TARTU UNIVERSITY VILJANDI CULTURE ACADEMY
Faculty of Arts and Humanities
Sound and Visual Technology

Jason Alexander Greenberg

NAVIGATING THE LAYERS OF A MIX IN VIRTUAL REALITY

Master's Project

Supervisor: Taavet Jansen, M.D.A.

Viljandi 2023

Abstract

This report presents a virtual reality (VR) sound installation project that aims to improve listeners' audio perception by providing an immersive experience of the extended self in VR. The project uses innovative audio technologies and visually captivating VR design to create an interactive and engaging environment for individuals to explore the elements of a song or its raw "mix." Through spatially mixed soundscapes, participants can experience a sense of depth, immersion, and interactivity and engage with the audio through physical gestures and movements. The question arises: How effective is virtual reality as a tool for enhancing the perception and understanding of sound mixing and instrumentation in music production, and what are key factors that contribute to its success or limitations?

Keywords: Virtual Reality, Spatial Audio, Sound Mixing, Unreal Engine, Immersive Audio Environments, Music Production.

Table of contents

Introduction

The study presents a VR sound installation project that explores the possibilities of combining virtual reality technology and audio perception to create an immersive and interactive audiovisual experience. The project was designed and developed in collaboration with Tartu University Viljandi Culture Academy students, teachers, and other residents of Estonia. The term "the researcher" used throughout this report refers to the student, Jason Alexander Greenberg, who conducted the entirety of the project and subsequent study.

The project aimed to create a unique and engaging VR sound installation to offer a new perspective on the intersection of sound and virtual reality. The researcher used Unreal Engine to design and build a custom VR environment. He integrated advanced audio perception and mixing technologies to create a dynamic and interactive soundscape. The researcher seeks the answer to the question:

1. How effective is virtual reality as a tool for enhancing the perception and understanding of sound mixing and instrumentation in music production, and what are key factors that contribute to its success or limitations?

The answers to this question will be explored. After describing the background and creation of the project, the results are shared. The report concludes with a reflection on the process and its effectiveness in answering these questions. The work of this project requires interdisciplinary knowledge of audio, video, design, and gaming technologies. This project is a prime example of the term “audiovisual technology.”

1. Framework

1.1 Overview of the project's objectives and significance

The project and subsequent study provided the researcher with a window into the potential of VR technology in sound installations. The project's general focus is on enhancing user perception through direct interaction with spatial sound. Brainstorming was conducted on how to create an immersive VR environment that could give listeners visual and physical insight into the dimensions of a song.

The significance of the project lies in its development towards the emerging field of VR or cross-reality (XR) sound installations, which could potentially revolutionize the way we experience music. By utilizing current audio frameworks inside a video game development engine, the researcher aimed to offer growth for sound perception for music consumers and creators alike. The study's findings could have practical applications for educators, students, musicians, hobbyists, sound designers, and acoustic researchers. VR and XR technology can provide a cost-effective and accessible alternative to physical acoustic spaces.

1.2 Background and context

The inspiration for this VR sound installation project came from the idea of providing a musically uninitiated person with a chance to see that a song has multiple elements and that there is more than the average person can initially distinguish. The researcher wanted to create a virtual environment that would allow people to interact with the different elements of a song and explore the intricacies of music in a completely immersive format. For those already musically initiated, this project provided a unique perspective on the depth perception of a mix, an understanding of the instrumentation of different genres, and a general sense of the music being heard.

The extended self is an idea that refers to people being able to identify with things beyond themselves. In a musical context, imagine a pianist extending themselves into the piano they have worked so arduously to master. This is quite relevant to VR experiences as they often

provide a sense of immersion to the user, as is their main selling point. VR can be so immersive as to slightly blur the lines between physical and virtual worlds.

Researchers have shown that a person's perception and behavior can be influenced by this immersion in the extended self. This can range from social interactions to consumer habits. (Belk, 1988). Regarding virtual reality, Yee, and Bailenson studied the development of virtual avatars and the influence of avatar appearance on individuals' self-perception and behavior. (Yee & Bailenson, 2007). This paper notes that virtual experiences can influence the sense of self. This suggests to the researcher that a VR sound installation has the potential to influence the sense of self in regard to music and highlights how the extended self factors into this interaction.

The project aimed to contribute to the exploration of virtual reality technology as a listening tool and provide a unique and engaging experience for the participants and their inherent sense of self.

1.3 Discussion of the current state of VR sound installations

Virtual reality has been around for many decades, but we are only now witnessing the emergence of sound installations in VR environments. These installations usually rely on developments such as spatial audio and interactive sound design. VR sound installations are becoming increasingly popular due to their ability to offer interactive experiences regardless of the surrounding environment. Traditional sound installations cannot match this versatility. One could argue that this makes physical installations more valuable due to scarcity, but that point will not be addressed here. VR environments allow a more dynamic experience for both the participant and the designer.

VR sound installations have the potential to revolutionize how we experience sound and music. They can offer a new way for artists and sound designers to experiment and explore sound and music and inspire interdisciplinary collaboration. The intersection of VR technology and sound design has many implications for everyone involved.

2. The Project

2.1 Positioning the project within the existing scene

This project is positioned with an expanding field of immersive technologies that open up new possibilities for artistic expression and audience engagement. Artists now have the ability to create fully immersive experiences that their audiences can explore in an engaging and interactive manner. Sound plays a crucial role in creating a sense of presence and shaping the overall experience.

VR sound installations have been gaining in popularity in recent years, with a growing number of artists and designers exploring the possibilities it offers. These installations range from interactive soundscapes to fully immersive musical experiences and often involve the use of cutting-edge technologies and techniques to create new forms of sonic expression. One example is the virtual reality theme park, The Void. The Void uses a variety of immersive experiences that use spatial audio and haptic feedback to create an engaging virtual environment. In The Void, participants navigate obstacles and face challenges while wearing specialized VR headsets. Using spatial audio in this installation helps create a more realistic and immersive experience for participants, allowing them to feel immersed in the virtual environment (Saxena, 2015).

The researcher builds on the achievements of his predecessors and seeks to contribute to the field and its possibilities and limitations. With spatial audio techniques and interactive design, the researcher aims to create an immersive and engaging sonic environment that broadens its participants' musical perceptions. By exploring the relationship between sound, space, and perception, we can hope to advance all three.

2.2 Project design and development

The VR environment was designed in Unreal Engine, a powerful game engine with advanced audio capabilities. The environment included a 360-degree soundscape with spatialized audio that reacted to the user's movement and interactions within the environment. The audio perception and mixing technologies used included ambisonics and binaural audio, which provided a highly immersive and realistic audio experience.

The design choices were carefully made to create a compelling and memorable experience for the participants. The environment was designed to be visually striking, with a mixture of realistic and surreal elements to enhance the audio experience. The researcher also incorporated user interaction and exploration, allowing the participants to control limited aspects of the audio and environment. To ensure a smooth and seamless experience, the researcher conducted thorough testing and iteration throughout the development process. This involved exploring different game engine possibilities and limitations and optimizing performance for the VR platform. The overall project design and development aimed to create a unique and engaging VR sound installation experience that fully utilized the capabilities of the technology.

2.3 Description of the VR environment designed in Unreal Engine

The implications of spatial audio in Unreal Engine, in terms of its built-in capabilities and the listener's perspective in relation to objects in the game, played a crucial role in creating the VR sound installation project. The game was initially developed as a first-person experience using MacOS, utilizing a first-person project template with essential lighting, player start positions, and simple movement programmed and mapped to the computer keyboard. In-depth research was conducted on Unreal Engine, with numerous tutorials and guides referenced to learn about the program's capabilities.

Visual scripting is a programming method that allows developers to create scripts and automate processes without the need for traditional text-based programming languages. Instead, visual scripting uses graphical elements and nodes to represent code and program flow, which can make it easier for non-programmers to understand and modify code. In Unreal Engine, visual scripting is done through the Blueprint system, which provides a visual way to create and modify

game logic, behavior, and interactions (see figure 1 in Appendix). Visual scripting is an advantage that modern game development holds over its' predecessors.

Once the basics of the engine were understood, sounds were imported correctly and converted into sound cues, enabling spatialization and adjusting parameters such as the inner radius of the sound, the attenuation radius, and loop mode. (see figure 2 in Appendix).

A consultation was made with Esteban Pruaño Arana, a freelance game developer specializing in Unreal Engine. It was soon discovered that although one may be well-versed in certain aspects of video game development, the field is diverse and multi-disciplinary, leaving little but efficient workflow techniques to be shared with the researcher. The most helpful advice from Esteban was to establish a parent class from which all further objects retain the framework. In Unreal Engine, a Parent class refers to a blueprint that serves as a base or foundation on which other blueprints are built. A Child class is a blueprint derived from a Parent class and inherits its properties and functions.

In the context of this report, the VR sound installation project was built using Blueprints in Unreal Engine, where different levels/songs were created as Child classes that inherited properties and functions from a Parent class. The Parent class contained the basic functionality of the VR sound installation, and the Child classes added unique properties and functionalities specific to each level/song.

In Unreal Engine, a static mesh is a 3D object that does not move or change shape during gameplay. It is like a sculpture that's part of the environment in the game. It can be used to create things like buildings, rocks, trees, and other objects that are not meant to move. Static meshes comprise vertices, edges, and faces that define the object's shape. They can also have textures to make them appear realistic. In this project, static meshes were used as components of the VR sound installation to create the different elements of the virtual environment.

A Parent class was established for the instruments and objects that represent them. Inside the static mesh, components for audio file playback, text display, and visual effects were added (see figure 1 in Appendix). A visual water fountain spray effect was modulated to flow circularly, with less frequency, and in various colors of color instead of water. The visual effects were later omitted from the Big Band level, as they added excessive graphical strain to the already sophisticated graphics of the Opera House level (see figure 3 in Appendix).

Following the creation of the first level, musical instrument 3D models were imported into the project, with child actors created for each recorded track of the Vulfpeck song "Back Pocket." The appropriate sound cue was attached, and visual effects were created for diversity. Each component had to be further adjusted based on its relative location to the main static mesh. The process was repeated for each level to sculpt the appropriate scenes, objects, or instruments to represent the songs being experienced. A main menu and pause menu was developed, with new control input mappings for the user, and the use of buttons and conditions was thoroughly explored.

The game was migrated to a VR project by exporting each level individually and recreating the project from a VR template in Unreal Engine. Virtual reality development in Unreal is currently not supported for MacOS, so an Oculus Quest headset and Oculus Touch Controllers were chosen as the medium for game development and subsequent gameplay experience (see figure 4 in Appendix). Several technical challenges were encountered during the testing phase, particularly in optimizing the application's performance for VR use. This included reducing the size and complexity of the 3D models used in the environment, optimizing the audio spatialization and attenuation parameters, and minimizing the processing power required for the particle effects.

Initially, the menu system was not optimized, and new control inputs had no use in the new gameplay environment. A main level was established for greeting the participant, in which the player is transported to the chosen song by using the walking and grabbing controls. The level simultaneously serves as a tutorial for gameplay, as participants cannot enter a song without navigating to it and subsequently grabbing it with the Oculus controls.

One of the biggest unforeseen obstacles in this work was exporting the project into a playable game file or application. There were a wealth of drivers, downloads, and internet forums that the researcher trudged through to finally achieve an exported product.

As the participant spawns into the level, their orientation in relation to the objects provides them with an image of the mix and the position of the objects in relation to the player is reflected in the speakers of the Oculus or headphones. When they grab an object, it becomes even closer and louder, and throwing it away loses volume, changing its panning in relation to the participant.

Before the demonstration/exhibition, colleagues were called upon to test and find kinks in the gameplay, such as discovering the need for an invisible blocking volume component around the border of each side of each level. Overall, creating the VR sound installation project was a complex process involving detailed research and in-depth experimentation with Unreal Engine's capabilities to create a fully immersive audio experience for participants.

2.4 Overview of the audio perception and mixing technologies used

Unreal Engine provides a robust audio engine that enables developers to create immersive audio experiences in their projects. The engine supports advanced audio features such as spatialization, occlusion, and attenuation. These features were utilized in the VR sound installation project to create a sense of presence and immersion for the participants. The researcher used the article "An Introduction to Spatial Sound Rendering in Virtual Environments and Games" by various authors in The Computer Games Journal to gain a foundational understanding of spatial audio and its implementation in virtual reality. (Beig et al., 2019)

Spatialization is the process of creating a spatial audio effect that simulates the position of sound sources in a 3D space. Unreal Engine utilizes HRTF (Head-Related Transfer Function) processing to provide spatial audio. HRTF processing models how sound is filtered and modified as it travels from a sound source to the listener's ears. This enables the audio engine to simulate the effect of distance, direction, and position of sound sources in a 3D space. (Beig et al., 2019)

Occlusion is the process of simulating how sound waves are obstructed by objects in the environment. Unreal Engine utilizes geometry-based occlusion, which means that the audio engine considers the shape and position of objects in the environment to determine how sound waves are affected. (Beig et al., 2019) Attenuation simulates how sound levels decrease as the distance between the listener and the sound source increases. (Beig et al., 2019) Unreal Engine provides several attenuation models, including linear, logarithmic, and custom attenuation curves. The audio engine determines the attenuation of sound sources based on their distance from the listener and applies the appropriate attenuation model.

2.5 Explanation of the design choices and their rationale

The design choices made in developing the VR sound installation project were carefully considered to ensure the most effective and immersive user experience possible. One of the most critical design choices was using spatial audio technology. Spatial audio refers to creating a three-dimensional sound field, which allows sounds to be positioned in specific locations within a virtual environment (Rumsey, 2012, p.1). This technology was critical in providing an immersive experience for the user and creating a realistic representation of a live performance.

Selecting the Unreal Engine as the primary tool for developing the project was not random. The Unreal Engine is a powerful game engine that gives users the means to create for the creation of immersive and interactive virtual environments (Epic Games, n.d.). It provides tools and resources for creating realistic and detailed 3D environments and sophisticated audio capabilities, making it an ideal choice for sound installation projects.

In terms of the visual design, the researcher created a realistic representation of a live performance venue, specifically an opera house for the big band level, to provide the user with a sense of being present at the rehearsal for a live performance.. The researcher also used visual effects, such as particle systems, to add visual interest to the environment. Other levels reflected the thematic contents and overall moods of the songs they housed (see figures 5-7 in Appendix).

The interaction design between the user and the virtual environment was also critical. Oculus Touch controllers were used to allow intuitive interaction with the virtual environment. These controllers use touch sensors to track the position and movement of the user's hands in real-time. The controllers feature buttons, triggers, and thumbsticks for interaction. By representing one’s hands in the virtual environment, the controllers enhance the sense of immersion and interactivity.

3. The Experience

3.1 Implementation and experience

The VR sound installation was implemented as a standalone executable file on Windows 10, which could be run using the Oculus Quest virtual reality headset. The exhibition was held in Room 202 of the Viljandi Culture Academy Peamaja. An Oculus Quest was donated by the XR Department at Mektory in Tallinn for the duration of the project. Over three days, the experience was showcased to 40 participants, including Tartu University Viljandi Culture Academy students and other Estonia residents. Each participant was asked to scan a QR code linked to a pre-experience survey (see figure 8 in Appendix). Participants were informed of the project's objectives and were given a brief tutorial on the controls and interaction mechanisms of the installation. They were then asked to explore and interact with the virtual environment and provide feedback on their experience.

Implementation of the VR sound installation was an essential stage in bringing the project to fruition, allowing the researcher to showcase the immersive and interactive qualities of the environment to a broader audience. The technical challenges during this stage highlighted the need for further optimization and refinement, particularly in audio spatialization and visual effects.

3.2 Participants and recruitment

The study recruited participants from Tartu University Viljandi Culture Academy. Participants were required to be at least 18 years of age and have average hearing ability. Recruitment was done through social media platforms, email lists, and word of mouth. A total of 40 participants completed the VR sound installation experience, although not all answered the surveys.

Participants wore the Oculus Quest headset and use the Oculus Touch controllers to navigate the environment and interact with the objects. The researcher explained the general purpose before beginning the experience. Ethical considerations were addressed by providing the participants with an information statement before starting the game. (see figure 9 in Appendix).

The safety of participants was addressed by providing a clear and unobstructed play area. Additionally, the Oculus headset has a perimeter that can be set to inform people when they are close to collision. Participants were also allowed to stop the experience at any time by taking off the headset or exiting the game. After completing the experience, participants were asked to fill out a post-experience questionnaire to provide feedback (see figure 10 in Appendix).
The questionnaire included questions about their overall satisfaction with the experience and the perceived realism of the sound and visual effects. Their understanding of the technology and sense of self were asked as well. Participants were asked to provide comments or suggestions for improvement. The study ensured the anonymity of participants by not collecting any identifying information. All participant data was kept confidential.

3.3 Procedure for the VR sound installation experience

The researcher began with a brief introduction and instructions on how to move and interact with the environment. Participants were instructed to use the Oculus Touch controllers to move around and interact with the objects (see figures 11-12 in Appendix).

After getting acclimated, participants were virtually transported to the main level. They were greeted by floating text with basic instructions on how to play the game. The song started immediately, and the participant could explore the songs and interact with instruments as the song looped.

Throughout the experience, the participants were free to move around and interact with the objects as they saw fit. The objects were positioned in a way that represented the song mix. If a participant picked up an object and threw it away, it would lose volume and change its panning in relation to them. If the participant moved closer to an object, it would become louder. These interactive elements allowed for interaction with the song. After exploring and interacting with the objects, participants could exit the environment by using the pause menu and selecting "Exit Game."

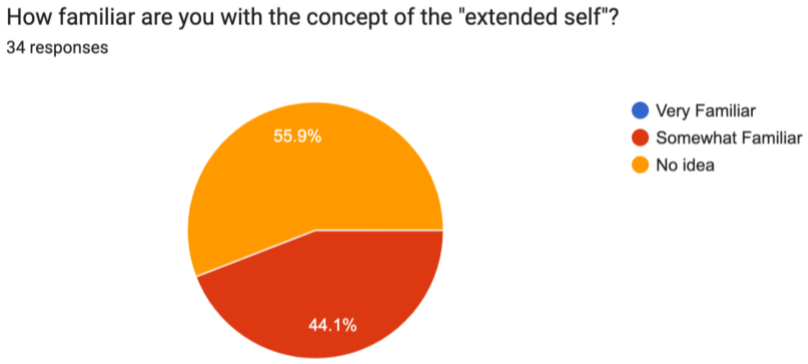
The game was designed for people to interact with the music naturally. The users were meant to feel a sense of control, so they would be inspired to shape their own experience of the song. Attention was given to making the virtual environment user-friendly. Clear instructions

and simple controls made this possible. The goal was to make the experience more intuitive, allowing people to focus on the music rather than figure out new technology.

3.4 Description of the user interactions and feedback received

Participants were recruited from Tartu University Viljandi Culture Academy. The age range of participants was from 20 to 52, with most being below 30. Of the participants, 70.6% were male, and the rest were female. Roughly three-quarters had tried VR before, typically less than once a month. Half had attended a sound installation before, and half had never heard of the concept of the extended self. (see figure 13). As this is a cultural academy, the study was perhaps skewed in that all participants perceived music as above average importance in their lives.

Figure 13. *How familiar are you with the concept of the "extended self"?*



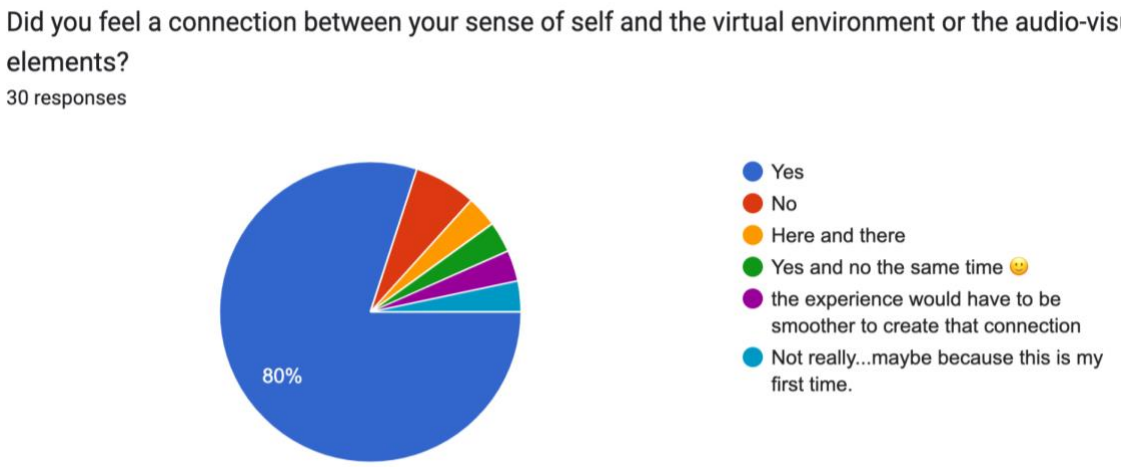
During the study, all participants except one were enthusiastic about trying the VR sound experience. After experiencing the VR sound installation, When asked if they felt a connection between their sense of self and the virtual environment or the audio-visual elements, 80% reported yes, 9.9% reported no, and 10.1% reported somewhat but not fully immersed.

Participants were also asked to describe how their sense of self extended to the virtual environment and the audio-visual elements. Their responses varied; some felt physically in the recording studio or on the stage. In contrast, others felt like they were in another dimension or "leading the situation." Most participants tried to move around and hear each instrument, while

some attempted to balance the sound or arrange the instruments. However, some participants reported feeling afraid of heights or feeling like they were a “tiny person” in between everything.

Participants were also asked if they believed the VR sound installation impacted their sense of self in the digital world (see figure 14). In response, 21.4% said yes, 64.3% said maybe, and 14.3% said no. Participants who answered yes elaborated on the impact, with some feeling more exposed to unexpected things or experiencing involuntary physical responses. Others felt that the VR sound installation changed how they interact with objects and move around in real life.

Figure 14. *Did you feel a connection between your sense of self and the virtual environment of the audio-visual elements?*



During the VR sound installation experience, one participant stood out in their understanding of the researcher's inspiration for the project. This participant was familiar with "The Art of Mixing: A Visual Guide to Recording, Engineering, and Production 2nd Edition" by David Gibson (Gibson,2019), a standard among the audio engineer community. In fact, the perception of sound illustrated in this book gave the researcher the initial inspiration for visualizing the mix in a 3D environment, resulting in this VR experience being created. This participant exclaimed that his perception of elements in a mix had been altered for the better due to this experience. He noticed how sounds became too cluttered and indistinguishable in the VR world if you put them too close together but had a nicer sound stage when placed appropriately

apart. This led him to see parallels with a real mixing environment in his studio and how he could achieve more dynamic and open mixes by making literal space for them. This realization is a simple yet fundamental one that should be noticed. This feedback confirms that the VR sound installation experience can be a valuable tool for audio engineers to improve their mixing skills and create more spatially aware and balanced mixes.

4. Final Thoughts

4.1 Reflection and discussion

The VR sound installation experience presented here aimed to explore the concept of extended self in music production and mixing and investigate how VR technology can enhance users' sense of self in a digital environment. The experience allowed users to interact with and manipulate audio and visual elements in a 3D virtual environment, simulating a real-world mixing environment. The users' responses and feedback revealed some interesting insights into the potential of VR technology for music production and mixing and its impact on users' sense of self in the digital world.

The collected data showed that most participants were under 30 and had tried VR before. This could show that younger people are receptive to new technologies and more likely to use them. The majority rated their experience with the game as highly immersive. They reported feeling a sense of "presence" in the virtual environment. This is crucial for enhancing a sense of self and engagement in the game. We asked about the impact of the VR sound installation on users' sense of self in the digital world. Some reported a definite impact while others were uncertain if it affected them. This shows that VR technology has some potential to create an engaging and immersive music experience.

One notable response was from someone who had read "The Art of Mixing" by David Gibson(Gibson, 2019). This participant recognized the similarities between the game and his home mixing environment. This shows the potential of VR technology to enhance the understanding of mixing principles.

4.2 Analysis of the project's outcomes and effectiveness

The project achieved its goals of providing a unique and immersive experience for participants to explore and learn about the art of mixing in a virtual environment. Insight was gained into the questions: "How effective is virtual reality as a tool for enhancing the perception and understanding of sound mixing and instrumentation in music production, and what are the key factors that contribute to its success or limitations?". People rated the experience positively,

reporting a sense of "presence" in the environment and feeling a connection between their sense of self and the instruments. One participant showed that their perception of elements in a mix had been altered for the better.

However, some limitations and areas for improvement were identified during the project. For example, some participants reported issues with the spatial audio and panning not feeling organic enough. This could mean that the audio algorithm in Unreal Engine could be improved. Additionally, some participants wanted to mute specific instruments, which was not possible in the current version of the game.

Other technical issues arose during the project, such as battery life problems with the Oculus Quest headset and crashes of the VR game file. These issues were resolved with solutions such as re-exporting the VR game file from Unreal and using a backup file of the game on a separate disk. During the migration of the project from the first-person build to VR, the visual effect for each instrument had to be modified to reduce strain on the computer's graphics processor (GPU). In the initial build of the game, the visual effect emitted 50,000 particles in the stream for each instrument, creating a swirling motion around the objects. This effect consumed significant processing resources, resulting in performance loss. As a solution, the particle count was reduced to 10, which maintained a visual effect without straining the GPU.

Despite these challenges, the project provided valuable insights for VR technology to be used in music education. In future development, exploring ways to allow for more interactive control over the mix and experimenting with different types of VR hardware could make the experience more immersive.

Compared to other VR sound installations, this project offered a more hands-on and dynamic experience, letting the user take an active role in the mix. This differs from other installations that are more passive, where users simply listen to the mix without controlling the sound. For example, the installation "The Night Cafe: A VR Tribute to Vincent Van Gogh" by Borrowed Light Studios presents an immersive experience that takes people into a painting by Vincent Van Gogh. However, it does not offer any interaction or control over the colors or characters (Borrowed Light Studios, 2021).

While this project presented some unique features, there is still much room for development. For instance, there is a need for better algorithms and technologies that can

accurately represent sound in a 3D space. Additionally, we can investigate how people perceive sound and how this can be used to create more compelling and immersive experiences.

4.3 Future directions

One of the strengths of this project was spatial audio, allowing more realism and immersion than traditional stereo audio. Spatial audio helped in creating a virtual sound environment that mimicked real life.

Another strength was its potential as an educational tool. It could be used to teach students music theory, mixing techniques, and sound engineering concepts in a more engaging and interactive way. For example, immersion could help students create a better relationship with the music they love. While the project was a success, there were some limitations.

One of the main limitations was the hardware and software requirements. The project relied on expensive VR headsets and high-end computers. This limits the accessibility of the experience for some people. Furthermore, the project could be improved by adding more interactivity. This could include volume adjustment or adding new audio effects. This would give users more creative control and a more personalized experience.

This project could be expanded to include more songs or albums, potentially covering a more comprehensive range of genres and musical styles. It could also be integrated with other VR experiences, such as virtual reality concerts or other interactive audio experiences, to provide a more comprehensive audio and music experience. In addition, the project could be further developed for educational use, such as for teaching music theory and mixing techniques to students more engagingly and interactively. This could include developing a curriculum or lesson plan around the VR sound installation or creating additional interactive elements that are specifically designed for educational use. One participant, in particular, reached out to the researcher for a possible adaptation of his upcoming singles into this format for a similar concert experience this August in Viljandi. This participant proposed using the adjoining room of the venue for the upcoming event to provide concertgoers with an alternative experience of his songs before, after, and perhaps even during the show.

The potential applications of VR sound installations in music and audio engineering are vast, and there is significant potential for further development and research in this area. With the

increasing availability of VR technology and the growing interest in immersive audio experiences, we will likely see continued growth and innovation in this field.

4.4 Suggestions for future research and development in VR sound installations

Although the project achieved a high level of spatial audio using the Oculus Quest and Unreal Engine, there is still room for improvement. Further research could focus on optimizing algorithms for panning and other spatial audio techniques to make them more natural and organic. The project used hand controllers to interact with the virtual environment, but there are other possibilities for interaction in VR sound installations, such as voice recognition or body tracking. Research could focus on developing and testing new methods for interacting with the virtual environment. The project focused on six different songs from different genres, but future research could expand the selection of music to include a wider variety of genres and styles. This would allow for a more diverse and inclusive experience for participants. The project showed potential for educational use, particularly for teaching music mixing and production. Future research could focus on developing VR sound installations specifically designed for educational purposes, allowing users to mix and produce their own music in a virtual environment.

The project focused primarily on sound and sight, but there is potential for incorporating other senses, such as touch or smell, to enhance the immersive experience. Research could explore the feasibility of incorporating these senses into VR sound installations. The project was conducted in a controlled environment, but future research could explore the effects of VR sound installations in different environments, such as live music venues or outdoor festivals. This would allow a better understanding of how VR sound installations can be used in different contexts.

One potential area of improvement for this and future VR sound installations could be integrating emerging technologies like XR Virtual LED and Virtual Wall. XR Virtual LED is a type of display technology that utilizes LED panels to create a virtual environment with high resolution and high brightness. At the same time, Virtual Wall is a type of projection technology that allows for the creation of a virtual space without the need for physical walls. By incorporating XR these technologies into the VR sound installation, it could be possible to create a more immersive and visually stunning experience for users. For example, the XR Virtual LED

panels could be used to create a virtual concert hall or recording studio environment that complements the audio experience. In contrast, the Virtual Wall technology could project virtual instruments or other elements into space. These technologies are still emerging and are not yet widely available, but they hold great potential for enhancing the immersive experience of VR sound installations. As these technologies continue to develop and become more accessible, it will be interesting to see how they are incorporated into the design and development of future VR sound installations.

Summary

This report details a virtual reality (VR) sound installation project that aimed to explore immersive audio environments in art and culture. The report outlines the background and context of the project and provides an overview of the current state of VR sound installations. It then describes the project's design and development, including the VR environment and audio perception and mixing technologies used. The report explains the design choices made and their rationale.

The experience section outlines the implementation and experience of the project. It discusses the recruitment of participants and the procedure for the VR sound installation experience. The report describes the user interactions and feedback received, which were generally positive. Participants reported feeling a sense of immersion in the virtual environment and a connection between their sense of self and the audio-visual elements of the installation. One participant reported that the project helped them understand the importance of making space in the mix, which can improve the overall sound quality of a recording.

The report concludes with a reflection and discussion of the project's outcomes and effectiveness. It analyzes the strengths and limitations of the project and provides suggestions for future research and development in VR sound installations. The report highlights the potential of VR and spatial audio to create immersive and transformative experiences in art and culture. Overall, the project demonstrates the potential of VR technology for creating interactive sound environments that provide new opportunities for musicians, sound designers, and music enthusiasts to engage with sound in innovative ways.

Finally, special thanks must be given to Artur Staškevitš for lending the Oculus headset, allowing use of the facilities at Mektory XR Center, and providing mentorship concerning the direction that was taken by the researcher in Unreal Engine development, as well as to Taavet J. Jansen and Esteban Pruaño Arana for their mentorship and insight respectively. Thanks also to the artists who contributed their songs to the experience, Dadi Freyr, Tevin Prince, Teemantkilpkonn, Vulfpeck, Lindy Hip Big Band, and Enda Reilly for making the stems of their songs available online for public use. Without their contributions, this project would not have been possible.

Reference list

Belk, R. W. (1988). Possessions and the extended self. Journal of consumer research, 15(2), 139-168. https://doi.org/10.1086/209154

Beig, M., Kapralos, B., Collins, K., & Mirza-Babaei, P. (2019). An introduction to spatial sound rendering in virtual environments and games. The Computer Games Journal, 8(3-4), 199-214. https://doi.org/10.1007/s40869-019-00086-0

Borrowed Light Studios. (2021). The Night Cafe: A VR Tribute to Vincent Van Gogh. Retrieved from https://www.borrowedlightvr.com/the-night-cafe

Epic Games. (n.d.). Unreal Engine. Retrieved from https://www.unrealengine.com/

Fuse Technical Group. (n.d.). Extended Reality (XR). Retrieved April 30, 2023, from https://fuse-tg.com/projects/extended+reality+(xr)

Gibson, D. (2019). The art of mixing: a visual guide to recording, engineering, and production. Routledge.

Rumsey, F. (2012). Spatial audio. Taylor & Francis.

Saxena, K. (2015, December 15). Inside the first VR theme park. MIT Technology Review. Retrieved from https://www.technologyreview.com/2015/12/15/71958/inside-the-first-vr-theme-park/

Yee, N., & Bailenson, J. (2007). The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. Human Communication Research, 33, 271-290. https://doi.org/10.1111/j.1468-2958.2007.00299.x

Table of figures

Appendix

Figure 1. Parent Class Blueprint

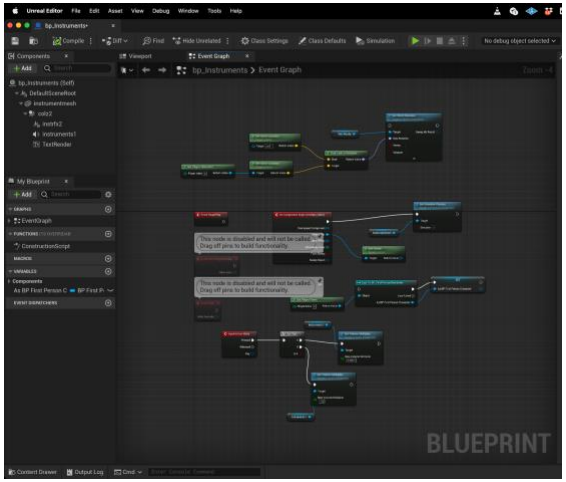


Figure 2. Sound Cue

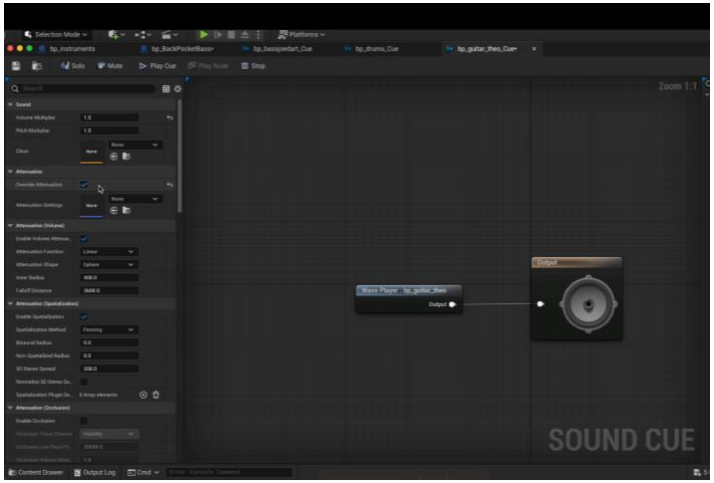


Figure 3. Opera House level

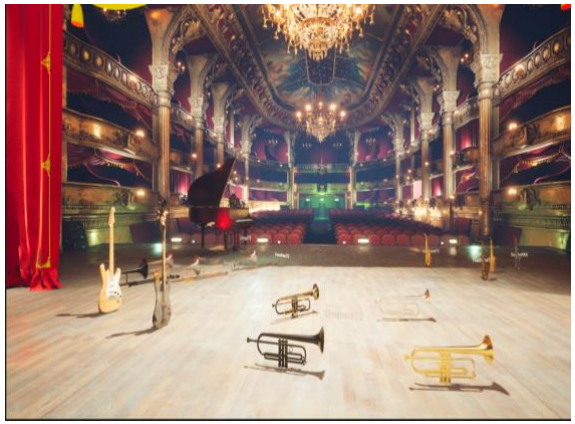


Figure 4. Oculus Quest and Touch Controllers

Figure 5. Vulfpeck level

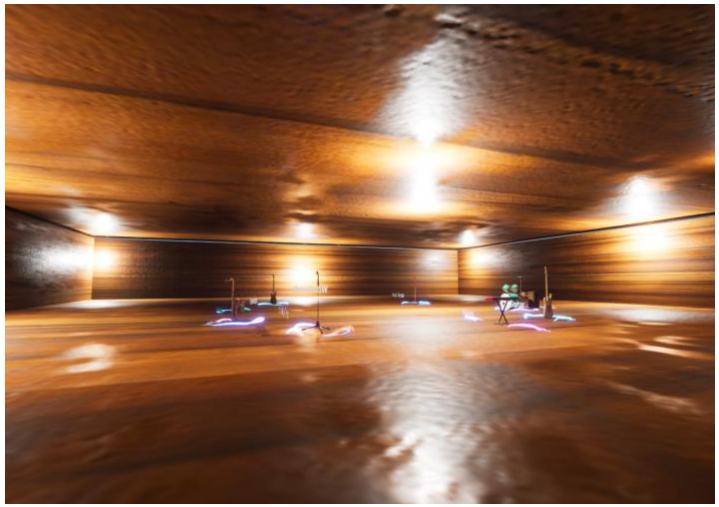


Figure 6. Monolit level

Figure 7. Skyscape level

Figure 8. Pre-Questionnaire

Experience a Mix in Virtual Reality

Pre-Questionnaire

Forms response chart. Question title: How familiar are you with the concept of the "extended self"?

Number of responses: 34 responses.

1. Age
2. Gender
- Female
- Male
- Prefer not to say
- Non-Binary
3. Have you ever experienced virtual reality (VR) before?
- Yes
- No
4. If yes, how often have you used VR technology?
- Rarely (less than once a month)
- Occasionally (1-3 times a month)
- Frequently (once a week or more)
- Never
5. Have you ever attended a sound installation before?
- Yes
- No
6. If yes, how many sound installations have you attended in the past year?
- 1-2
- 3-5
- 6 or more
7. How familiar are you with the concept of the "extended self"?
- Very Familiar
- Somewhat Familiar
- No idea
8. On a scale of 1-5, how important is music in your life? (1 = not important, 5 = very important)
   1 2 3 4 5
9. Put on the headset and enter the mix of different songs! Experience songs from Get Ready!
   Great!!
   Idk about this...

Figure 9. Participant Info Sheet

Ethical Considerations and Participant Information Statement:

Before participating in this study, please read the following statement regarding ethical considerations and your rights as a participant. Your participation in this research is voluntary, and you may withdraw at any time without any consequences.

Purpose of the Study:

The purpose of this study is to investigate the impact of virtual reality (VR) technology on the listener's extended self and their perception of audio-visual elements in a digital world. By participating in this study, you will help us better understand the potential of VR technology to enhance the perception and mixing process of music and its impact on the listener's extended self in a digital world.

Confidentiality and Anonymity:

Your privacy is of utmost importance to us. All information collected during the study, including your questionnaire responses and interview transcripts, will be kept confidential. No personal identifying information will be associated with your responses, and all data will be stored securely on password-protected devices. Results from the study will be reported in aggregate, and no individual participant will be identifiable in any publications or presentations.

Potential Risks and Discomforts:

There may be some potential risks or discomforts associated with participating in a VR environment, including motion sickness, disorientation, or eye strain. If you experience any discomfort or adverse effects during the VR experience, you may choose to stop participating at any time without any consequences.

Voluntary Participation:

Your participation in this study is entirely voluntary. You may choose to withdraw from the study at any point without any negative consequences. If you decide to withdraw, any data collected from you up to that point will be securely deleted.

Consent:

By participating in this study, you confirm that you have read and understood this participant information statement and the ethical considerations involved. You acknowledge that your participation is voluntary, and you may withdraw at any time without any consequences. If you have any questions or concerns, please do not hesitate to contact the researcher(s) for further clarification.

Figure 10. Post questionnaire

Post VR Experience

Forms response chart. Question Title: Did you feel a connection between your sense of self and the virtual environment or the audio-visual elements?

Number of responses: 30 responses.

Please answer the following questions after completing the VR sound installation experience. Your responses will help us understand your perceptions of the audio-visual elements and the impact of the experience on your extended self in the virtual environment.

1. On a scale of 1-5, how would you rate your overall experience in the VR sound installation? (1 = poor, 5 = excellent)
   1 2 3 4 5
2. Did you feel a sense of "presence" or immersion in the virtual environment?
- Yes
- No
3. On a scale of 1-5, how would you rate the quality of the audio-visual elements in the VR sound installation? (1 = poor, 5 = excellent)
   1 2 3 4 5
4. Which level of the VR sound installation did you find most engaging or enjoyable? Please explain why.
5. Did you feel a connection between your sense of self and the virtual environment or the audio-visual elements?
- Yes
- No
- Other…
6. If yes, please describe how your sense of self extended to the virtual environment and/or the audio-visual elements.
7. Do you believe that the VR sound installation had an impact on your sense of self in the digital world?
- No
- Yes
- Maybe
8. If yes, please elaborate on the impact the VR sound installation had on your sense of self in the digital world.
9. Would you recommend this VR sound installation experience to others?
- Yes
- No
10. Any additional comments or feedback regarding your experience in the VR sound installation

Figure 11. In the Main level

Figure 12. Reaching for bass in SkyScape level

Non-exclusive license to reproduce thesis and make thesis public

I, Jason Alexander Greenberg,

1. I herewith grant the University of Tartu a free permit (non-exclusive license) to reproduce, for the purpose of preservation, including for adding to the DSpace digital archives until the expiry of the term of copyright, “Navigating the Layers of a Mix in Virtual Reality”, supervised by Taavet Jansen.

2. I grant the University of Tartu a permit to make the work specified in p. 1 available to the public via the web environment of the University of Tartu, including via the DSpace digital archives, under the Creative Commons license CC BY NC ND 3.0, which allows, by giving appropriate credit to the author, to reproduce, distribute the work and communicate it to the public, and prohibits the creation of derivative works and any commercial use of the work until the expiry of the term of copyright.

3. I am aware of the fact that the author retains the rights specified in p. 1 and 2.

4. I certify that granting the non-exclusive license does not infringe other persons’ intellectual property rights or rights arising from the personal data protection legislation.

Jason Alexander Greenberg
10/05/2023