume of the synth

            if (audioSource.isPlaying) return; //Have an if statement to fix a bug
            audioSource.Play();//Play the synth when collided with an object
        }
        else
        {
            //make the line renderer the max length and add a light to the end point
            GetComponent<LineRenderer>().SetPosition(0, transform.position);
            GetComponent<LineRenderer>().SetPosition(1, LaserEnd);
            ColisionLight.transform.position = LaserEnd;
            audioSource.Stop(); //Make sure the synth does not play when the laser has no collision
        }
    }

    private void Laserbeam()
    {
        //Add a line renderer to the object
        LineRenderer lr = gameObject.AddComponent<LineRenderer>();
        lr.material = material;
        lr.startWidth = width;
        lr.positionCount = 2;

        CollisionLight(); //Add a collision light
    }

    private void CollisionLight()
    {
        //End Point Colission Light settings
        ColisionLight = new GameObject();
        ColisionLight.AddComponent<Light>();
        ColisionLight.GetComponent<Light>().intensity = 20;
        ColisionLight.GetComponent<Light>().bounceIntensity = 20;
        ColisionLight.GetComponent<Light>().range = width * 2;
        ColisionLight.GetComponent<Light>().color = laserfcp.color;
        lightPos = new Vector3(0, 0, width);
    }
}
```

9.2 Appendix 2 – Synth Script

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Synth : MonoBehaviour
{
    //Define the variables for the synth
    public double frequency = 440.0; //Tuning of the synth - standard
    private double increment;
    private double phase;
    private double sampling_frequency = 48000.0;

    //Volume settings
    public float gain;
    public float volume = 0.1f;

    //An array to hold all the frequency values
    public float[] frequencies;

    void Start()
    {
        //Create a range of frequencies that equal to an octave.
        frequencies = new float[13];
        frequencies[0] = 440.00f; //A4
        frequencies[1] = 466.16f; //A#4
        frequencies[2] = 493.88f; //B4
        frequencies[3] = 523.25f; //C5
        frequencies[4] = 554.37f; //C#5
        frequencies[5] = 587.33f; //D5
        frequencies[6] = 622.25f; //D#5
        frequencies[7] = 659.25f; //E5
        frequencies[8] = 698.46f; //F5
        frequencies[9] = 739.99f; //F#5
        frequencies[10] = 783.99f; //G5
        frequencies[11] = 830.61f; //G#5
        frequencies[12] = 880.00f; //A5
    }

    //The function creates a sine wave
    void OnAudioFilterRead(float[] data, int channels)
    {
        increment = frequency * 2.0 * Mathf.PI / sampling_frequency;

        for (int i = 0; i< data.Length; i += channels)
        {
            phase += increment;
            data[i] = (float)(gain * Mathf.Sin((float)phase));

            if(channels == 2)
            {
                data[i + 1] = data[i];
            }

            if(phase > (Mathf.PI * 2))
            {
                phase = 0.0;
            }
        }
    }
}
```

9.3 Appendix 3 – Risk Assessment Form

RISK ASSESSMENT SUMMARY SHEET

UNIVERSITY OF LINCOLN

1. Location

Campus: Isaac Newton Building, Brayford	**Assessment Date: 22/04/2022**
College / School / Department: Science/Computer Science	**Re-assessment Date: 22/04/2024**
Building / Area: Various lab spaces	**Risk assessment team members: Ernestas Milinskas**
Accountable Manager: Ernestas Milinskas	

2. Details of further action necessary to control risk (with dates)

Task	Action	Who is Responsible	Date

3. Summary of risks (with controls in place)

Assessment of risk	Low	x	Medium		High		Very High	

Risk to Pregnant Workers?	Yes	x	No	
Or to Disabled Workers?	Yes	x	No	

4. Evaluation

This assessment is an accurate statement of the known hazards, risks and precautions. I certify that the control measures will prevent or, if this is not possible, control the risk subject to the level shown in section 3 (above) and that staff will be adequately trained and supervised, and the identified control measures implemented. The contents of this assessment will be communicated to staff and all relevant persons.

Signature of Assessor:	Date: 22/05/2022
Signature of Accountable Manager (if not Assessor):	Date: 22/05/2022

Probability of Injury/Loss/Harm (P)

1	Very Unlikely
2	Possible
3	Probable
4	Very Likely

Severity of Injury/Loss/Harm (S)

1	Minor	Mild bruising, minor cuts, mild chemical irritation to eyes or skin. No absence from work or absence of less than 3 days.	Minor property damage
2	Serious	Loss of consciousness, burns, breaks or injury resulting in absence from work for more than 3 days. Other non-permanent chemical effects.	Serious property damage confined to the workroom or area
3	Major	Permanent disability or other reportable injury or disease.	Major property damage affecting the building
4	Fatal	Death	Property damage affecting the loss of one or more buildings

Risk Assessment Detail Sheet General hazards

Task	Hazard	Who might be harmed and how	Before Controls (Initial risk) P	S	3+	Control Measures	After Controls (Revised risk) P	S	Overall Risk P x S
Using VR Headset with study participant(s) as part of lab study. Hazards apply to participant(s) and researcher(s), and should be managed by the researcher(s).	Trip, fall or collision with wall/furniture	Participant	2	1	2	Ensure VR floor area is free of objects. If standing, ensure VR safety chaperone system is enabled and correctly mapped to floor space. If seated study, ensure headset is only worn while seated, and that walls and objects not used in study are out of reach when seated. Participant should be briefed on headset safety before using it. Participant should be made familiar with other study equipment (e.g. controllers, keyboard) before wearing headset. Participants who may be vulnerable to fall/collision (e.g. pregnant) should either be screened, or asked to self-assess and self-screen.	1	1	1
	Headset wire entanglement	Participant	3	1	3	If headset is wired then participant should be made aware of possible trip/entanglement hazard, and given advice on what to do if entangled (eg. remove headset, ask for help).	2	1	2
	Collision with other person	Participant Researcher others	2	1	2	Ensure that no other person enters the VR space while participant is wearing headset. If researcher needs to enter VR space, then they should pay attention to participant at all times. VR space should not be positioned close to doors or other room entry points.	1	1	1
	VR Sickness/ eye strain	Participant	2	1	2	Participants should be warned about sickness, and told to stop if feeling ill or suffering vision symptoms. Protocols should be put in place to enable participant to stop study. Researcher should check that headset is fitted correctly.	2	1	2
	Other hazards identified by manufacturer	Participant	2	1	2	Relevant manufacturer H&S guidelines should be followed (e.g. https://www.oculus.com/legal/health-and-safety-warnings/).	1	1	1

	Fatigue	Participant	2	1	2	Researcher should limit time spent in VR, paying attention to any manufacturer guidelines.	1	1	1
	Psychological discomfort	Participant	2	1	2	Participant should be appropriately informed about content in advance.	1	1	1
	Additional hazards for mobility impaired participants e.g. wheelchair user.	Participant	2	1	2	Researcher should ensure that study condition is accessible for individual needs of participant. Researcher should pay extra attention to possible cable entanglement (wired headsets) and be prepared to assist if required.	1	1	1
	Covid19 infection	Participant Researcher	2	3	6	Researcher should clean equipment before and after use with disinfectant known to be effective against Covid19, **and/or**, suitable cleaning materials should be provided for participants and researcher to use to clean equipment during the study, as they consider appropriate. Where cleaning materials are provided, participants should be made aware of them, and invited to use them. If cleaning is not possible, then equipment should be left untouched for a suitable time between participants (suggest 48 hours). Researcher should wash or sanitise hands prior to study. Participants may also be invited to clean hands. Researcher should consider whether the lab space is appropriately ventilated. Researcher may offer face masks to participants. Non-absorbent faceplates may be used with the headset, if they are available. Social distancing, mask wearing, and other Covid19 safety protocols required by the University or UK Government should be adhered to.	1	3	3

Risk Assessment: Low x Medium High Highest Score on any line 3

Score	Overall Risk	Acceptability
1 - 5	Low risk	Reasonably acceptable risk. Modify wherever possible. Implement control measures. Monitor.
6 - 12	Medium risk	Tolerable risk. Review and modify wherever possible. Enforce control measures. Review regularly. Monitor.
13 - 16	Very High risk	Unacceptable risk. Stop work and modify urgently. Enforce control measures.

Overall Risk Rating

Score	Degree of Risk	Acceptability
1 - 5	Low risk	Reasonably acceptable risk. Modify wherever possible. Implement control measures. Monitor.
6 - 12	Medium risk	Tolerable risk. Review and modify wherever possible. Enforce control measures. Review regularly. Monitor.
13 - 16	Very High risk	Unacceptable risk. Stop work and modify urgently. Enforce control measures.

9.4 Appendix 4 – Participant Information Sheet

UNIVERSITY OF LINCOLN

Participant Information Sheet/Information about the research

(Draft Version 01 / Final version 1.0: 21/05/2022)

Title of Study: The creation of a musical instrument within a virtual space for education.

We are inviting you to take part in a research study. Before you decide, it is important that you know why we are doing the study and what is involved. Please read the following information carefully.

What is the purpose of the study?

The aim of the study is to find if a virtual reality program can be used as a musical instrument to play and learn music. This study is part of the undergraduate dissertation project for University Of Lincoln School of Computer Science. The study will be taken place within the Isaac Newton Building, University of Lincoln.

Am I eligible to take part?

Anyone is eligible to take part.

Do I have to take part?

Participation is completely voluntary. You should only take part if you want to and choosing not to take part will not disadvantage you in anyway.

What will I be asked to do?

Firstly, the consent from should be completed and returned to 19696934@students.lincoln.ac.uk to take part in the study. This study will consist of one task.

The task will take 15 minutes and will involve playing the virtual reality game, where the task will be recreating a melody. After the 15 minutes, a short interview will be conducted to gather some thoughts about the program. The results from the interview will be transcribed and stored with the answers being anonymous. Furthermore a system usability scale form will be given to rate the usability of the system, the results from the questionnaire will be anonymous.

Will I be paid expenses for taking part?

You will not be paid to participate in the study.

What are the possible benefits / risks of taking part?

While there are no benefits for the participants, the use of virtual reality equipment might cause motion sickness. Although these risks are unlikely, safety instructions will be given when virtual reality is being used.

Will anyone know I have taken part?

The information we collect will be handled in confidence. No one will know you have taken part, as your responses are anonymous.

Where will my data be stored?

The data obtained from the study will be stored securely on the university OneDrive in password protected files. Only the researcher/researchers will have access to it. Paper copies will be stored in a secure cabinet/office at the University. The data from this study *may* be put in an Open Access repository for other researchers to use in future research.

What will happen if I don't want to carry on with the study?

If you need to withdraw from the study at any point, without a reason, please contact 19696934@students.lincoln.ac.uk.

Once the study is completed, the data would be anonymous so it will not be possible to remove the data provided, as I will not be able to identify you in any way.

Page 1 of 2

The creation of a musical instrument within a virtual space for education. Participant Information Sheet Draft 01 Version 1.0 21/05/2022 Ethics reference: N/A

What will happen to the results of the research study?

The results from the interview will be transcribed an used as part of an undergraduate dissertation project.

Who is organising and funding the research?

This research is being organised by Ernestas Milinskas at the University of Lincoln.

Who has reviewed the study?

All research conducted by the University of Lincoln is looked at by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by a University of Lincoln Research Ethics Committee.

What if there is a problem?

It is very unlikely that this study would cause you any harm. If you have a concern or a complaint about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions. The researchers contact details are given at the end of this information sheet.

Further information and contact details

Contact details

Ernestas Milinskas

Undergraduate Student

Email: 19696934@students.lincoln.ac.uk

Dr Patrick Dickinson

Associate Professor / Programme Leader, School of Computer Science, College of Science
Email: pdickinson@lincoln.ac.uk

Website: https://staff.lincoln.ac.uk/pdickinson

9.5 Appendix 5 – Consent Form

UNIVERSITY OF LINCOLN

Ethics reference: N/A

Participant Identification Number for this study:

CONSENT TO PARTICIPATE IN RESEARCH

Title of Project: The creation of a musical instrument within a virtual space for education.

Name of Researcher: Ernestas Milinskas

Name of Participant:

Please initial box

1. I confirm that I have read the information sheet dated 21/05/2022 (version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected. ☐

   I understand that should I withdraw then the information I have given us up to this point will be deleted/destroyed. However, once the anonymised data set has been created it will not be possible to remove my anonymised data from the analysis.
3. I understand that individuals from the University of Lincoln may look at research data collected during the study, to ensure that the study is conducted appropriately. I give permission for these individuals to have access to my records; I understand that my personal details shall be kept confidential. ☐
4. I would like to receive a summary of the results of the study Yes ☐ No ☐
5. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Ernestas Milinskas	22/01/2022	
Name of Person taking consent	Date	Signature

2 Copies: 1 for participant; 1 for researcher site file;

9.6 Appendix 6 – System Usability Scale

System Usability Scale

1. I think that I would like to use this system frequently.

   Strongly disagree | Strongly agree

1	2	3	4	5

2. I found the system unnecessarily complex.

   Strongly disagree | Strongly agree

1	2	3	4	5

3. I thought the system was easy to use.

   Strongly disagree | Strongly agree

1	2	3	4	5

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

   Strongly disagree | Strongly agree

1	2	3	4	5

5. I found the various functions in this system were well integrated.

   Strongly disagree | Strongly agree

1	2	3	4	5

6. I thought there was too much inconsistency in this system.

Strongly disagree				Strongly agree
1	2	3	4	5

7. I would imagine that most people would learn to use this system very quickly.

Strongly disagree				Strongly agree
1	2	3	4	5

8. I found the system very cumbersome to use.

Strongly disagree				Strongly agree
1	2	3	4	5

9. I felt very confident using the system.

Strongly disagree				Strongly agree
1	2	3	4	5

10. I needed to learn a lot of things before I could get going with this system.

Strongly disagree				Strongly agree
1	2	3	4	5

9.7 Appendix 7 – Interview Questions

What is your musical ability level?

Have you used VR before?

How would you describe you overall experience with the program?

What did you like the most about the program?

What did you like the least about the program?

What did you think about the menus?

How easy/difficult was it to interact with to menus?

What did you think about the projectors?

How easy/difficult was it to interact with the projectors?

How easy/difficult was it to recreate the melody within the game?

If you could change one thing in this product, what would it be and why?

With more development, would you see this program in schools to aid in teaching?

9.8 Appendix 8 – Interview Questions & Answers

What is your musical ability level?

“Have a lot of knowledge”

“Non-existent”

“Intermediate”

“I can play multiple instruments and I wrote songs before”

“None ”

“None ”

“Zero ”

“Previous knowledge”

“None”

“None”

Have you used VR before?

“Yes”

“Only a few times”

“Yes”

“No”

“Yes”

“Yes”

“Yes”

“Once years ago”

“Yes”

“Once or twice”

How would you describe you overall experience with the program?

“It was ok, it was confusing in some areas like picking out notes for the projectors but it was fun overall”

“Pretty simple, but the button that enables the customization menu should be changed to the trigger button so its coherent with the UI elements”

”Very positive, very enjoyable and easy to use. Also quick and easy to learn”

“I was just confused”

“Very simple, intuitive, even with not much musical ability you can put your hand through and play a note”

“The beginning was hard to understand but then after it was fun”

"To an extend, if you did not know how the control scheme, then I would not know how to use the program. Awkward to know what notes are what/what to use. Eventually you would learn it but a tutorial would be helpful."

"Good-easy"

"Pretty good, it was fun and it was easy to use. I'd say you can use it in a way you can make your own notes and have fun with it"

"A lot of fun, it was really fun actually"

What did you like the most about the program?

"The customization"

"Not so much the customization of the colours, but having colours and being able to reorganize the projectors was helpful"

"How creative you can be with the colours and the notes are also very well replicated which is nice to see"

"I liked the colours within the program"

"The fact that you can just pick up the projectors and move them."

"Creating the melodies with the projectors"

"The ability to change the colours on the projectors as that helped to distinguish between notes on the projectors"

"It was intuitive"

"The range of notes and projectors to play and mess around with."

"I think it was novel in a way, being able to interact and move the objects, it was pretty intuitive to use once you got used to the controls, and that there is merit in the system"

What did you like the least about the program?

"Assigning the notes"

"Just that button that enables the customization menu"

"I think the environment is kinda too bright/the colour choices are unusual for an environment so if you used it for a while, it might affect you."

"Having to move in 360"

"The fact that the note menu you were playing with was at the side instead of being in the front near the customization menu"

"How far the menu was so it was hard to get specific colours"

"If you had a menu open and you moved the projector, the menu would shake violently."

"Could not remember the notes that were being played"

"The fact that you would have to rearrange the lasers"

"I felt like the controls at the beginning were a bit difficult to use, also felt that there was some confusion on what projector was being used. And made a few mistakes when assigning the projectors."

What did you think about the menus?

"They were clear and concise"

"Pretty simple to use, maybe having a separate interactors for the letters and numbers (note name and octave)"

"Very good, used friendly, at the start its difficult to understand which buttons to use but it might be a VR thing"

"They worked"

"The menus were fine, but they were too high up"

"I liked the menus, it's just the customization menu that was far"

"They were good menus, just need stabilizing more and be more obvious with the wrist menu"

"The colour changer was complicated, only needed one pallet. Audio feedback when you make a selection might have been a good addition to add."

"The menu was easy to use and easy to understand"

"They were good, but a bit far away so it was hard to use them"

How easy/difficult was it to interact with to menus?

"Very easy"

"Pretty easy"

"Easy to interact with, it was done in a way that is easy to understand"

"It was kinda inbetween those two"

"Very easy"

"Wasn't difficult, it was just faraway"

"They were easy, kinda understood what I needed to do with everything"

"After getting the hang of the controls it was fine, but maybe a box with instructions or a system like that would aid."

"It was really easy"

"It was simple to use, there was no problem with interaction but getting accurate colours was hard"

What did you think about the projectors?

"Good, easy to use"

"I liked them, just having different colours for the laser/projector was unnecessary"

"The name itself is confusing but their fine, being a sphere is good as it makes it more realistic as it makes it easier to grab "

"They were the easiest part"

"They were good, they were easy to use"

"I liked the projectors, the laser was 2d which I did not like"

"They were detailed, to an extend the shapes did not have much meaning so if you had no knowledge, you would have no idea what they were for but after playing for a bit they would have become common knowledge."

"I liked the designed/context."

"They were ok"

"They were pretty awesome, they worked, they had fair amount of activity cause of the customization. They did a cool thing"

How easy/difficult was it to interact with the projectors?

"Pretty easy"

"Easy, but maybe having locations where you could put the projectors would be better rather than having them float"

"The way it was done, it was simple to use. You put your hand through to play the melody so its easy for the user. The fact that you can also grab and put them is good as you can set them how you want"

"Easy"

"Easy to use"

"It was easy"

"It was very easy"

"Their fine"

"It was really easy to understand"

"I missed them a couple of times but that might be based on my experience in VR and not the actual game"

How easy/difficult was it to recreate the melody within the game?

"It wasn't difficult but what made it hard was trying to figure out the notes were assigned to which projector"

"Pretty easy, it was easy to learn"

"I think it might be easier for a user with musical background while it might be harder for a user without music knowledge as I have some musical knowledge"

"Easy"

"Pretty easy"

"It was easy"

"I found it easy but it was kinda hard to remember which notes were what and to remember the order."

"Medium, it was hard to remember the notes that were selected. Apart from colours it was hard to tell what has been assigned"

"It was really easy to recreate it"

"Pretty easy, it was just the principle of setting up the notes and where they had to be."

If you could change one thing in this product, what would it be and why?

"Add the notes that are selected underneath the projectors so you can see what notes you're playing"

"That customization button, also maybe have a different method of changing the note. Also have predetermine structures of projectors that the user can spawn instantly"

"The environment as it is too bring, making it a bit more mono might help"

"The colour changer, it did not make sense to me"

"Something to show that if you have the melody in front of you, to show what progress you have made so far while playing the song"

"Make the menus closer to the user"

"Have a piece of text in front of the projector which shows what note is currently selected."

"See the notes that are being played, some kind of prompt for the safety area, metronome"

"Probably to add more notes and add more things to play with"

"Make the menus closer so you can interact finely and change starting position of the projectors so they are in front of the sheet music."

With more development, would you see this program in schools to aid in teaching?

"Yes"

"Yeah"

"Yeah, I think it's a good program to aid and teach notes. It's good to train your ear to music notes"

"Maybe"

"I would say so yeah."

"Yes"

"Yes"

"Yes"

"Yeah"

“Yeah, I think so, I can see this in primary school or even secondary school. And I could see this in commercial”