



MECAMIND XR

Creative Technology Bsc. Graduation Project

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Abstract

The goal of this project was to evaluate whether virtual reality can contribute to the design process by stimulating movement. To achieve this following question was asked: *How does a VR experience that stimulates physical movement in a creative environment, aid with the design process?*

To answer this question, research was done through literature research, background research of the current state of the art, followed by an auto ethnographic study of virtual reality experiences that resulted in 5 themes: music, interactable objects, role models, story and setting, and walking. These themes were then applied in an iterative tinkering process which resulted in a final prototype, which was then evaluated with a A-B style within-subject testing user evaluation.

The results show that the created prototype was well received and showed signs of increased movement. The three-dimensional drawing tool and the music were the favorite elements of participants of the evaluation.

It has been concluded that virtual reality can indeed contribute to the design process, as it allows for embodied design methods that are not possible in the real world.

There is a strong recommendation to continue research to evaluate how much of the themes contributed to increased movement. Mainly the drawing and music aspect seem to have the most potential for future research. To expand on this, investigating the effect of types of music on movement could create a better understanding of how to improve on this aspect.

Furthermore, looking into ways to stimulate increase of movement in different drawing methods is encouraged. Finally, there is a strong recommendation to give a high priority to evaluate motion sickness within development for virtual reality.

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Chapter 1: Introduction

In this chapter, an introduction of the projects background and goal will be given. Followed by the research questions that will be used to research and design a system that should complete the project's goal. Finally, an outline of this thesis will be given.

1.1 Project Context

This thesis will focus on integrating movement into design activities, which could have a positive impact on the overall design process. This moving while designing stems from a recently developed philosophy in design, called Embodied Design Thinking, which is based on the concept of the mind and body being one whole [1].

Johnson-Glenberg claim that aspects from Embodied Design Thinking can be used to make abstract concepts easier to understand and have potential to be used in settings such as education to improve the teaching of topics such as mathematics or physics. By incorporating movement in an educational setting, students should be able to grasp these concepts much more easily than within traditional teaching methods [1]. And as design can be narrowed down to defining, understanding and solving problems, the idea that moving while designing is beneficial is not that far-fetched.

It is important to also use the body while designing physical interactions to get a better understanding of the interaction that is being designed, this is perhaps an earlier sign of Embodied Design Thinking within interaction design [2]. In addition, it is easy to get stuck in a scenario where you are sitting and are physically inactive, while being mentally engaged in the design process. This can cause laziness and a disconnect from the interaction that is being designed.

Furthermore, it has been discovered that physical activity has a positive influence on the functioning of the brain. For example, going for a walk after encountering a problem to solve, can help the brain to form connections that will make it easier to find a solution afterwards. In a sense, by moving you are subconsciously processing the problem. According to Johnson-Glenberg, this can be justified as more neural pathways are active, when physical activity is being performed, so combining this within a design or learning setting, it can cause a stronger learning signal or memory trace [1].

While there are many tools in the design process, there are not many target movement-based designs, like for example role playing [3]. Embodied design methods could be a solution to this problem.

The goal of this project is to design a tool/icebreaker to integrate movement in the design process (See figure 1). This could be to make people more comfortable with the idea of or to get people in the flow of designing while moving.

To achieve this, a tool will be created, using technologies like augmented reality or virtual reality in combination with a game engine, this will be further clarified in Chapter 2.2 State of the Art.

This tool will immerse the user into a creative environment where they are encouraged to move by the experience that it offers. This should get the user physically engaged in a creative process which aids the design process in which they are currently involved.

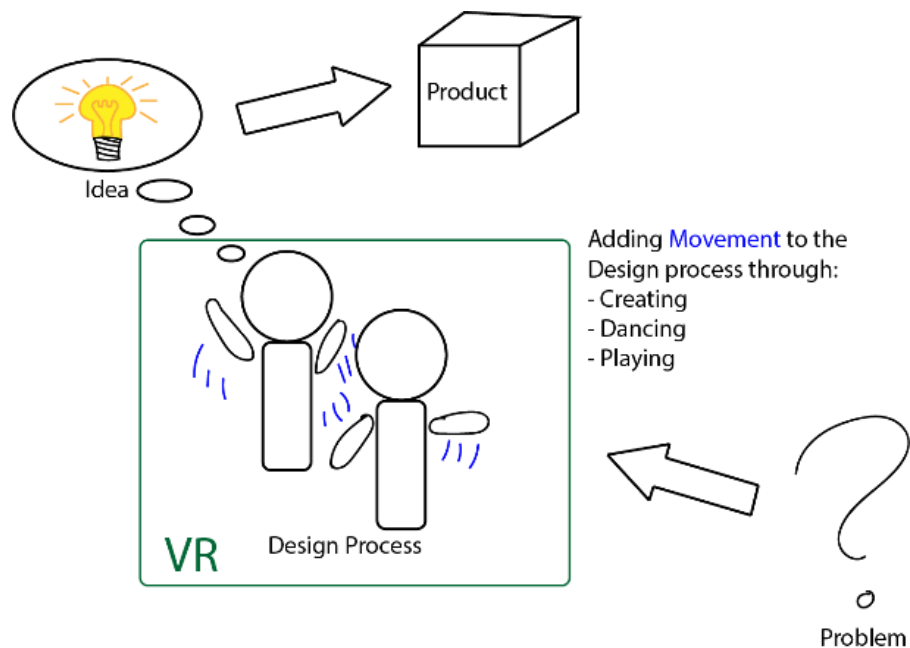


Figure 1: An overview of the design process and the aspect this project will focus on

1.2 Research Questions

To achieve our goal of creating an Embodied Design Tool in Virtual Reality, we have several research questions that will need to be answered throughout the process.

1.2.1 Main

The main research question of the project, that will be used to evaluate whether the end-result of the project has answered our goal is: *How does a VR experience that stimulates physical movement in a creative environment, aid with the design process?*

In the first part of this project we will mainly focus on the background research, such as the theoretical grounding and current state of the art of the Embodied Design and Virtual Reality scene.

1.2.2 Theory

For our theoretical grounding we will ask ourselves the following question: *How can embodied interactions be used in a Virtual Reality experience, so that it offers an engaging and embodied experience to the user?*

To answer this, we have made two additional questions:

- *How does presence affect the user's capacity to become engaged in a creative environment?*
- *What is presence and immersion?*

1.2.3 State of the Art

To find out what has been done already and what is currently available and develop our State of the Art, we aimed to answer the following question: *What is the state of the art in embodied design tools and methods for creativity?*

To answer this question, we split it up into three other questions:

- *What embodied design method/tools/applications related to creativity are there?*
- *What systems have been made to stimulate physical movement?*
- *What VR platforms could be useful and what are their traits?*

1.2.4 Design

Next, to design our system we will answer the following research question:

How can a VR experience encourage physical movement, while also be engaging and offer a creative experience that also mentally challenges the user?

This will be done by evaluating and answering the following two sub-questions:

- *How can we operationalize the insights about presence and immersion productively for this particular VR application?*
- *What techniques are there that could benefit or hinder this VR application?*

1.2.5 Evaluation

Lastly, the resulting system will be evaluated using the research question:

How well does the designed VR experience stimulate physical movement in a creative setting?

To come to this conclusion, there are several sub-questions:

- *How does highly interactive environment aid with stimulating movement?*
- *How does music impact the movement of the user while within the virtual environment?*
- *What parts, if any, distracted from the overall experience of being physically engaged in the creative process?*

1.3 Outline

In the Chapter 2, we will look at the background of the project's context, such as the theoretical grounding and state of the art. In Chapter 3, we will list and explain our methods and techniques on the several auto ethnographic studies and the user evaluation have been performed as well as how the prototypes were made. Followed by Chapter 4, where we will discuss the ideation phase of the project, and the resulting identified themes. Then in Chapter 5, the tinkering process will be covered, as well as the elements that make up the design of the final concept. Chapter 6 will cover the evaluation of the final design, by first describing the design of the user evaluation, followed by the results. In Chapter 7, using the results given in Chapter 6, a discussion will be made about the final design and conclude whether it's been successful in achieving the projects goals. Then finally, in Chapter 8, future recommendations of the work will be given for future development and research.

Chapter 2: Background Research

In this chapter, we will first be covering main theoretical concepts related to immersion, presence, embodiment and the creation of these. Then we will cover the state of the art and discuss other embodied design tools, other systems which stimulate movement and give an overview of VR platforms.

2.1 Theoretical Concepts

2.1.1 Immersion

There has been a lot of discussion and research done on Immersion and *Presence* and how they relate to one another. In many circumstances, people use *Immersion* and *Presence* interchangeably in the sense that they both describe the feeling of having the ability to influence things in the environment [4]. However, there is clearly a difference between *Immersion* and *Presence*. According to Walther-Hansen and Grimshaw *immersion* is “*becoming physically or virtually a part of the experience itself*” (p.81) [4]. Evans and Rzeszewski seem to have a similar position on *immersion*, and argue it is a state “*where the attention of the gamer is on the game or experience, not the technology or the inter-connectivity of the technology with other technical devices, or the functioning of hardware or software in the background*” (p.27) [5]. We will then define *Immersion* as: the ability or capacity of an experience or device to get the full attention of the user, and remove the distractions of all other elements that are used in the background.

2.1.2 Presence

Now that *Immersion* has been defined, we can more easily separate and define what *Presence* really is. *Presence*, has been defined by Walther-Hansen and Grimshaw as: “*the feeling of “being there” in the world*” (p.81) [4]. However, Evans and Rzeszewski are more specific to what *Presence* stems from, they argue that *Immersion* and *Embodiment* are a prerequisite of *Presence* and therefore removing one of these will lower the amount of *Presence* that is being experienced [5]. This gives us a deeper understanding of where *Presence* comes from, unlike the more abstract definition from Walter-Hansen and Grimshaw. Using this information, we will define *Presence* as the feeling of being inside the virtual world that the experience is creating. It is reliant on the feeling of a high level of *Immersion*, before it can be experienced by the user. In addition, the higher amount of *embodiment* inside the experience, the better the sense of *presence* that can be achieved. When *presence* is being experienced, the user perceives this virtual world as reality.

2.1.3 Embodiment

Establishing what *Embodiment* is, will help in the understanding of its importance. According to Johnson-Glenberg, *Embodiment* is the concept of the body and mind being a whole [1]. She argues that *Embodiment* in an educational context could enhance the learning process: “*When a motoric modality is added to the learning signal, more neural pathways will be activated and this may result in a stronger learning signal or memory trace*” (p.3) [1]. This can also be seen in practice from ‘learning by doing’. In contrast, Wölfel and Gehmann have put this into the perspective of virtual reality and say that, we use our body as a guide to locate ourselves in space and time, which explains why we don’t necessarily need to represent the user through a virtual avatar when using a first person perspective [6]. Instead our cognition is able to make sense of our situation and allows us to embody our real selves into the virtual realm. Thus, we can conclude that integrating *Embodiment* can enhance the overall design process. This can be assumed, as the design process can be defined as a process of understanding and finding a solution to a problem. However, in the context of Virtual Reality, we define *Embodiment* as the user “being” their virtual representation in the experience, where their mind is connected to a virtual-version of themselves.

2.1.4 Creating a sense of Embodiment

There are several tricks designers use to give the user a sense of *Embodiment*. One of these is full body representation of the user’s avatar within the virtual world. Wölfel and Gehmann argue that it “can even prevent simulation sickness because it provides a reference point” [6]. To add to this, Born et al. claim that having a personalized avatar for the user, to one that closely resembles them, can have a big impact on the *Embodiment* perceived [7]. In addition, making the avatar more advanced by mapping the user’s own limbs can give a massive boost to the amount of *Embodiment* perceived by the user [7]. This can be done by tracking the user’s head, hands, fingers, and in more advanced setups even the users arms, feet, legs and torso can be tracked [8]. This means that having a virtual representation of oneself, helps with the embodiment of the virtual self, even more so when the avatars and tracking solutions grow in complexity. Moreover, they also give users a reference which helps prevent motion sickness. However, perspective also plays an important role. Perspective has a big influence in the amount of *Embodiment* perceived by the user, more specifically a first person perspective has a big positive influence in contrast to a third person perspective [7]. Which makes sense, as experiencing something from the first-perspective, means that you are experiencing what the virtual avatar, that you are embodying, is experiencing. But there other ways to create a sense of *Embodiment* besides visual elements. Fröhner et al. claim that “*haptic feedback showed positive effects on embodiment in VR*” (p.1) [9]. Haptic feedback can be used to give the illusion of touch or of the force from recoil experienced when using a weapon. Finally, the design of an experience can also help with creating a sense of *Embodiment*. Some Virtual Reality experiences are built upon game mechanics designed for traditional games that were meant to be played on a television or computer monitor. These experiences however, seem to try and make traditional mechanics and controls work, without using the limitations of Virtual Reality in its design [5]. This can severely affect the embodiment that can be experienced, and will in some cases leave the user overwhelmed, frustrated or severely nauseous.

Therefore, designers can give users a sense of *embodiment* by having a visual representation of the player avatar's body inside the experience; mapping the user's movements to the player avatar; making use of body tracking, which can be simple by tracking only the user's fingers and hands but can be greatly improved by tracking more parts of the user's body; and using a first person perspective. But most importantly, Virtual Reality experiences should keep in mind the limitations of its platform within their design, to prevent users being left frustrated and nauseous.

2.1.5 Creating Presence using Embodied Interactions

There are several manners of *Embodied interactions* that can be used to create a sense of *Presence* to the user. According to Wölfel and Gehmann, the integration of a virtual body of their avatar can give the user something they can relate to [6]. Leaving this out, the user might experience a "*a lower contribution in the emergence of self in the virtual environment*" (p.255) [6]. However, a study by Lugin et al. seems to disagree, they found that their "*results did not confirm any significant advantages or disadvantages of the degree of avatar body visibility completeness on said effects*" (p.23) [8]. This might suggest that the positive effects of the integration of a virtual body of an avatar could be more of a personal preference of users. This may be why some developers omit full-body presence of player avatars inside their games and experiences. Interestingly, however, Lugin et al. also suggest that the more a user feels embodied within an experience, the more genuine their reactions towards events inside the experience become [8]. This also suggests that users experience a higher level of *immersion* which in turn causes a higher level of *Presence*.

Another way *Presence* can be created is by having a high interactivity with the environment, which is a feature that virtual reality games are known for. An example of this would be being able to pour yourself a drink using a bottle and a glass, or being able to draw on surfaces with markers. These examples also show how affordances of the environment are used to enhance presence by embodied cognition, according to Shin [10]. Alzayat et al. say that because this interaction with the world is facilitated by our own body, instead of a series of buttons and joysticks, the feeling of having a body inside the virtual environment can be created [11]. This is true even more so when using methods like finger and hand tracking. Furthermore, this also seems to have a relation to *Immersion*, as we are removing old fashioned inputs, with intuitive and invisible controls, thereby removing the focus on the hardware. Combining this with our previously established definition of *Presence*: "*the feeling of being present in the virtual world that the experience is creating*". We can now see that letting the user embrace their own body, and using it to interact with the virtual world, can be a powerful tool to create a sense of *Presence*.

Thus, with the use of *Embodied Interactions*, such being able to see the body of the user's avatar and being able to interact with the environment and making use of its affordances, a sense of *Presence* can be created.

2.2 State of the Art

2.2.1 Existing Embodied Design Tools

There are several tools and design methods out there that incorporate Embodiment as part of their design. However, due to the recent development of Embodied Design Thinking the amount is rather limited as not many tools have been designed with this new philosophy in mind. Currently, finding any tools that utilize VR has been unsuccessful, so all tools that are being discussed will not utilize this technology.

The *Ideating in Skills* (liS) toolset is aimed at supporting the co-design processes [12]. liS is a sort of workshop that can be carried out with stakeholders that involves the touching of physical objects, thereby stimulating the embodied use of these pieces. While it was received well, one of the issues with this design was that it only encourages small, finer movements and not movement of the whole body. Currently, a new version of this toolset is being developed which is supposed to improve this [12].

Another tool, called *Bodystorming*, is all about using the body. It's a variant of brainstorming but a lot more physical. It has roleplay sessions, which can also be performed at locations where the product will be used to get a better understanding of the context of the use case. [3]

Other methods focus on the experiential aspect of using the body: How does it feel to perform this movement? These techniques are called: attunement, attention, and kinesthetic empathy. They can be used for self-observation and the observation of others [13]. This is similar to *Material Props in Context*, which also explores the context in which an object or material can be used, as well as the touch of an object or material [14]. But understanding how something fits on the body is also a method, this is called Topology of the Fabric [15]. Here fabric is placed on a person to explore ways materials can be used. Another method called *Props for Embodying Temporal Form* also explores how objects can be used by placing it on the body of a person, but focusses on known actuators [14]. They also talk about a method called *Embodying Past Expressions* which has a similar approach but uses copies of photos of old objects of historical significance to translate this embodied experience into a visual language. This results in ideas of how technology can be integrated in clothing.

An approach similar to Bodystorming and roleplay is *Stakeholder Drama*, derived from *Object Theater* where stakeholders perform a small scene that is built around a certain object or scenario [14]. This gives insight in how stakeholders react to certain events or how they use certain objects or devices.

OWL bodyProps is a design method that uses wearable probes which are worn by interviewees. Once applied, they are asked several questions revolved at what they think the probe does or is, and most importantly how it feels. Their answers aren't limited to reality, they can come up with any kind of device whether it exists or not [14]. Resulting in "radical imaginings grounded in

desire, which can lead to new concepts for embodied technology design. This method thus embodies latent desires” (p.5165) [14].

Props for Undesigning is a design method that uses everyday objects and consists of 3 rounds. In the first round, the world is the same as normal, where everything behaves as one would expect them to. Then in the second round, this is changed and the world becomes a more “phenomenological realm of durational, embodied experiences” (p.5165) [14]. Finally, in the last round, the world is reverted back to normal but it’s in a new state. The use of the props interferes with the established ways of engagement and undermines the understanding of how these engagements should act, causing the creating of new movements behaviours [14].

Collaborative somatic inquiries is a method that is done in pairs. Starting with a small workshop that aims to give a sense of body awareness. And then followed by a session where two people have to make movements in relation to each other, where one person has their eyes closed and the other open. This creates an understanding of new movement patterns [14].

Embodied Design Improvisation is another method that tries to help in the understanding of how objects can be translated into robotic devices, by exploring how they can interact with humans. This allows designers to highlight well known aspects which are hard to put into words. Highlighting these aspects allows others to reflect and discuss on these elements and use their resulting understanding into new applications that can be used by others [15].

2.2.2 Existing systems that stimulate physical movement in games

Knowing the importance of movement in the design methods, we first want to see how movements are currently triggered in Virtual Reality in existing games and applications.

Within the space of VR, there are several games that stimulate physical interaction. In particular Beatsaber, Blade and Sorcery, Superhot VR and Until You Fall have been used by people as a way of working out in a gamified setup. These games get the user to move by making movement part of the game design as a way to reaching the goals set within these experiences.



Figure 2: A screenshot of Beatsaber. Source: <https://store.steampowered.com/app/620980>

Beatsaber (fig.2) has the user slice blocks in a certain way, but does this to the elements of the song that has been selected. In addition, mines and walls that reduce the chance of the player succeeding, get the user to move their whole body by evading these obstacles.



Figure 3: A screenshot of Superhot VR. Source: <https://store.steampowered.com/app/617830>

Blade and Sorcery, on the other hand, gets the user to move their body by having them fight enemies with swords, bows and magic. When all enemies have been defeated, they win the game. This is similar to the design of Until You Fall and Superhot VR (fig.3), but for the latter the user is invited to move and in some cases move as little as possible by making the speed of time dependant on how much and when they move. In this example, movement becomes an integral part of the game, not only because users have to move to

eliminate enemies, but also because they have to plan and manage their movement otherwise they will get hit by a storm of bullets and fail the game.

Outside of VR there have been several attempts to stimulate movement in the gaming space. Earlier attempts used optical information captured by a camera. One of these systems was made by Sony and was called the PlayStation EyeToy (fig.4), an accessory to Sony's PlayStation 2 game system, released in 2003. The design of these games relied mostly on the user acting to something happening on screen, which showed the game world with the EyeToy's camera feed as a background. For instance moving their arms in a certain pattern, or blocking projectiles with their hands that were heading towards the player. There were even multiplayer games, which mostly took the form of party games, where players have to perform a certain action competitively, the one who did it the best or the fastest would win the game, think of actions like running in place [16].



Figure 4: Image of the EyeToy
Source: <https://en.wikipedia.org/wiki/EyeToy>



Figure 5: Image of the Wii and the Wii Remote Source: nintendo.nl

In 2006 Nintendo took this concept to the next level, and made a whole game console centered around movement based game controls, this led to the creation of the Wii (fig.5). This system relied on a Wii Sensor Bar which would send out infrared light, which would be picked up by a sensor in the Wii Remote. Games developed for this system, always involved some kind of movement: shooters would have the player aim using the Wii remote, racing games would make the player use the Wii remote like a steering wheel. One of the most popular games of the Wii is Wii Sports which uses the controllers in ways one would normally use equipment from the several

kinds of sports integrated within the game. Baseball would turn it into a baseball bat or as a glove when pitching a baseball, as boxing gloves when boxing or as a bowling ball when bowling. Several sequels were made that added more kinds of sports and activities [17].

In 2009, Nintendo released the Wii Balance board (fig.6), which was an accessory to the Wii and could be used in the game Wii Fit. This is an exergame that is more about personal welfare and healthcare. The device could weigh the player, track his posture by measuring the positioning of the weight on the board. Most activities in this game revolved around Yoga, balancing and strength training. Nowadays, the Wii is being recommended by the Vestibular Disorders Association, an organization that helps people who are suffering from balancing problems, as they claim it can be used to aid in the treatment process for Vestibular disorders [18].



Figure 6: Image of the Wii Balance board
Source: <https://www.wiigamesinfo.nl/wii-kopen/nintendo-wii-balance-board/>



Figure 7: Image of the Kinect for Xbox 360
Source: <https://nl.wikipedia.org/wiki/Kinect>

Microsoft, also tried to get into this market with the Kinect (fig.7) for Xbox, released in 2010. Originally made for the Xbox 360, this device is still popular in even non-gaming communities as it can be used on computers as well. The Kinect was a more capable product as it is able to get depth information as well. Using the data captured by its various sensors, developers can map a virtual skeleton to players, which are used within games to determine the effects of their movements on the game world [19]. Games designed for this device, ranged from dancing games, such as Just Dance, to action games like Kinect Star Wars and Harry Potter for Kinect. The last two games require the player to perform several physical movements in a specific way to perform actions or unleash their powers in-game.

In 2013, Sony made a competitive device to the Kinect and Wii: the PlayStation Move for the PlayStation 3 (fig.8). Later in 2016, it was made compatible with the PlayStation 4, to be used with Sony's VR-headset that was named PlayStation VR. Games made use of the Move in a similar way as the Wii Remotes were used with the Wii. During the announcement, Sony boasted that the Move wands could be used for 3D-modelling due to their high precision tracking [20].

In conclusion, requiring the user to move to perform action and tying game mechanics to movement appear to be effective ways to stimulate movement.



Figure 8: Image of the Playstation Move wand and Playstation Camera. Source: <https://www.coolblue.nl/product/103158/playstation-move-starter-pack.html>

2.2.3 Existing VR Platforms

There are several VR platforms, these can be separated into hardware and software. In the following section, we will discuss several platforms in their respective categories and conclude with which ones we will use for this project.

2.2.3.1 Hardware

There are many VR headsets available, each with their own features. These features can be the types of tracking available (inside-out or outside-in), degrees of freedom (DoF), field of view, controllers and whether they are standalone or require a computer.

There are two categories of VR systems, this is mainly determined by whether they need to connect to a computer or not: tethered and untethered. A recent development in VR hardware has made it possible to run entire virtual worlds from inside of the headsets. We will not define using a laptop or desktop backpack (also known as VR backpack) as untethered for this project.

Note: *At the time of writing this short notice, new virtual reality headset have been announced by HTC with improved fidelity and capabilities. As this news has come past the state of the art research, these new headsets will not be discussed in this section.*

Tethered VR headsets:

- *HTC Vive Pro (2016)*

The Vive Pro is the successor of the Vive, which was a popular headset when the Virtual Reality market started. However, this time it is aimed at the Professional grade market and Enterprise, this is also reflected in its price of 1.490 euros for a full set. It uses the new SteamVR 2.0 tracking, which is more precise than its predecessor. And also allows for a playspace up to 100 square meters. The display has a per eye resolution of 1440x1600 per eye with a refresh rate of 90Hz and a field of view of 110°. The controllers feature a multifunction trackpad with haptic feedback. With an optional add-on this headset can be used wirelessly [21].

- *HTC Vive Cosmos (2019)*

The Vive Cosmos is perhaps the more true successor in the gaming space to the original Vive. At a price of 829 euros for a full set, however it excludes the SteamVR 2.0 Base stations. The display has a per eye resolution of 1440x1700 at a refresh rate of 90 Hz and has a field of view of 110°. The controllers have joysticks unlike the ones of the Vive Pro and buttons, making it more in line with other VR game controllers. And just like the Vive Pro, there is an optional add-on that allows wireless functionality [22].

- *Oculus Rift S (2019)*

The Rift S is the successor to the Rift, which was one of the first consumer VR headsets. A full kit which includes the headset and Touch controllers cost around 449 euros. Unlike the HTC Vive's covered before, this headset does not need any additional tracking equipment as the headset has sensors which are used for tracking the headset and controllers by itself. This allows for easier set up times, while only the headset has to be plugged into the computer. The display has a per eye resolution of 1280x1440 at a refresh rate of 80Hz and a field of view of 115°. The Touch controllers are equipped with sensors that track the user's fingers, so gestures can be directly translated into VR applications, besides this feature it closely resembles the controller of the HTC Vive's that has been discussed earlier [23].

- *Valve Index (2019)*

The Valve Index is Valve's first VR headset, aimed at gaming and tinkering. A full kit costs around 1.079 euros, this includes the Knuckle controllers, the headset and 2 SteamVR 2.0 Base stations. The display has a per eye resolution of 1440x1600 per eye at a refresh rate of 80 / 90 / 120 / 144Hz and a field of view of 130° which can be adjusted to the user's liking. Customizability is a big part of the Index's design, lens distance and thereby also field of view can be adjusted, speakers can be re-orientated and even changed. There is also a USB-port on the front of the headset on which custom modules can be connected, such as a cooling fan, LED-matrix or a device that adds smell to the experience. The Knuckle controllers are designed to be part of the user's hand, with straps that keep the controllers steady when the user has let go of holding the controllers. This is added with finger tracking and a grip sensor to allow for more realistic interactions with the virtual world [24].

- *Primax 8K X (2020)*

The Primax 8K X is a very high-end headset that delivers 4k visual quality per eye and offers the highest field of view on the market, and comes at a price of 1.299 euros. This includes the headset, 2 Knuckles controllers and 2 SteamVR 2.0 Base stations. The display has a per eye resolution of 2840x2160 at a refresh rate of 90Hz and a high field of view of 200°. The Knuckles controllers are exactly the same as the ones provided with the Valve Index [25].

- *HP Reverb (2020)*

The Reverb is a high-end headset that offers great clarity with a price of 899 euros. This includes the headset and 2 controllers and makes use of inside-out tracking. The display has a 2160x2160 resolution per eye with a refresh rate of 90Hz and a field of view of 114°. The controllers don't offer finger tracking and have a similar design to the Oculus Touch controllers [26].

Untethered VR headsets:

- *HTC Vive Focus (2019)*

The Vive Focus is a headset aimed at an all-in-one enterprise solution for VR, and therefore does not require to be connected to a computer. The full set costs 877 euros and comes with the headset and one controller. As it's an all-in-one headset it also keeps track of its own position and orientation, so no additional equipment is required. The display has a per eye resolution of 1440x1660 at a refresh rate of 75Hz and a field of view of 110°. The single controller features a trackpad and 2 big buttons to make it easier to use as it's not aimed at usage for gaming. Finally, it has an average battery life of 3 hours [27].

- *Oculus Quest 2 (2020)*

The Quest 2 is an all-in-one headset aimed at the gaming space of VR. The full set costs 349 euros for a 64gb model, and is also available with 256gb for 449 euros. This includes the headset and 2 Touch controllers, identical to the ones provided with the Oculus Rift S. The display has a per eye resolution of 1832x1920 per eye at a refresh rate of 75 / 90 / 120Hz and a field of view of 95°. It has an average battery life of 2-3 hours [28].

This is an affordable all-in-one solution for gaming. However, it requires a valid Facebook account to be used, which may provide some privacy concerns due to Facebook's data collection [29].

- *Oculus GO (2018)*

The GO is a competitor to the Vive Focus as it is also an all-in-one solution for enterprise VR. A set costs 249 euros and features the headset and one controller. The display has a per eye resolution of 1280x1440 per eye at a refresh rate of 60 / 72Hz and a field of view of 95°. The controller has a trackpad, 1 big trigger and 2 smaller buttons. Unlike the previously mentioned headsets, this one only is capable of 3 degrees of freedom (in contrast to 6 DoF), which means that it only tracks the rotation of the headset and controller and thereby does not allow much movement within its applications. It has an average battery life of 1.5-2 hours. Again, this headset requires a Facebook account to be used [30].

2.2.3.2 Software

There are many software platforms available for use in VR. These range from already developed social spaces which provide tools to use, to game engines which give free reign of how the experience will be but require more programming knowledge of the developer.

Applications

This category consists of platforms which are already existing applications available on the market that also can be used to develop new custom experiences.

Engage

Engage is a VR application, developed by Immersive VR Education Ltd, aimed at virtual communication. It allows its users to have meetings, social gatherings and presentations in virtual reality. There is full body presence within the application, which allows for expressive movements. It features cross platform support, so different headsets can be used without issue. There is also an editor that allows users to develop new content, however this feature is part of a paid subscription [31].

Spatial

Spatial is an XR application, developed by Spatial Systems, is aimed as a virtual conferencing tool. It allows users to have meetings, both using VR, AR and normal desktop view. Body presence is limited to waist up and avatars are generated from a picture provided by the user. There is cross platform support as mentioned before. There is a lack of an editor, but there are a lot of tools for collaborative work, in addition to sharing content: videos, images, models and documents [32].

Rec Room

Rec Room is a VR application, developed by Rec Room Inc, aimed at creating social spaces and interactions. There is body presence in the form of a floating body, hands and head. One of its biggest features is that you can create new objects and worlds using a pen tool. It also makes heavy use of affordances of objects making them intuitive to use. Rec Room is available for free on Steam, iOS, Oculus, Xbox and Playstation [33].

Neos VR

Neos VR is a social VR application, developed by Solirax, that allows users to create custom content, this is the main driving force behind its design. Body presence is dependent on the player's avatar, which can range from a floating hands and head to full body presence combined with additional trackers for arms and legs. It features an integrated content browser, where users can import pre-made objects with their own functions, or import their own models and media and program their behaviours from within the VR experience without needing to take off the headset. Objects can be modelled and adjusted, new materials can be made and painted on these objects. This application does have a learning curve however, but there are many tutorials available online. However, this can also be a great collaboration tool. Neos VR is free and available on many if not all VR headsets [34].

VRChat

VRChat is a social VR application, developed by VRChat Inc, and is one of the biggest social VR platforms on the market. It features full body presence and can also be enhanced with more trackers, however this is dependent on the selected avatar. Users can create their own avatars and worlds using their own Unity SDK plugin. Like Neos VR, content creation is what fuels VRChat, however instead of doing it within the experience, it has to be done using Unity. Users can express themselves within the experience using gestures, emotes and by participating in activities. The main focus of this experience is creating social settings for users to interact with. VRChat is available for free on Steam, the Oculus Quest and Rift, and on Viveport [35].

Game engines

This category consists of platforms which can be used to freely develop applications with great flexibility.

Unity

Unity is a free to use game engine developed by Unity Technologies. It's a popular engine within the game development scene, but can also be used for making apps, animations and other applications. It has support for creating VR applications. In addition, it has a marketplace where assets can be bought. Overall, Unity is a flexible, powerful tool that is also lightweight. It makes use of the programming language C# [36].

Unreal Engine

Unreal Engine is a free to use game engine developed by Epic Games. It's also a popular engine, but a lot more focused on games, architecture and television production. It has support for VR and also features a marketplace. In contrast to Unity, Unreal is more focused on nice visuals and is generally more demanding, while being powerful. It uses C++ as its programming language but can also be programmed using Blueprints, which is their own version of a visual scripting language. Due to the nature of its scripting language it can be harder to get into [37].

2.2.3.3 What will be used

From this information, it has been decided that the application will be built with a focus on being used with the Valve Index. This headset has been chosen as it allows for intuitive interactions with the environment with its Knuckle controllers and also features a great balance between visual clarity, field of view and a great selection of refresh rates. These traits also allow for an increased sense of immersion and embodiment as the technology becomes more invisible and translates more of our physical interactions to the virtual world.

A Oculus Quest 2 compatible version could be made, as it's a great affordable option and untethered, which is ideal for the aim of this project. This however, will depend on the amount of available time and the amount of effort needed to translate the designed interactions. Lastly, the game engine Unity will be used for developing the experience as it's flexible, lightweight and does not require any additional licenses. Lastly, there is enough information available on how to develop a VR experience within Unity.

Chapter 3: Methods and Techniques

In this chapter the methods and techniques of the performed studies and the iterative design process will be discussed.

3.1 Auto Ethnographic Study of Existing VR Experiences

An auto ethnographic study was performed during the ideation phase of this project to see how virtual reality games try to engage the user and how they get the user to move around and interact with the world. The result from this study can be found in Chapter 4. The auto ethnographic method, is based on self-experience and reflecting upon those experiences. This will help us get a better understanding of our feelings and emotions toward those experiences and allow us to gather what drives these experiences and makes them work.

Several games were played and evaluated, ranging from games that fully focus on physically engaging the player, to social experiences where people can meet and engage in activities together. The final selection of games that have been evaluated were: Beatsaber, Creed: Rise to Glory, Rec Room and VRChat.

These games were evaluated by playing them in a relaxed setting. Between levels, notes were taken about the experience that had been had, what elements stood out and general observations from looking at the design. Then once the play session was complete, these notes were looked at again, and then further explored and expanded. The results were discussed with the supervisors and elements were labelled. This led to finding core themes, which have been presented in Chapter 4: Ideation. To validate the study's findings, references in literature were searched that highlighted and confirmed the theories that made up these themes. Then these themes were used to ideate several concepts that could be used to apply these themes into a virtual reality experience, that would engage the user both mentally and physically in a creative process.

3.2 Tinkering Process

With the aid of the themes identified from the auto ethnographic study as covered in Chapter 3.1 development of the virtual experience started. This was done through a weekly cycle of iteration and evaluation, again using auto ethnographic means. A more detailed explanation of the approach will be covered in Chapter 5.1. The resulting concept will be thoroughly discussed throughout Chapter 5.

3.3 User Evaluation

At the end of the tinkering process, a user evaluation was performed to determine whether the resulting design fulfilled the goal of its design. This was done by creating several tasks for the participants to perform while in the VR experience. A more detailed approach is covered in Chapter 6.1 and it's results will be covered in Chapter 6.2. A discussion will be held using the observations and results in Chapter 7.

Chapter 4: Ideation

From the earlier mentioned auto-ethnographic study, five themes were found which will be examined and discussed in the following section. After which we will discuss the ideas and concepts that emerged from these themes.

4.1 Extracting essential generative themes from current platforms

4.1.1 Theme 1: Music stimulates Movement

While playing the virtual reality game Beatsaber, I discovered that music can stimulate people to move around more. More specifically, high energy music seemed to have the best effect. While I was playing I switched between high and low energy music and noticed that the game had to do more to get me enjoying the moving more for low energy music than for high energy music, I saw this by the difficulty level I was playing these songs at.

Literature seems to support this, as according to Gaston: *“Rhythm is the primitive, dynamic, driving factor in music. It stimulates muscular action. It induces bodily movement. It becomes particularly stimulating when it consists of detached notes.”* (p.42) [38]

Thus, music could be a great way to get people moving within the experience that is being created.

4.1.2 Theme 2: Story and Setting help immerse the player into their role within the experience

In the VR boxing game Creed – Rise to Glory, which is based on the Rocky and Creed films, I noticed that I took the role of being a very strong boxer. This was because all the environments looked like the typical boxing clubs or stadiums that you see in movies. In addition to the environment, the story was about having to fight a famous boxing champion, and throughout the game you would have quick training sessions followed by a boxing match and after each win you would fight in more and more professional events. This really gave me the feeling like I was someone on a mission to rise through the ranks and become the champion. From this I gathered that the world within the virtual experience in combination with the story can guide the player into assuming their role within the world and immersing themselves into that role.

This is also supported in literature, as according to Ermi and Mäyrä: *“In several contemporary games also the worlds, characters and story elements have become very central, even if the game world would not be classifiable as an actual role-playing game. We call this dimension of the game experience in which one becomes absorbed with the stories and the world, or begins to feel for or identify with a game character, imaginative immersion. This is the area in which the game offers the player a chance to use her imagination, emphasize with the characters, or just enjoy the fantasy of the game.”* (p.8) [39]

This means that the setting and story can be used to immerse the user into the role of someone who is creative within our environment.

4.1.3 Theme 3: Virtual Characters as Role-models

While playing Creed – Rise to Glory and VRChat, I noticed that the way your player avatar looks can influence how you behave. If you are playing as a smaller cute or a big muscled character, you will act in most cases accordingly, unless when you are trying to intentionally break away from the stereotype. In Creed, I felt like I was very strong and acted overly macho as my avatar was heavily muscled. In VRChat this really depends on what character you choose, you can play as your favourite character from a game and experience the dream of being that character. Others who made their own, can express themselves in those forms. This can be distilled down to 'Avatars or other characters can give players an example of how to act in an environment'. Within literature this theory is also supported as according to Wölfel and Gehmann *"the physical appearance in the virtual world influences the social behaviour: A wheelchair person experiences similar social exclusions in the virtual world as experienced in the real world [16]. This also includes the similar and distinct physical characteristics one shares such as gender, ethnic group and race."* (p.255) [6]

Having virtual characters within the experience could help get the user more comfortable and help the user even more with guiding them into a specific behaviour.

4.1.4 Theme 4: Walking helps loosen up the mind

Unlike the other themes discussed so far, this was an 'accidental' discovery I made outside of VR, during my daily walks. I felt that while walking and being around in nature and on the move, I would think of my project and internally debate and process concepts that I picked up throughout my work before. This resulted in many new ideas about the project for possible concepts. It feels less of a bad thing when you have lesser ideas and you just walk away from them, leaving them behind you. This could also be related to Embodied Design Thinking, as you are on the move and are both mentally and physically engaged in the same thing. So, walking can help processing a concept and allow for new ideas to come to mind more easily.

Within literature this is supported within an article by Jabr, in which he argues that *"Walking at our own pace creates an unadulterated feedback loop between the rhythm of our bodies and our mental state that we cannot experience as easily when we're jogging at the gym, steering a car, biking, or during any other kind of locomotion. When we stroll, the pace of our feet naturally vacillates with our moods and the cadence of our inner speech; at the same time, we can actively change the pace of our thoughts by deliberately walking more briskly or slowing down."*

Because we don't have to devote such conscious effort to the act of walking, our attention is free to wander--to overlay the world before us with a parade of images from the mind's theatre. This is precisely the kind of mental state that studies have linked to innovative ideas and strokes of insight." (p.3) [40]

Integrating an element of walking could have a positive impact on helping the user to process the problem they are designing for and to come up with innovative new ideas. The feasibility of this within virtual reality however, needs to be looked at.

4.1.5 Theme 5: Everyday objects induce (social) interactions

During my time in the VR games VRChat and Rec Room, I observed that objects such as a ball or pencils can stimulate interactions to take place between players or the environment. It seems that simple everyday objects can create interactions. VRChat and Rec Room take place in social environments, these can be made by the developers or the users themselves, which mostly involve these kinds of interactions. In many environments, you will find some objects, like a pen that allows you to draw in a 3-dimensional space, or spaces like a bar or living room which invites players to socially interact with one another. Even though these objects are fairly normal, they invite us to use them, perhaps more so than in the real world. Perhaps, this is due to the novelty effect of virtual reality, which is likely as in contrast to the other themes I was unable to find any literature to support these findings. However, that does not mean it's a bad thing, as these objects invite interactions, it can be used to the advantage of the experience. In addition, the affordances of these objects make it easy for us to understand and use the items. I feel that because these items are so simple and recognizable, they can become a powerful tool to start interactions within a VR experience. Perhaps, when these objects are given another purpose or behaviour in addition to what we expect them to do, this can create even more interaction.

With this information then, there could be a lot of benefits of populating the environments with interesting objects. Making these objects look like the ones we interact with on a daily basis can help with communicating their use and behaviours.

4.2 Ideas resulting from the identified themes

Several ideas were made based on the themes that were identified during the auto ethnographic evaluation. These were inspired by several sources: existing games, creative experiences, real world experiences and posts created by developers/tinkerers on web forums such as r/Unity3D, r/virtualreality on Reddit.

A problem that was struggled with before any concrete ideas came to mind was the idea that it should be usable throughout any stage in the design process. However, while performing the background research (Chapter 2) it became clear that this isn't realistic and/or feasible.

One of the first ideas was a creator space, inspired by Such Art [41], a creative VR experience that's currently still in development, but has a preview version available on Steam. It allows players to express their creativity through the use of various tools, such as all kinds of paint brushes. For this project, instead of painting on a canvas like you can do in real life, the idea of drawing in 3D was the main part of this concept. This would require more movement as drawings aren't limited to a specific plane or size. A slight twist to this could be modelling in 3D. this would mean that instead of drawing, the user could create 3D objects in the air and these could then perhaps be exported to other programs.

Environments came to mind such as an office setting, the Design Lab as found on the university's campus and a nature environment such as a forest. These environments would have white board that could be drawn on and if there was online functionality, then the contents of the whiteboard would be shared between those who connected. This idea allows for collaborative creative processes.

A different take on this would also play into the walking theme. This take would consist of a non-Euclidean space, an environment that defies the rules of space. A user could walk around and by turning the corner end up into a totally different environment. This would be done on a scale that allows users to freely walk around without requiring a joystick, stimulating the user to move around and explore new places. This could be distracting however, but perhaps it could inspire the user as well.

From the identified themes it became clear that everyday objects could have some influence on creating interactions, so the environments would be populated with coffee cups or other objects that would make sense to have a place within the environment. From background research it also became apparent that holding objects and looking at them from other perspectives could be beneficial, adding more potential to this idea.

Chapter 5: Tinkering with the themes

In this chapter, the process of exploring the five themes covered in Chapter 4 will be discussed, as well as the auto ethnographic evaluation of the resulting prototype and its elements. Then the code behind the core functionalities will be covered.

5.1 Approach

For the next phase of the development of the final concept and prototype, a tinkering environment was made within Unity which would act as a playground where concepts from the identified themes would be implemented and evaluated. Each week, several goals would be set to work on and implement.

Once this was done, the current state of the concept would be evaluated. For the evaluation, an auto ethnographic study was used throughout the design and iteration process. This means that I would mostly be evaluating the current state of the concept based on my experiences while using it. I evaluated the concepts on whether it aided the experience in achieving its goals, how it made me feel when using the features that were implemented at that time and finally what could be improved. However, to prevent a biased result, at the end of the concepts development a pilot test was done to verify my own claims.

5.2 Implementing the themes

During the design and tinkering process, the identified themes that resulted from the auto ethnographic study were looked at and at how they could be implemented. In the following section, this will be covered and discussed.

5.2.1 Theme 1: Music stimulates movement

Music was from the moment it was identified a big part of the ideated concepts. However, I did not want the experience just to feature some music, without it having a role or impact on the experience itself. Either the music had to interact with the movement or it had to interact with the environment and subconsciously influence the user to move with the world.

Ideas that had been considered were, music that dynamically orchestrates with the user's movement. So would the user only move a little, a small part of the music would be played. Were the user to move more, the music would become bigger in scope and more instruments would be added. This however, was complicated and would take a long time to properly function as intended. So the music started out as being a background element that the user could influence, by selecting what song and thereby what mood they were into at that moment.

Later on, the music became more part of the experience, as the intensity of the music got linked to the wind strength and turbulence that affected the trees in the environment. Seeing the world react to the music felt right as the world would be moving with you. This was then expanded by making the particles be affected by the wind as well, making music and the world feel more connected to the experience and activities of the user.

5.2.2 Theme 2: Story and setting help immerse the player into their role within the experience

The story wouldn't be looked at in a way of a story that unfolds within the experience, but a story can also be told through the setting. So the setting became a bigger focus. At first the setting was mostly formal, with mostly grayscale tones.

Later on in the tinkering process, I realized the environment was too formal and wasn't playful, at the time there still plans for multiple environments, such as: outdoors area and area that was even more like the Design Lab. However, at this point, focus needed to be put on improving existing features, so the current environment was changed into a more homely environment, with a big window that looked over a forest area. This made the environment feel more informal and comfortable, and added some welcome elements of nature.

More objects were added later on, to add to this homely feeling and to make the environment feel less empty.

Later on, when the music-wind mechanic was implemented, more windows and presence of nature was added so users could see the trees at all times. The trees move with the music, so by having lots of windows, there would be more opportunities to try to let the user move with the trees around them.

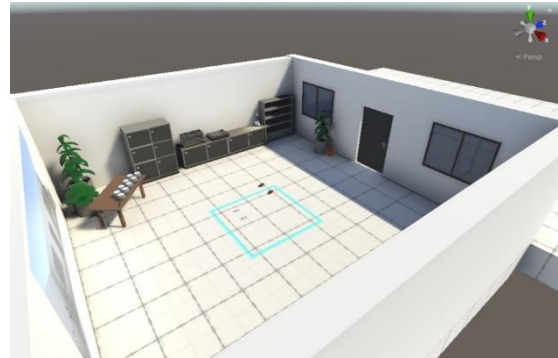


Figure 9: Tinkering prototype version 1 – Simple environment where the user can draw in 3D and put on music.



Figure 10: Version 2 of the creative environment featuring more nature and homely elements

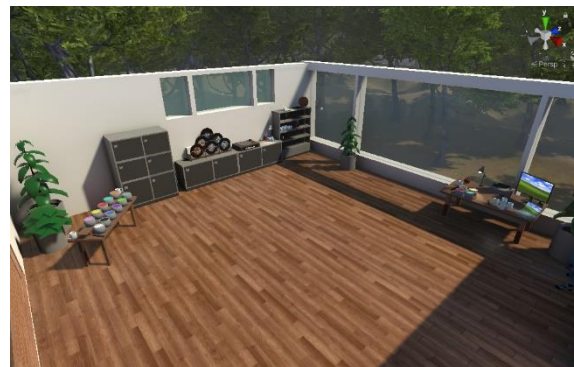


Figure 11: More object were added to the creative environment



Figure 12: The final version of the creative environment with all features added

5.2.3 Theme 3: Virtual characters as role-models

This theme was considered at the start by either adding background characters within the environment. These characters would be doing similar movements as the user, to make moving around seem like the normal behaviour in this virtual space.

Full embodiment was also considered from the start, to make the user feel more connected to the virtual space they were in. As mentioned in Chapter 2, this would help with engaging the user and make them feel part of the world.

During development, a character model was added to the player to give a sense of embodiment, it would follow the player, lower its head and crouch when the user would and move its arms with the controllers (fig.13). However, certain features, like snap turn would interfere and break this functionality. Also, while testing, the hands did not align well with the hands of the player. It became clear that this would require too much focus to work correctly, which would be to the cost of lesser developed core features. For



Figure 13: Player VR rig with avatar

this reason, this theme did not make it into the final concept and was scrapped early on in development.

5.2.4 Theme 4: Walking helps loosen up the mind

This theme took a while to get a clear implementation. First, the idea of a non-Euclidean space came to mind. This would be an environment that defies our understanding of space that would have the user walk in circles with there being a new environment around every corner. This idea, while an interesting concept, would be very complex to implement and may have been too distracting from other elements in the experience. While walking could still be done in the final concept, it would require a very large play space, one that was unable to be utilized within the evaluation.

A different aspect of this theme, was implemented however. This implementation depends on the doorway effect, which is the phenomenon where: *“walking through a door and entering another room creates a “mental blockage” in the brain, meaning that walking through open doors resets memory to make room for a new episode to emerge.”* [42] This is done by having the user first enter the world through a tutorial area (fig.14), where they can try out and get used to the controls. Then there’s a door that leads to the creative space, which they can open simply by opening the door with their hands (fig.15).

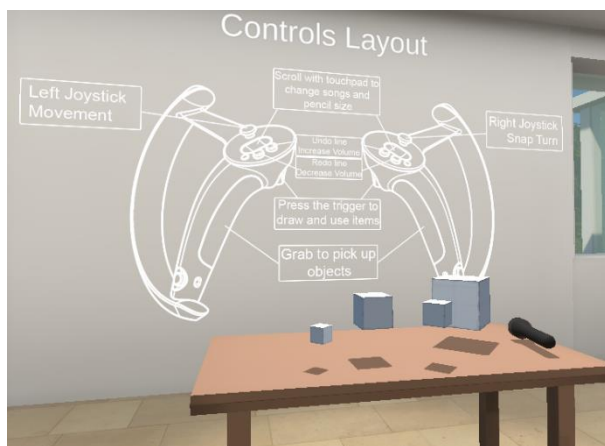


Figure 14: Tutorial area featuring controls and few objects to get used to interaction



Figure 15: Door to the creative space

5.2.5 Theme 5: Everyday objects induce (social) interactions

Everyday objects became part of most of the designs, while research showed that looking at objects and playing around with them could help with getting to new ideas. They also have the special trait of affordances, which means they have a clear use or idea of how they should be used once the object has been identified by a person. For example, when seeing a pencil, one would immediately assume they can be used to draw with. This trait can be very helpful to communicate meaning and their function to a large number of people without showing a pop up or hint that says: “This is a pencil, you can draw with it.” This also means, there would be no

need to come up with special objects that perform certain actions, as all that needed to be looked for is: “what do we use in real life?” This was later on combined with even more interactions in the environment, eliminating the need for UI’s that broke down the realism.

5.3 Evaluation of the core features and their evolution

There are several core features within the final design of the experience: a vinyl record player that can play music of vinyl's, a 3D pencil which is used to draw in 3D, a 2D canvas that projects the 3D drawings on a 2D plane and interactable everyday objects. These elements grew over time into what they are now through the auto ethnographic evaluation that was performed throughout the tinkering process. In the following section this process will be described for each of these core features and how it affected them.

5.3.1 Vinyl Record Player

This started out as just being a Music Player (fig.16), it was a simple user interface within the world that could be interacted with by pointing the controllers. It would take songs that were linked to a Music player script and display them in a dropdown menu, which then could be selected by the user. At first it did its job, but I soon realized that I needed to change my design mentality going forward as I wasn't designing for VR but for regular 2D monitors. I had to get rid of user interfaces as they would break the immersion, so I looked at new ways to get a similar system but more physical.

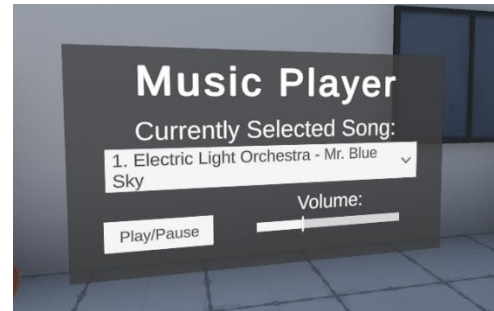


Figure 16: The first implementation of what would eventually become the vinyl record player

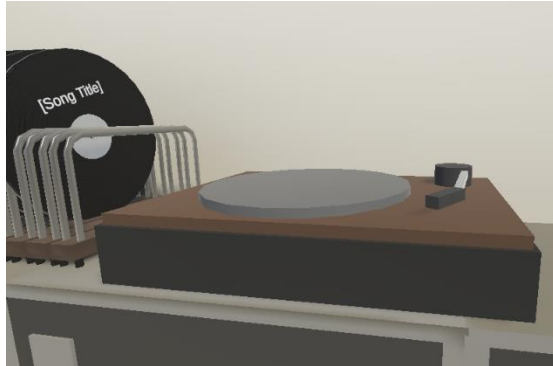


Figure 17: The second iteration of the record player

Nowadays, we mostly rely on apps such as Spotify to play our music, but there's something special about having a physicalized form of music, so I focused on that. The most interesting form of physical music is the vinyl record player. Putting on music on one of these can even be considered a ritual: You grab the album you, you remove it from its cover, place it on the turntable, let it turn and put the arm on the record. It requires a lot of deliberate movements and it gets you in the feeling of enjoying the music. So I tried to incorporate this in the more physicalized music player (fig.17). For this

I took my previous script and adjusted it so instead of the player knowing all the songs, each disk would hold a song and when the player detects a disk, it would load that song and play it. This already felt more natural and really made me realize how impactful such a small change can be and this confirmed that I was on the right track. To let the user know what disk held what song, a text was placed on the disk that would display the name of the track. The disk was also changed from just being a flat cylinder to actually looking like a vinyl record, with a rim that would be assigned a random colour.

At this point, the disk would only hold one song, and while that's fine as a proof of concept, it would not be sufficient in a use case as the song would loop over and over, making it more annoying over time. This also happened while testing, so I needed to change this fast. Therefore, I made another type of disk that would hold playlists, which could be just like your Spotify playlists, holding music from all over, or just music albums. This was done using the same principle, the disk would hold the music and the player would read off it, only now the disk would remember what song index was being played. This worked really well, and at this point the text on the disk would display the playlist title and the player looked like a cube. This looked off and decided to make the disks and player a bit more realistic. So I edited the disk model and made a simple record player, so it was immediately clear what it's function was. I also edited the UV map in a way that one could give it a texture of an album cover and that it would be displayed in a similar fashion as on some real world records. This change also eliminated the need for text which again minimized the use of UI. A normal map was added to give the disk the same texture as a vinyl record. At this point, it felt even better to use and was visually more attractive. Then some racks were modelled to store the disks so they would be presented in an appealing fashion (fig.18).

This was the design record player for a while, until I wanted to re-implement the playback controls the UI version featured. To give more control to the user as some songs may not be the right one at a certain moment, or because the volume is simply too loud or too low. So first I looked at adding physical buttons to the player, but this would make the whole design overly complicated as I liked the simplicity of the current design. So I made a remote, which could skip songs, decrease and increase volume, and pause the playback. A simple model for the remote was made that mimicked the button placement that was used on the index controller. However, the lack of a need for a pause button became clear fast, as it would interfere with some of the programmed functionality, but also because one could simply remove the disk and playback would stop. Putting the disk back would start the song again from the start, which was a sacrifice I was willing to make. I once again tested the controls and it worked well, as I mapped the changing of songs to the touchpad which has scrolling functionality. Now you can easily scroll through the songs which feels rather satisfying to do. As feedback I added a light, similar to that of old tv remotes, that will light up when an input is made.



Figure 18: Vinyl display with the final selection of playlists and the final representation of the record player, currently displaying the current time as there's no disk being played

The next problem was, that you didn't know what song was being played and how far it was with playing. So I added a display that made use of a text UI element, that would display the name of the current song, as well as its index in the amount of songs on the disk. And a slider was used to act as a progress bar, which indicates the current position in the song.

At this point the record player felt done as it had all the features I wanted, but was also very customizable. Next, I made a selection of music, which were organized in their intensity. My idea behind this was that depending on the mood the user was in they could choose the right kind of music.



Figure 19: The record player is playing a playlist, with the remote on display

Then, after a discussion with my supervisor where we looked at ways to connect the music to the whole experience, I looked at having the music affect the wind that affected the environment. This was done with a function that would calculate the volume/intensity at that moment of the song being played, which was then passed through to a wind controller that would use these values to give different values to the intensity and turbulence of the wind. When trying this out, I felt inspired as it felt like the music was breathing life into this world which, I feel is a very interesting concept to explore further. This was later linked to all the particles within the experience, to give the sense that the whole world was connected. This is the current and final design of the vinyl record player. In a way it's a core part of the experience as it is connected to all of the other elements.

5.3.2 3D Pencil

The 3D pencil at the start was imagined as a tool to draw in the air or 3D model in 3D space (fig.20). It was made as a creative tool that required the user to move around to be used. This became the core part of the experience. The first iteration focused on the drawing aspect and this became the focus throughout the following iterations. The pencil relies on the Line renderer component within Unity, when the trigger is held, a line is created and takes the positions of a point at the tip of the pencil at regular intervals and assigns this to points on the line. This was tweaked heavily to

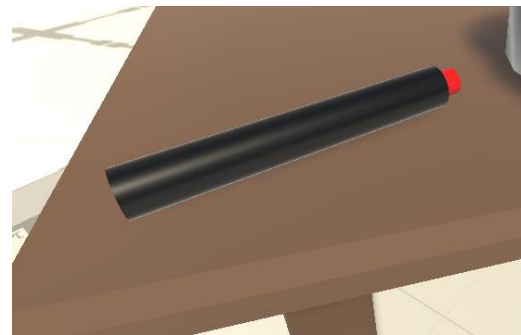


Figure 20: The 3D Pencil

ensure that lines would not feel awkward, but were smooth. For lesser hardware, an optimized functionality was made that would limit the points on each line and optimize the line after the line was finished. This was at first enabled by default, but it caused some gaps when drawing, so after tweaking some of the code, I was able to leave this off, but could be enabled if desired. At this moment, you could only draw in the colour red, or whatever colour had been assigned. It ran well and it felt okay, but it wasn't anything flashy or exciting to use.

I first wanted to address the issue of only having one colour, and my first thought was a UI that was bound to the hand where you could choose a colour. However, while making this interface, I came to the earlier mentioned realization where I was in the wrong design mindset, and going off my newly acquired inspiration of making physicalized interfaces, I changed direction. Instead, I decided that a paint can would be more fitting, this became the way to change pencil colour. By dipping the pencil into the paint, one could draw in a new colour. This already made the whole system feel more natural. To communicate the change, the new colour would also be applied to the pencil tip. At this point, I added more paint cans to the scene, each with different colours. This led me to come to the conclusion that it would be nice to be able to create your own paint colours within the experience, but this was put on the backlog as the experience of drawing needed more work.



Figure 21: The drawing station, with pencils and various colours available to use

In discussions with one of my supervisors, it became clear that drawing should feel like a party or like fireworks. This required the use of particles, which would spray off the pencil. For this, I added a particle system to the same point of the pencil that was used to get the location of the next point of the line that was being drawn. This would emit particles when moved over a distance and would only be active when actually drawing. This added something to the experience, but it still felt lacking, so I increased the number of particles, and gave them gravity, collisions and gave them the same colour as the currently used paint. This did help a lot, and it felt more like the fireworks mentioned earlier.



Figure 22: Particles being emitted while drawing

So now that the drawing experience was in a better state, I moved on adding more functionality, mainly error correction, as there was no way to get rid of lines. So I changed the way the lines were made and added them to a list that the pencil kept track of. By pressing a button the last added entry would be removed. I also wanted to add a way to change the pencil size. For this I thought scrolling or pressure would be appropriate, however in the first iteration, it was implemented on the A and B button of the Index controller. To visualize the size, I also scaled the tip of the pencil, which looked rather odd and required tweaking to line up with the actual size of the line. This worked great, and removed the need to spend a lot of time filling in some areas. Now I changed the control to scrolling and it felt a lot better than spamming a button to change the size. The earlier mentioned undo function got mapped to the B button. At this point I did find an issue with the way lines work, which is that they rotate with the camera. So from one

angle it would look great, but from another it would break especially with lines of different thickness. I tried out the other drawing method, of using the Z-transform but this would twist the lines and make it look worse. So fixing this was put on the backlog too.

At this point, the idea of being able to draw on a whiteboard or post-it was also made. This was put on the backlog however, as the main tool needed to be focused on more.

Next, I wanted to change the look of the size preview as in its current form it looked rather odd (fig.23). So I added a preview sphere where the line is being drawn, which becomes visible when picking up the pencil. As the line did not react to changes in line thickness while drawing, this functionality was disabled to prevent unintentional input while being engaged in the drawing process. This unintentional input happened a lot while testing and it felt frustrating. This preview would also receive the same colour as the one that was selected, and due to the preview being unlit, it would even have the same shade as the actual line.



Figure 23: The pencil has drawn a line and the preview is visible



Figure 24: A paint splat (left) and the eraser (right)

At this point, I was looking at adding more than one way objects interact with the world, so I went back to the paint cans. They were very one dimensional, as they were only used to change the colour of the pencil, but they could be picked up. So I added another way of painting, by tipping over the paint can the paint would spill out and cover a part of the floor (fig.24). This already made the paint can more fun to use. At first this included painting on walls, but due to issues with lining up rotations of surfaces, while still having a

random rotation as to not make the texture used seem too similar, this was limited to the floor. As a way to get rid of paint, an eraser was added. This also seemed like a good way to clear up lines, but the functionality of this would have been complex due to the lack of colliders on the lines. As unfortunate as this was, it felt like a nice way to get rid of the paint, and also required the user to actually go down on their knees and clean it up adding more movement opportunities.

Now that the pencil tool looked like it was mostly finished, I added some minor features to make the experience feel more complete. First was the redo function, an error correction feature in case a line was not to be deleted. For this I had to rework the line manager, as it also became clear that it was unintuitive to only be able to delete the lines of the currently held pencil (there were 3 pencils in the scene at this point). So I made a new script that would store a reference to all the lines that had been created and kept track of the last line that was “deleted”, which was

just made invisible to the user. When pressing redo, the line will be re added to the list of lines and be made visible again. For complexity's sake, I limited the redo's to 1 and due to the way it's handled a line can be redone after a new lines has been made, while that's unconventional there is no real issue in having it act this way.

Now that the tools features felt complete, I still wanted to improve the feeling, so haptics were added. The frequency scales with that of the line points being drawn. This made the drawing feel a lot nicer to use, but I figured it might be even better when linking the actual speed of the controller with the haptics. This was experimented with, but proved little results and was left on the drawing board. The paint cans were also given haptics, mostly as a bit of feedback to signal that it had spilled some paint.

At this point, the wind was linked to the music, and a way to link the music to the drawing was being looked at. To get this done in a fast and easy way, I made it so the particles can be influenced by the wind, thus the music has some influence on how the particles behave. This worked well enough without needing to make new complex algorithms.

This became the final design of the pencil tool. A few more things were looked at such as the earlier method of creating your own colours, but this wasn't able to be done due to time constraints.

5.3.3 2D Canvas

The 2D canvas was actually a mirror early on in development, and was supposed to let you see your own movement through the player's avatar, which got scrapped throughout development. Despite this, the mirror stayed for a long while, even when the environment got changed. However, as trees were added, this had a major performance impact on the experience, because of the mirror. This was found during an evaluation session, and I started to think about it throughout. While I was engaged with the experience, energized by music playing off the record player. I was drawing intensely, but angled towards the mirror. At that point, I realized, that I was subconsciously using the mirror as a painting canvas. And so I took off my headset, and changed the mirror into just that and continued, and I was blown away. As it seemed to work really well with this new function and as it had solved all the performance issues that were being experienced. At this point, I had a feeling I was getting closer to achieving the prototype's goal, but I was cautious due to a potential bias in opinion. This was expanded upon, by also showing the paint that was spilled on the floor from the paint cans.



Figure 25: Result from an auto ethnographic evaluation of the concept, which resulted in changing the mirror into a painting canvas.



Figure 26: Different angle showcasing the build-up of the 3D painting.

In another discussion with my supervisors, the issue of being bothered by the 3D paint was being discussed as it could become too much to look through. So near the end of the development, when I was making final changes, I added “3D paint glasses”. These glasses need to be placed on a display, to showing the paint in 3D. This gives the choice to the user, to either paint in 3D or paint in 2D but see it only in the traditional sense of 2D on the canvas. During a pilot test however, it was made clear that the appearance of glasses gave the wrong idea of how they functioned due to its affordances. A new idea was proposed, keeping the glasses but needing them to be worn by the user. This however, was too late to be implemented in the final design.



Figure 27: The 3D paint glasses on the display in the final version of the prototype

5.3.4 Interactable objects

In all the concepts objects were placed throughout the environment. At first, that's all they were, an object that could be picked up, thrown around and in some cases interacted with some toggled behaviour. A ball was added which was bouncy to play around with. While this was fine, it was rather one dimensional, but there was no clear idea to improve this. At first the physics were quite wrong, as objects would drop immediately and not receive any velocity at the moment of release. This was soon fixed, by changing what the SteamVR Throwable script does when items are picked up. In addition, you could no longer move items through walls or surfaces when held.

This made interactions more fun, but still items were one dimensional in their use. In a meeting, the idea of items spawning different items when breaking, came up. I quickly started implementing this and it did add some playfulness to the experience and gave a sense of what could appear next. This wasn't without its issues, however. It allowed for an interesting behaviour that would create a chain reaction, as more and more items would break and create infinite items. While funny, this required some more work to make sure that the program wouldn't crash due to running out of memory. Some fail safes were implemented that in its current state prevent it from creating similar scenarios. While the current interaction was fun, it needed some "juiciness". So particles were added that would spawn when an item would break, covering up the disappearing and appearing objects (fig.29). Furthermore, the velocity of the previous item was carried over to the new items, which made them feel more dynamic when they appeared. During evaluation, it became clear that this was a nice way to play around with objects and more items were added.

This feature was also added to the paint cans, and would result in 2 paint cans that had a random colour. However, this felt wrong, as the chance of getting the colour you wanted was small and after the paint spilling was added, this felt more like an annoyance than it was useful. So this feature was removed from the paint cans.



Figure 28: A collection of objects that can be picked up and interacted with.

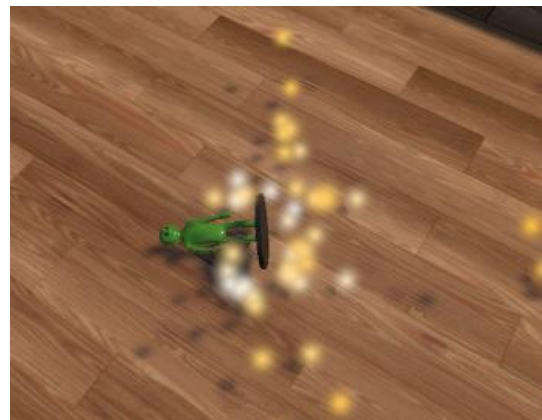


Figure 29: A new object is spawned and particles are emitted.

5.4 Summary of the Final Design

The final design contains the vinyl record player, which allows the user to play playlists off several pre-selected vinyl records. They can control the playback using the remote, by either increasing/decreasing the volume or changing songs by scrolling the controller's touchpad. The record player calculates the intensity of the part of the song that is currently playing, and gives these values to the wind manager, which in turn changes the wind strength and turbulence. The more intense the music, the harder the wind will blow. This wind also affects all the particles in the scene.

The 3D pencil, allows the user to draw in the air. While drawing the pencil will emit particles and give a haptic rumble, to add an extra dimension to the drawing. They can dip the pencils into paint cans to change the pencil's colour. These paint cans can also be used to spill paint on the floor, which can be removed using the eraser. The user can also redo and undo their work, while holding the pencil, and increase the line size.

The 2D Canvas, lets the user see their work in 2D on a regular canvas. This gives the user a choice how they want to draw their work. In case users want to only draw using the canvas, the 3D glasses can be used as a switch to disable the 3D paint view.

The interactable objects are scattered throughout the environment, and offer the user something to play with. They can throw balls, pickup and inspect objects and throw these to create new objects. All these objects make use of affordances to communicate their function to the player.

5.5 Technical Realization

In this section the architecture of the earlier mentioned features will be discussed without diving too much into the code behind it. Each system was designed to be as standalone as possible, however some features have become interlinked but can be easily separated. First the music will be covered, this includes the record player, ambience controller and the wind controller.

Then the drawing will be covered, which includes the drawing pencil, paint cans, eraser and the canvas. Then the objects will be discussed, followed by any other smaller technical features.

For a look at the code behind these functionalities, you can find it here:
<https://github.com/Z3PHR4X/MecaMind-XR-Graduation-Project>

5.5.1 Music Player

5.5.1.1 Vinyl Record Player

The *Vinyl Record Player* or *Music Player*, handles the processing and playback of the music and *Playlist Disks*.

Much like a real life record player, the music player does not hold any music. Instead, it reads the music off the *Playlist Disk* that is currently placed on top of it, or in coding terms that it *entered collision* with. Once a disk has come into contact, it is “mounted” into either the *M Disk* or *P Disk* slot, depending on what kind of disk it is. This is determined using the tag of the disk types. Once mounted the disk is told that it’s being played and the song at the current index is being loaded and played.

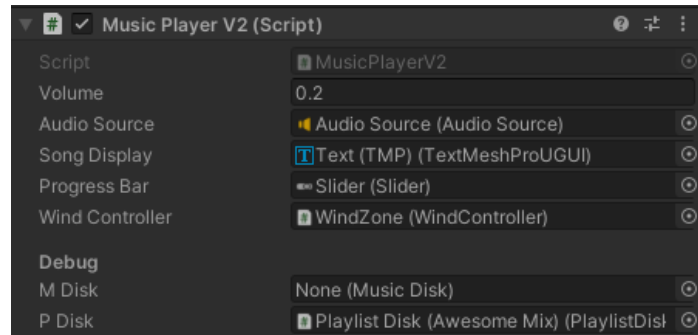


Figure 30: The Music Player script within the inspector with a playlist disk that is currently being played.

Please note that the *M disk* is still an artifact of earlier iterations and its inclusion only serves as a backwards compatibility to earlier iterations of the *Music Player* implementation.

The *Music Player* does not keep track of what index of the song that is currently being played. Instead it tells the *Playlist Disk* to increment it’s index, this allows the user to switch between disks and come back to where they left off.

As a track ends, the index on the disk is incremented and the function that loads and plays the song is called. When the index is outside of the track range, it gets reset to zero creating a loop. There are various other functions within the script that handle skipping songs and adjusting the playback volume these are accessed through the *Music Player Remote* (5.5.1.3).

To play the music, an audio source is used. This component only holds 1 audio file, which is why songs are loaded as they are being played.

While playing, the *Song Display* text element is also updated, to show the current index of the song and the amount of songs, as well as the name of the song that is being played. In addition, a slider UI element is used as a progress bar, which tells the user how far the song currently is based on the time that its playing and the total song length.

During this, the *Music Player* calculates the song volume/intensity using the audio data that is currently being played. This is then passed onto the *Wind Controller* (5.5.1.4), which will be covered later.

5.5.1.2 Playlist Disk

The *Playlist Disk* holds a list of audio files, which contain music, it also holds a playlist name and a cover image. Besides that it keeps track of whether the disk is playing and what current song index it is at.

The disk is designed to have an easy to use interface to let outside users create a *Playlist Disk* to their own preferences. Music can be dragged and dropped into the list and a cover can be imported from the original album or just a regular texture.

At start-up, the disk is renamed to show the name of the album which is useful for debugging. In addition, the material where the cover goes is given the cover texture as its diffuse element. This takes care of a part of the tedious work to setup a disk.

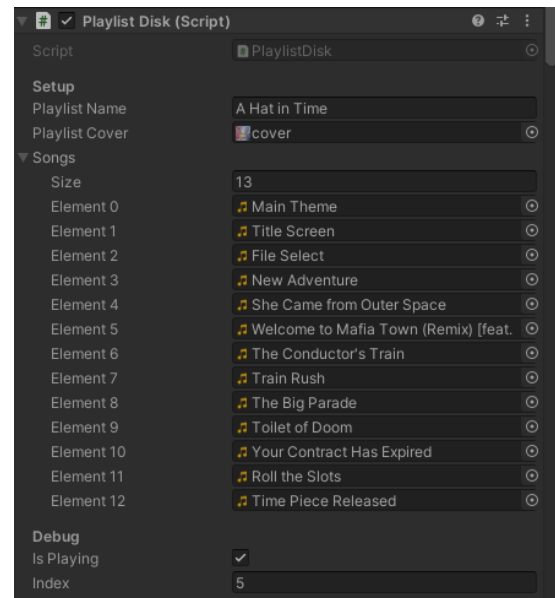


Figure 31: The *Playlist Disk* script within the inspector of a disk that is currently being played.

When a disk detects it its being played, it will play an animation that indicates the disk is playing.

5.5.1.3 Music Player Remote

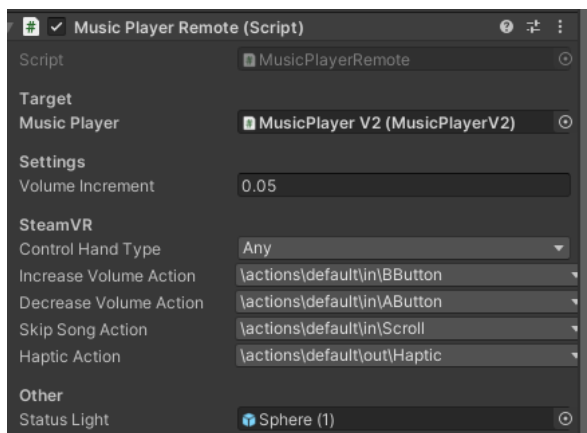


Figure 32: The *Music Player Remote* script in the inspector

The *Music Player Remote* allows the user to control the playback of the *Music Player*.

It holds a target, which is the *Music Player* that it's bound to. This allows the remote to control the playback from anywhere, unlike a real life remote. And the volume increment can be set to adjust the amount of fine tuning the user can do to the music volume.

There's a section that covers the SteamVR input settings. This can be used to change the button layout that is used by the script to detect the inputs from the controllers. Currently, the 'Control Hand Type' says Any, but once the object is picked up the script will determine what hand is holding the remote and will make sure the input is only measured from corresponding controller.

Currently, the A and B buttons of the Index Knuckle controllers are set to change the volume of the playback. The touch pad is set to a scroll, which lets the user scroll through the playlists songs in both directions. Finally, haptic feedback is provided to make the user feel their input as well. Any input is also reflected into the lighting up of the 'Status Light'.

5.5.1.4 Wind Controller

The *Wind Controller* controls the Wind zone, that applies wind physics to the environment: it rotates the wind and changes its intensity and turbulence. It has many settings that can be tweaked which affect the behaviour of the wind while playing the scene.

At random intervals the wind direction changes using a lerp function and random values that are listed under the 'Wind Direction' section of the script within the inspector (fig. 33). These are used to rotate the wind zone, so that it seems like the wind is changing direction.

Using the values passed through by the *Music Player*, the intensity and turbulence of the wind are calculated. These values are clamped between their respective minimum and maximum values set within the inspector under the 'Intensity Settings'. These values affect how hard the wind blows based on a lower or higher music volume/intensity. Currently, it is adjusted to feature little wind at lower volumes/intensities and large gusts of wind at higher volumes/intensities. By tweaking the values in the inspector this effect can be made so it becomes more subtle.



Figure 33: The Wind Controller script and Wind Zone in the inspector.

5.5.1.5 Ambience Controller

The *Ambience Controller* only keeps track whether music is currently being played. If so, it will lower its volume so that the focus is shifted to the music that is being played. When there's no music playing, it will slowly fade back in so that there's no eerie quietness, but instead let the user listen to the forest around them.

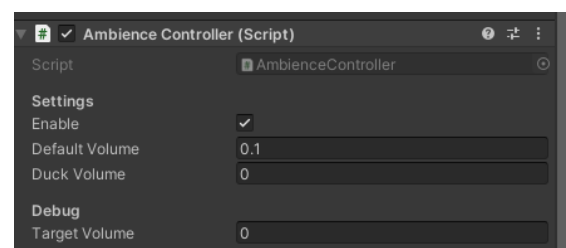


Figure 34: The Ambience Controller script within the inspector displaying a few settings.

5.5.2 Drawing

5.5.2.1 3D Pencil

The *3D pencil* consists of several parts, there is the main script that manages everything related to drawing and a smaller script on the pencil itself.

Each instance of the Drawing VR prefab contains a drawing pencil and manages its own line until the line is completed. After which it adds it to the *Line Manager* (5.5.2.2).

The script also looks for the controller input as defined in the *SteamVR* section in the inspector. When the trigger is held, a *line* is created that gets updated with new positions at a certain frequency (currently set to 60 as seen in fig.35). Once the trigger is released, the line is added to the *line manager* and detached from the pencil.

The line functions by having a list of points in the world in between which a line is made. By drawing more of these points get added and creates a line that follows your movements.

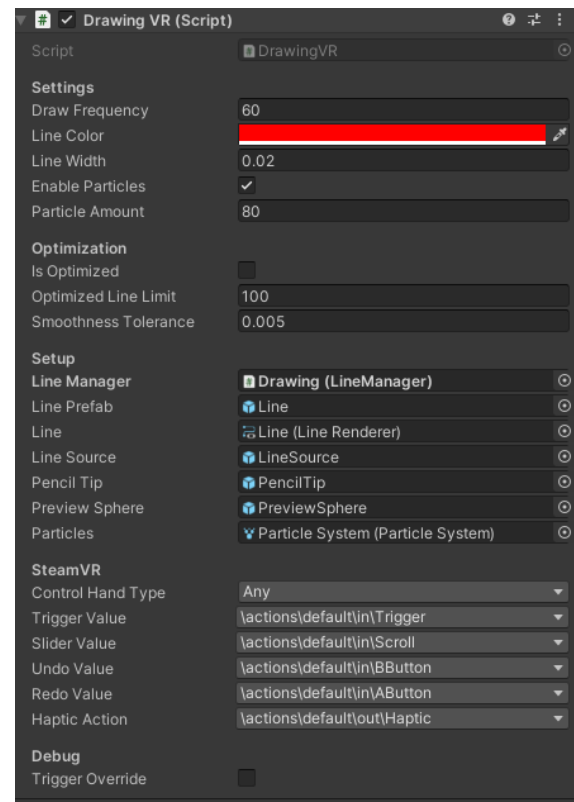


Figure 35: The main drawing script in the inspector

Due to the nature of the line component, changing colours and line thickness does not affect the current line, to counter this changing the pencils colour while drawing will detach the line and create a new one. To prevent the line preview to constantly change size due to the positioning of the hand while drawing, the resizing of the pencil cannot be performed while drawing.

The small script acts as a link between the pencil and the main script when interacting with other objects. It passes through the information when changing the pencils colour with a paint can and identifies what hand is holding the pencil and passes this through. The identification of the hand is done each time the pencil is picked up.

5.5.2.2 Line Manager

The line manager keeps track of all the lines within the scene. And stores 1 previously deleted line, which gets overridden when a new line is deleted. This allows the user to undo and redo lines from each pencil in the environment.

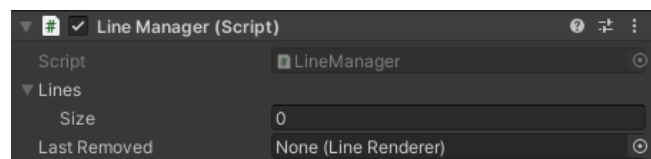


Figure 36: The Line Manager script in the inspector, showing the list that holds the lines and a slot for the redo function

5.5.2.3 Paint Can

The *paint can* or '*colour picker*' allows the user to change the colour of their pencil. It can be set to a specified colour or assign itself with a random colour when the scene is started.

Once the *pencil* collides with the can, minor haptic feedback is provided and the colour of the pencil is changed.

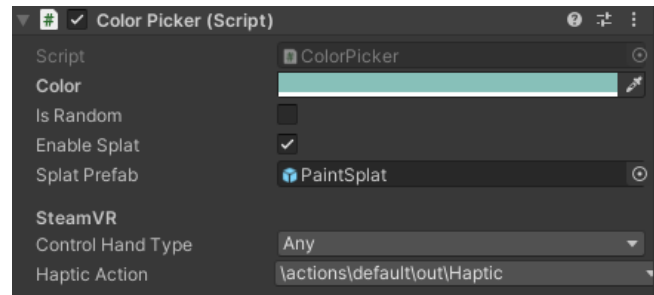


Figure 37: The Color Picker script in the inspector

It can also spawn paint splats (when enabled) when the user grabs the paint can and shakes it with the top facing the ground. This is done using a ray cast and checking whether the object is aligned with the top facing down and checking its velocity. The splat is a plane with a texture that is coloured depending on the colour of the paint can.

5.5.2.4 Eraser

The eraser has the sole task of erasing paint splats by looking whether they collide with an object with the tag 'Paint'.

5.5.2.5 2D Canvas

The 2D canvas is a plane with a material that uses a render texture as its diffuse and emission. The plane is scaled by -1 in the X-axis to mirror the image.

Behind the plane is a camera that can only see the layer of the Lines and the Paint splats. This lets the plane act as a painting canvas, while still allowing for 3D drawing.

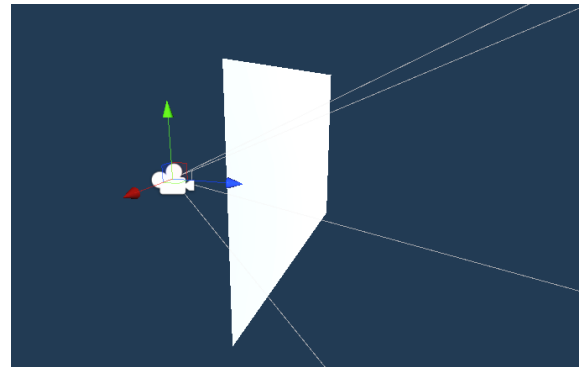


Figure 38: The setup of the 2D canvas, showing the position of the camera in relation to the plane

5.5.3 Objects

5.5.3.1 Object Behaviour

The Object Behaviour script's function is to determine whether an object has “broken” after impacting a surface. This is determined based on the magnitude of the objects velocity and the ‘break factor’ which determines the force required to break the object based on the objects mass.

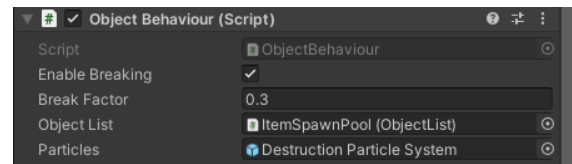


Figure 39: The Object Behaviour script as it appears in the inspector

When an object breaks, it spawns between one or three objects taken from an object list that holds a list of objects that can be spawned. When spawned the velocity of the original object is transferred. And particles are spawned. When an object breaks, it sends a broadcast to all objects tagged with “objects”, that disables the object behaviour for a short time. This prevents a chain reaction of objects spawning and keeps the program stable.

5.5.4 Scene Management

5.5.4.1 Start-up Device

The Start-up Device is basically a copy of the vinyl record player, but also loads the scene that needs to be loaded from the disk. Once a disk is playing and the information is loaded. It starts loading the specified scene and shows the progress on a progress bar (similar to the record player).

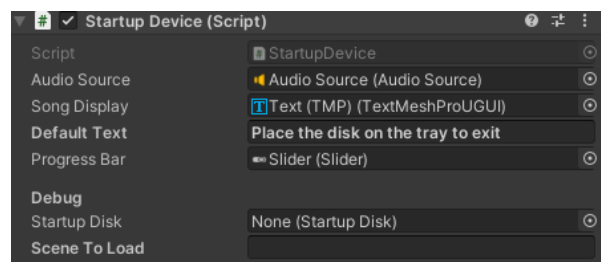


Figure 40: The Startup Device script as it appears in the inspector

5.5.4.2 Start-up Disk

The Start-up Disk is similar to a Playlist disk but only stores one song and holds a scene that it needs to load. Besides that it has the exact same behaviour as the other disk.

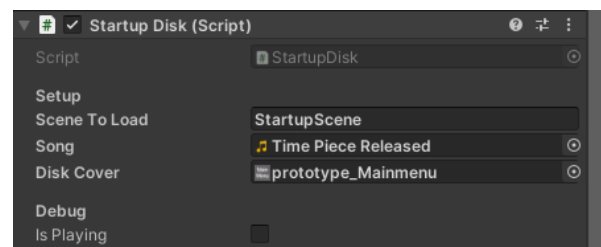


Figure 41: The Startup Disk script as it appears in the inspector

Chapter 6: Evaluation

This chapter will cover the final evaluation of the project which will be used to decide whether the current concept fulfils its goal. First, the design of the evaluation will be covered, after which the results will be discussed.

6.1 Evaluation Design

The goal of the final evaluation is to find out whether the current concept, in the form of the final prototype covered in Chapter 4, fulfils its goal to stimulate physical movement in a creative process. Mainly, how effective the incorporated elements of the themes are in getting the user to move within the virtual environment.

There are several research questions related to this evaluation:

Main: How well does the designed VR experience stimulate physical movement in a creative setting?

- 1. How does highly interactive environment aid with stimulating movement?*
- 2. How does music impact the movement of the user while within the virtual environment?*
- 3. What parts, if any, distracted from the overall experience of being physically engaged in the creative process?*

To achieve this, an all-or-nothing evaluation will be performed using the A-B prototype method. Prototype A will have users enter the full experience that has been designed. Within subject Prototype B, is a basic version with the same environment, but with all the advanced behaviours turned off. This mainly makes the drawing the most interesting part, but this time it won't have any particles. Each participant will start out with a random prototype, after which they will use the other one.

While participating in the evaluation, participants will be given several tasks to complete.

These tasks are:

- Explore the environment
- Find out which objects have what function
- Draw an object of the researchers choosing
- Draw something of your own choice

Meanwhile, the movement of the controllers and headset will be tracked using scripts created for this purpose. At regular intervals, these will log their movement distance into a log file. This information could help with determining the increase in movement between prototypes.

Acceleration of the controllers and headset were also supposed to be logged, but during the testing before the start evaluation, this code appeared to not work as intended. As such, acceleration was removed from the data that would be gathered to make sure the evaluation could proceed.

Once the user has completed the testing, they will be asked to fill in a questionnaire asking several questions about their experience. This questionnaire can be found in Appendix 1. This questionnaire also contains playtesting questions from the book 'Art of Game Design - A Book of Lenses' by J. Schell [43], to also get answers on the overall experience. Meanwhile, the questionnaire will be supplemented by a discussion with the aim of getting additional information and understanding of their experiences.

6.2 Results

The evaluation was conducted with a total of five participants, of which three started with prototype A (the full designed experience) and two started with prototype B (the basic experience) over a span of two days. In coming section the findings will be discussed (6.2.2), but first some notes will be made about the evaluation itself that came to light while it was being conducted (6.2.1).

6.2.1 Notes

After performing the pilot test, a few issues with the prototype were identified, mainly: throwing didn't work well; the player could appear on top of objects as the collider of the player would move with the head of the user; and grabbing required getting used to due to position of the point that determined whether an object was grabbable. The throwing issue was looked at and mostly fixed. The other issues were not able to be fixed in time for the evaluation, to still provide a working version ready for user testing.

During the second part of the evaluation, where participants tried the other prototype, task 1 and 2 were combined due to the duration of the evaluation being longer than initially expected and task 3 was skipped entirely. It must also be mentioned that at the point of switching the prototypes, it was observed that the motivation of some participants dropped. This could mean that the within subject test was not the right choice to evaluate the application.

After the first two evaluations and discussing the preliminary results with my supervisors, two more questions were added to the questionnaire that could improve the results of the test. These questions were: "Did you feel more creative?" and "How do you usually draw?" These questions give more insight in the effects of the application and as a comparison to see whether there's a behaviour shift in the way the participants draw while in the virtual environment.

6.2.2 Findings

Now the findings will be discussed, the results of the questionnaire will be looked at, supported by the observations made during the test. Then we will look at the movement data collected throughout the evaluation.

6.2.2.1 Questionnaire and observations

Overall, the designed experience was well received. People understood most of the elements in the experience, with a few pointers given in some occasions to aid the participant. Out of the 5 participants, 3 had to take a break due to experiencing mild nausea from motion sickness, because of the joystick controls. However, after a short break, they were able to continue the evaluation. It is clear that the implemented movement method, using joystick controls to move around, is not well suited for those new to virtual reality.

While within the virtual experience, I felt stimulated to be more physically active

5 responses

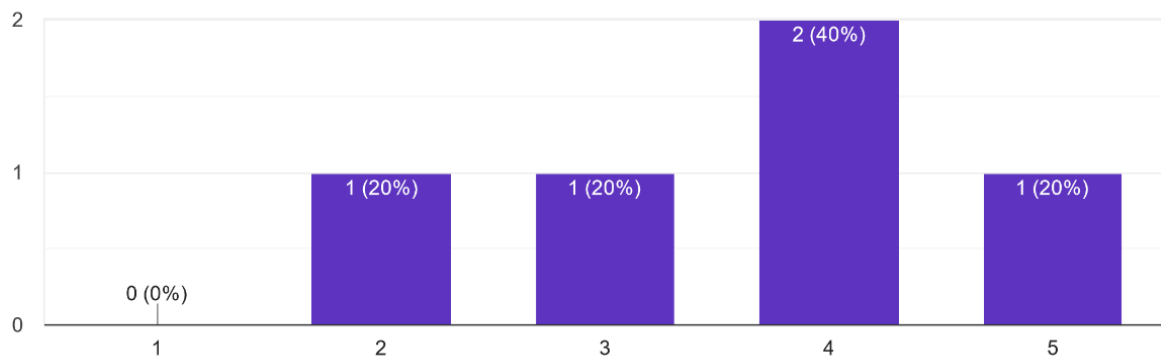


Figure 42: Results from the question regarding their experience of being physically active while within the application. Going from left to right Disagree – Slightly Disagree – Neutral – Slightly Agree - Agree.

From the questionnaire, we can see that on average the participants felt stimulated to be more physically active (see fig.42). One participant slightly disagreed and one was neutral with the statement. Three participants responded positively, two of which slightly agreed with the statement. From observations it was noticed that at first participants would make use of the joystick quite a lot, but later on would physically walk around to navigate the environment and to see their drawing from different angles. This change in behaviour could be explained by the fact that they are hesitant to walk around at the start, but get more comfortable later on. In one case, a participant would sit down and move using the joystick at the end of the evaluation, this was due to the motion sickness. One participant explained that they didn't want to bump into anything and thus mostly relied on the joystick to move. From observations, this participant mostly turned physically and used his upper body to reach around places.

While within the virtual experience, I felt engaged in the creative process

5 responses

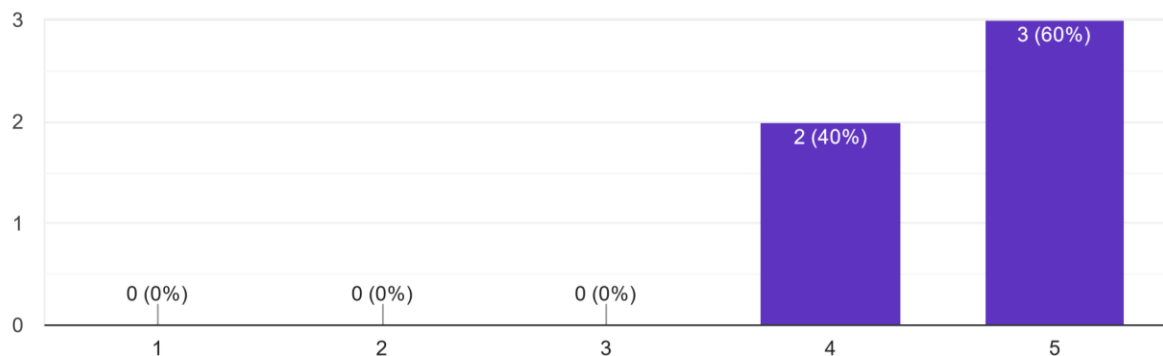


Figure 43: Results from the question regarding their experience of being engaged in the creative process while within the application. Going from left to right Disagree – Slightly Disagree – Neutral – Slightly Agree - Agree.

All participants felt engaged in the creative process (see fig.43), while they were in the virtual experience. Three participants responded with agreeing to the statement, while two slightly agreed. This is supported by observations, as participants would create interesting and detailed drawings. In addition, they made comments like “Oh I can draw in 3D”, “this changes the game” and “This is awesome”, while interacting with the drawing pencil.

From the interview that was performed alongside the questionnaire, it was gathered that the drawing pencil was very well received and was perhaps the most interesting aspect of the experience. It was also noted that the particles added to the pencil, made using it feel a lot better. There was also a wish of being able to draw while holding 2 pencils at once. Unfortunately, due to an issue with the SteamVR player controller, this was not possible. It was also discovered that the participants all drew very differently to one another: some would draw small dioramas with a lot of detail, while others would draw bigger outlines of something. At one point, a participant asked for a ladder so that they could continue their drawing.

I feel like prototype A stimulated me to be more physically active than prototype B

5 responses

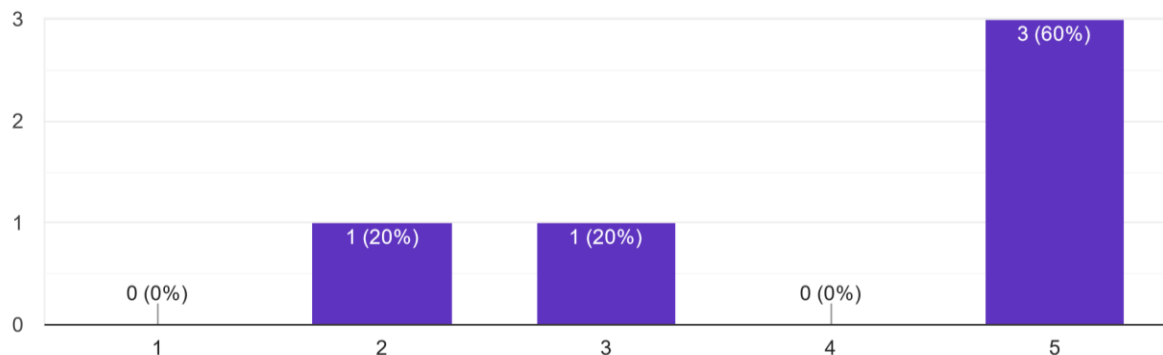


Figure 44: Results on the question whether they felt more physically stimulated by prototype A or B. Going from left to right Disagree – Slightly Disagree – Neutral – Slightly Agree - Agree.

A majority of the participants (see fig.44), three of them, felt more stimulated by prototype A (the full experience), than by prototype B (the basic experience). One felt neutral on the statement, and one slightly disagreed. Participants mentioned that objects in the scene added more stimulus to move around, and that the music helped a lot to get into the mood to move around. The most mentioned element that stimulated them was the 3D drawing.

However, while they did mention the effect of the objects, most participants played with the objects for a short while and then moved on. There was only one case where a participant played with the objects for several minutes, giving several responses such as *“That’s awesome!”* and *“This is pretty fun.”*

On the subject of music, a lot of participants mostly made use of disk featuring the “Awesome Mix”, which contains pop songs from the 60s and 70s. This could be due to their personal preferences, none mentioned anything in particular about the music selection. It should also be noted that most lowered the volume to make sure they could hear any hints or tasks, as the speakers on the VR headset suppress most sounds from the outside. Despite this, the music was a well-received part of the design. Some participants danced to the music, one even started singing. During the interview, an idea was proposed to a participant of having Spotify integration within the application, to which they responded negatively. Their reasoning for this was that they would then just put something on without thinking about it, but now they have a selection to try out or go back to, each with different feeling that can be used as a source of inspiration. This also happened to this participant in particular, who was inspired to draw a space ship while listening to the music well known to be featured in a science fiction comic book movie. Surprisingly, none of the participants noticed the effects of the music on the world, while the opposite was expected.

Elements that did not stimulate the participants that were mentioned in the questionnaire were objects that didn’t have much interaction, experience of nausea, moving with the joystick, the uncertainty of their position in the physical space, issues with the player hitbox and in one case all elements outside of the music. The latter is quite interesting, as that participant did move around a lot through the way he was drawing.

Elements that distracted from the experience that were mentioned were: mostly bugs and nausea, but also the chord of the headset, that paint cans could fall when changing the pencil colour and the fact that you could only hold one object due to the SteamVR bug. It was also mentioned that the music player remote, should have been integrated as an interface on the users wrist.

The most frustrating aspects of their experience engaging with the application were mostly related to bugs and motion sickness. One would have liked to have seen the position of the pencil on the canvas, being able to save their creations and changing the music. One mentioned visual fatigue from the headset. Other common mentions were having issues with grabbing objects related to the hitbox of the hand (mostly smaller objects), the physics not allowing them to throw objects as they expected. Lastly, concerning the pencil there was some

frustration with the way the lines are rendered (facing the camera) and that the pencil wouldn't snap to a natural position in the users hands.

Overall, their favourite moments of the experience was the drawing. One participant described it as very mind consuming and therapeutic, and also noted that because it is 3D you can easily express yourself without being able to draw well. The particles that emitted while drawing were also well liked. One participants favourite moment was throwing the basketball into orbit (by breaking the physics) and putting hats on everything (including their drawings).

When asked whether there was anything that they wanted to do but they couldn't was, there were several interesting responses. Most of these were related to the drawing aspect: being able to animate the drawings, mix colours, being able to copy and paste, move, selecting and grouping lines, and the ability to go higher. The ability to create outlines to define spaces was also mentioned, in the sense that you could plan out your drawing. Others were related to object interaction such as throwing with momentum and the ability to wear hats and the 3D glasses.

When asked what they would add, remove or change, participants responded with fixing bugs, being able to create animations of drawings, add more tools to the drawing feature set (selection, moving, grouping, duplicating), adding an inventory for items, being able to spawn in prefabs, a sketching tool, reducing the nausea, throwing and catching, having a colour that resembles a rainbow, being able to throw colours to recolour lines and items, making the birds in the environment more lifelike (giving them behaviours such as landing in the room) and the addition of more dynamic objects such as the basketball.

Most participants felt that they were drawing in the experience and saw that as the central part of the application.

Participants would generally describe the experience to their friends and family as being very fun and cool. There was also a mention of it being therapeutic. Another said that it's a lot more creative to draw in 3D than sitting in front of a screen and that it could be a great first step for big 3D projects. And again related to the motion sickness and nausea, that it's not for those with a weak stomach.

When the participants were asked whether they would use the application as a tool during the design process, three out of five answered with a clear yes. However, it became clear, that first the bugs and nausea needed to be fixed. Reasons for not using the application were that it needed more features for designing and it needing better depth perception for the drawing. In addition, many answered with situations they would use the application as a tool for, mainly brainstorming and explaining how something works or rough sketches. An interesting use that one participant mentioned was using it to create a rough sketch or wireframe to then export to a 3D modelling software like Blender or Maya. This outline could then be used as a reference to visualize how they could make a certain object out of a cube or sphere.

When asked whether they felt more creative while using the application all of the participants answered with a yes. Which fits with the result from one of the starting questions where all participants felt more or less engaged in the creative process.

Many of the responses within the questionnaire are in line with the observations that were made during the evaluation. Mentions of bugs and issues with picking up objects were known issues. And the issue of nausea came up before conducting the evaluation.

6.2.2.2 Movement Data

To verify whether participants actually moved more between the prototypes, their movement was tracked within the experience (as mentioned in section 6.1). As the second half of the evaluation was cut down in length, the distances will only be compared between each phase of the evaluation resulting in 2 figures containing the movement data for each phase. As there is one more participant that started with prototype A, results have been shown on a per participant basis.

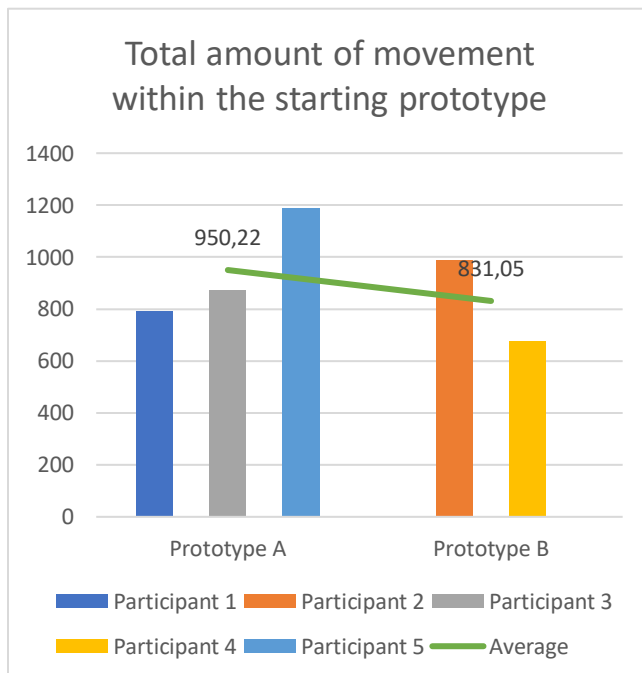


Figure 45: Diagram showing the movement during the first part of the evaluation for each participant.

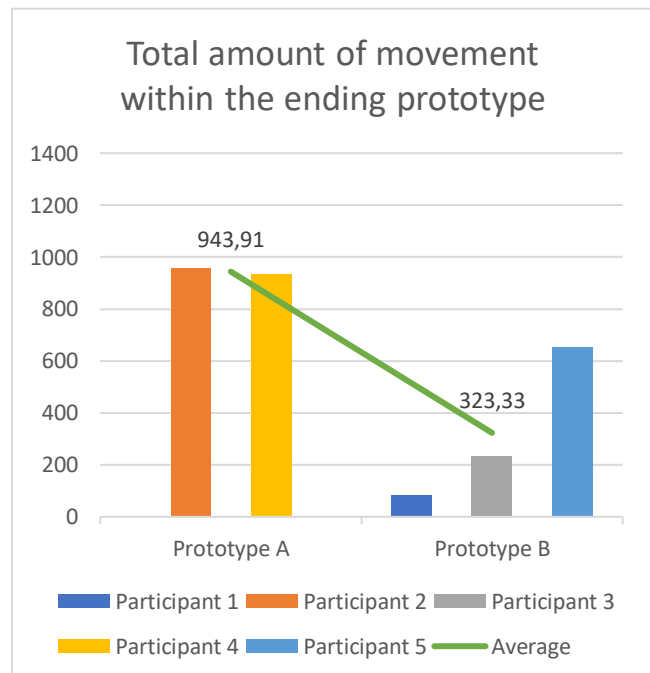


Figure 46: Diagram showing the movement during the second part of the evaluation for each participant.

As seen in the figure 45, there is a slight difference in the amount of movement in the starting phase between prototype A and B. This is also shown in the average which is higher for prototype A. In figure 46 the amount of movement for the second phase is shown and now there is a clear difference between the two prototypes, with the average amount of movement being higher for prototype A. What's more, the average movement in prototype A is very similar while starting and ending in this prototype. This could indicate that there's indeed a stimulating element within this prototype.

This drop in movement when switching from prototype A to prototype B, could be because of a drop of motivation as mentioned before, or because of the vast difference in interactivity with the environment. In contrast, participants moving from prototype B to A, have moved a more similar amount within both prototypes. However, the average movement is higher for prototype A in this case. Interestingly, each participants movement between prototypes seems to have a similar relation in their ordering of how much they moved compared to the other participants.

6.2.3 Summary

Overall, the evaluated design was well received, participants felt engaged in the creative process and a slight majority felt stimulated to be physically active. From the gathered movement data and results from the questionnaire, it can be said that there are signs of an increase in movement in prototype A, featuring all of the designed elements as covered in Chapter 5. However, it is unsure whether this is due to the nature of prototype A or due to the way the evaluation was set up and conducted. This will be more heavily discussed in the following chapter (Chapter 7).

Parts that were well liked were the 3D pencil and the music. Bugs and nausea were the biggest distracting and frustrating factors. Participants wanted to see an expansion of the drawing tools, more dynamic objects. Participants said the experience was fun and made them feel creative, one even called it therapeutic. A slight majority (3 out of 5) said they would use it as a tool during the design process, mostly during brainstorming, explaining concepts or as an aid for use with 3D modelling.

The complete results of the questionnaire can be found in Appendix 2.

Chapter 7: Discussion

In this chapter we will discuss what has been done within this project, and examine what could have been done better or differently. To achieve this the results and observations from Chapter 6.2 will be used.

Within this project, a VR experience has been designed and created through tinkering and an auto ethnographic approach (Chapter 5) using the themes identified in Chapter 4. Throughout this tinkering process, the design evolved from a simple environment with UIs to a more detailed environment with many interactable objects that have many different functionalities. The resulting design and prototype was then evaluated using an A-B everything or nothing method with within-subject testing (Chapter 6.1), the results of which have been processed and discussed in the previous chapter (Chapter 6.2).

As discussed in Chapter 6.2, it was observed that many participants had a drop in motivation when they hit the second part of the evaluation where they switched between prototypes. As evident from the movement data gathered, there is a major difference between moving from prototype A to B, to moving from prototype B to A. This is assumed to be due to the vast difference in interactivity with the environment, as the environment in prototype A could be considered to be more interesting. Using this knowledge, it could be said that within-subject testing may not have been the right method to evaluate the difference between these prototypes. This could be due to the beforementioned drop in motivation, the difference in interactivity or a learning effect that prevented participants to be curious about their surroundings. However, from the observed experiences of participants and answers of questionnaire, it has been shown that participants had more enjoyment interacting within prototype A. This could indicate that while the testing method was perhaps flawed, there are signs that prototype A could have the intended effect of engaging users both physically and mentally.

Perhaps, a better testing method could still be A-B everything or nothing, but instead of within-subject testing, the between-subject testing method could be performed. This would mean that there are still two prototypes, like before, but now each participant only experiences the one prototype they are assigned to at the start. In addition, this would also require the questionnaire to be re-evaluated and changed, as currently it relies on participants having experienced both prototypes.

Many of the elements that distracted the participants from the experience or that caused frustration were due to bugs or things that needed to be fine-tuned. Many of these issues were known beforehand, these could have been given a higher priority to be fixed to perhaps get a better result. Or rather, have the most glaring issues looked at and adjusted. However, at the time the biggest priority was to have a working version and to prepare the evaluation.

Nausea was the biggest problem with the experience. The problem of motion sickness was not anticipated until just before the evaluation. The reason for this is that the experience was designed, made and evaluated from the perspective of someone who is used to the effects of

virtual reality. This caused features such as teleportation movement to be put on the backlog. Now that the perspective has changed using this newly found knowledge and realization, in hindsight the implementation of teleportation should have gotten a higher priority. Not only because many of the participants suffered from nausea during the evaluation, but also because many end users may not be as experienced with virtual reality or might be more sensitive to motion sickness. It is clear now that the first thing that should be done is to fix the elements or give alternatives for existing implementations that cause these strong feelings of motion sickness and nausea.

Expanding on this, with the current movement method (using the joystick to move around), it was observed that many participants stood still. While this behaviour changed as the session went on, it is not known whether this was due to their experience of motion sickness or becoming more comfortable with the idea of physically navigating the space. Perhaps, this behaviour will change with the introduction of teleportation, however, the effects of this need to be researched. It could also be that the space in which the evaluation was conducted, felt too small to the participants and made them feel cautious to move around. Only having walking would be the best movement method to minimize nausea and to increase movement. This however, would either require a big open space that might be unrealistic to achieve for many end users. Another option would be to redesign the environment in such a way that it would adjust itself based on the size of the user's calibrated play space. The latter would be the most realistic approach, but requires more research and needs to be evaluated based on whether the virtual environment might not become too small. To support this concern, when asked if the scale of the environment felt right, a participant responded that the current scale was fine and felt big which allowed for more space to freely draw and play.

Lastly, an element that was overlooked was the way people draw. During the first two evaluations, it was observed that both participants drew very differently. This meant that instead of making big strokes while drawing as experienced during the tinkering process, some participants would draw small but detailed dioramas. This meant that the movement between participants would be harder to compare. Looking at the gathered movement data, this difference in behaviour of the participants is still visibly present within figures 35 and 36. But as discussed before, it cannot be clearly compared due to the vastly different results for those moving from prototype A to B due to the various factors that have already been discussed.

Chapter 8: Conclusion

In this chapter a conclusion will be made whether the resulting design presented in Chapter 5, has been successful in achieving its intended goal, following the results of the evaluation from Chapter 6, and the discussion from Chapter 7.

The goal of this project was to create a virtual reality experience that would stimulate physical movement within the design process. Following the results from the evaluation (chapter 6) and the discussion (Chapter 7), there are indications of increased movement while using the application. However, it is uncertain whether the special features from prototype A increased movement. As discussed in Chapter 7, this uncertainty is due to the possibility that the testing method was flawed, as there is a big difference between the movement that was measured when moving from prototype A to B. This difference was more so than for those moving from prototype B to A. Whether this is due to the within-subject testing method's learning effects, a genuine difference in movement because of interactivity, or a drop in motivation due to the length of the evaluation is unclear. However, there are slight signs from comparing both prototypes during the starting phase that there is an improvement in the amount of movement that was performed within prototype A compared to B. In addition, participants responses were positive and mostly in favour of prototype A when asked which prototype stimulated them to move more.

However, it is clear that aspects of virtual reality can promote creativity as is supported by the comments of being able to draw in 3D and the feeling of playfulness it invoked in the participants. Nonetheless, other aspects such as motion sickness need to be heavily considered while designing such an experience. Out of the themes that were identified during ideation (Chapter 4), it is clear that music did have an impact based on what was discussed in the interview and what was observed.

So, to answer the question *“How does a VR experience that stimulates physical movement in a creative environment, aid with the design process?”* Clearly, there are benefits to using virtual reality to get people to move while they are participating in the design process. Moreover, VR can open new pathways to do things, such as drawing and sketching visualizations, that cannot be done in the current traditional design setting. VR based design tools can make the process of quickly making or getting a feel of something, easier and less tiresome than doing it while sitting behind a computer. It is currently unclear whether the VR experience designed for this project is the answer to getting designers to become more comfortable with moving more or gets them to move more during the design process. Even though, the results of prototype A showed increased movement from the user while designing, further research in this subject is needed to conclude whether users would actually move more while designing with this, or any, VR experience. However, it can be stated that when improved, the designed VR experience could have a stimulating effect on brainstorming, explaining concepts, and even the planning out and creation of wireframes for use during 3D-modelling.

Chapter 9: Future Work

This chapter will focus on what things should be focused on in the future and recommendations for other researchers who are looking for things to explore in their own work.

For this project, were it to be continued and improved upon, the first priority should be minimizing the motion sickness as much as possible. The nausea participants experienced forced them to take breaks and distracted them from the creative process. Ways to improve this would be adding teleportation as an optional movement method, lowering the field of vision by applying a vignette effect when moving with the joystick and adding a fading animation when snap turning. These are common ways that VR games use to lower the perceived motion sickness.

In addition to this, the biggest bugs should be fixed as they were disorientating and frustrating. The grabbing issues were related to the object detecting point used to grab objects. This issue can be fixed by tweaking the placement of this point or increasing its detection range. Furthermore, an issue exists where the user can only hold and use one item. While it's technically possible to hold 2 objects, an issue causes the left hand to appear dominant over the right hand, meaning that only the left hand handles inputs and the right hand doesn't respond. To fix the disorientation problems, a closer look needs to be taken to the player VR controller used within the project. As in the current version, the player collider moves with the headset. This causes an issue where the player moves on top of a table when leaning over it, or being able to stand on top of other objects.

There's more that could be done besides fixing bugs and improving the user experience. More dynamic objects could be added, as these are a clever way to give more reasons for the user to move around. In addition, these could perhaps be more interesting than the static objects that make up most of the objects in the current design. A suggestion that was made was a ping pong table, which built upon the bouncy basketball found within the current prototype. Perhaps, adding ways to play with the physics, allowing for creating of contraptions like a Rube Goldberg machine. This builds upon the idea of objects having multiple uses, but also lets users be creative and create something new out of objects within the scene.

Another suggestion would be adding more tools, such as an inventory that allows keeping certain objects on your virtual body, or a way to spawn in objects, but also expand upon existing tools and add to their functionalities.

Currently, it is unclear whether all the elements (music, interactable objects etc.) that were implemented actually contributed to an increase of movement. There's a strong recommendation on exploring these elements further and evaluating how much these elements impact physical movement, as to get a better understanding of how movement can be encouraged.

Lastly, there is a strong recommendation to carry out a new user test, this time using the between subject method. This should get remove the learning effect and motivation drop that was observed during the evaluation that was carried out. In turn, the results will be more reliable and show a better representation of use cases and movement between the different prototypes. To build upon this, finding a better way of neatly logging the movement would be advised, as currently the log was also filled with errors from SteamVR. Most ideal would be creating a CSV at runtime so that it can be easily imported and analysed with analytics and statistics software. Moreover, adding more trackers to the user could improve the quality of the data and the claims that can be made, but could also affect the users comfortableness and hinder movement.

For other projects, there are several things that have potential and are interesting to look further into. One such topic is the combination of drawing and music. While this has been explored within this project, there is a potential for a better design that combines these elements and makes them work in tandem. There are clear signs that music helps loosen up, can inspire and help focus on the task at hand. This relation of drawing and music could be a very interesting topic to look further into in future projects.

Another interesting topic to look into would be the effect of types of music on movement. It was shortly discussed that music can ease people up to the idea of moving, and in the evaluation it was observed that people started dancing and moved more. From the auto ethnographic study in Chapter 4 it was said that high intensity music gets people to move more. However, this was based on personal experiences and hasn't been proven through research, which makes it an interesting topic to research.

During the evaluation it was observed that every participant drew differently to one another. It could be insightful to see how these different drawing methods can be stimulated to allow for more movement.

Finally, while not being so much of a topic to research. There is a strong recommendation to evaluate the impact of any features or design decisions that are made on the perceived feeling of motion sickness and nausea within a virtual reality application. Unfortunately, within this project this was underestimated due to a difference in familiarity and resistance to these feelings, which in turn caused design decisions to be made that negatively impacted the user experience for those new to VR or who easily experience motion sickness. It is therefore advised to regularly evaluate the current state of a VR project in this regard.

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Appendices

Appendix 1: Evaluation Questionnaire

Section 1 of 3

Questionnaire Evaluation MecaMind XR

Form description

Which prototype did you start with?

Multiple choice

☐ Prototype A

☐ Prototype B

☐ Add option or [add "Other"](#)

Required

While within the virtual experience, I felt stimulated to be more physically active *

Disagree

1

2

3

4

5

Agree

While within the virtual experience, I felt engaged in the creative process *

Disagree

1

2

3

4

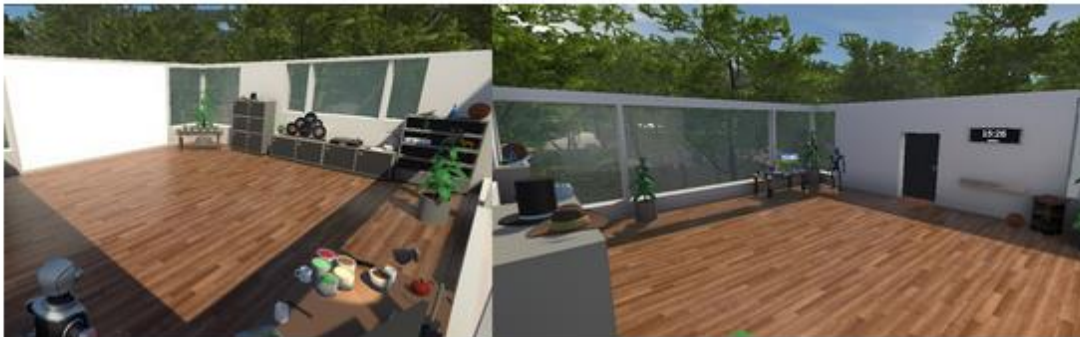
5

Agree

The two prototypes

This section talks about Prototype A and Prototype B. Prototype A is the full experience: Music, particles, object interactivity etc. Prototype B is a basic version, leaving in only the drawing tools and basic objects.

Visual aid of the main prototype



I feel like prototype A stimulated me to be more physically active than prototype B *

	1	2	3	4	5	
Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Agree

Which elements did stimulate you? *

Long answer text

And which elements did not stimulate you? *

Long answer text

Which elements did you find distracting from the experience? *

Long answer text

Your experience



Description (optional)

What was the most frustrating moment or aspect of what you just played? *

Long answer text

What was your favourite moment or aspect of what you just played? *

Long answer text

Was there anything you wanted to do that you couldn't? *

Long answer text

If you had a magic wand to wave, and you could change, add or remove anything from the experience, what would it be? *

Long answer text

What were you doing in the experience? *

Long answer text

How would you describe this experience to your friends and family? *

Long answer text

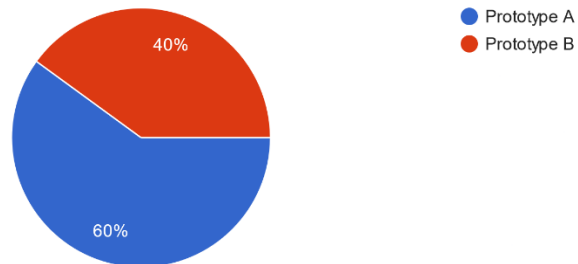
Would you use this application as a tool during the design process? *

Long answer text

Appendix 2: Questionnaire results

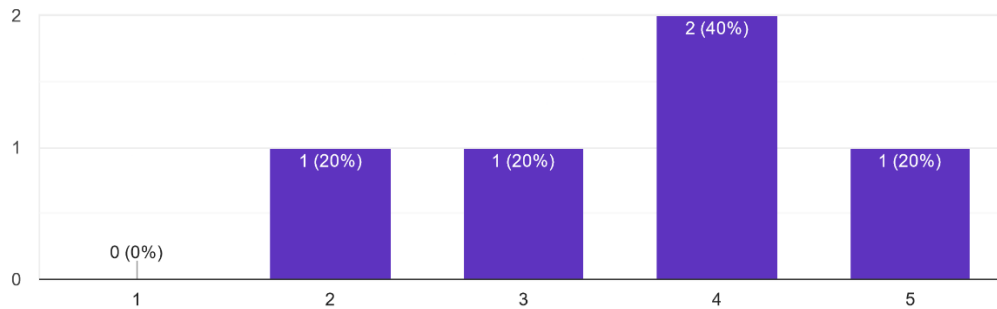
Which prototype did you start with?

5 responses



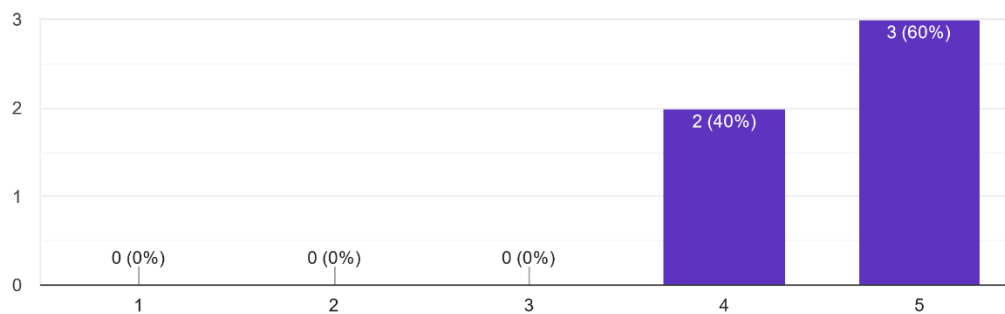
While within the virtual experience, I felt stimulated to be more physically active

5 responses

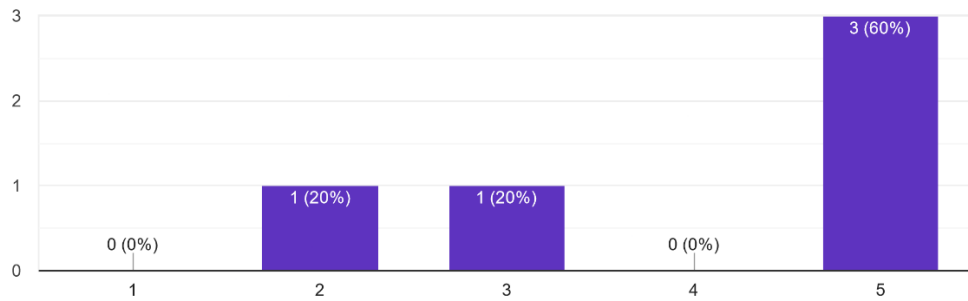


While within the virtual experience, I felt engaged in the creative process

5 responses



I feel like prototype A stimulated me to be more physically active than prototype B
5 responses



Which elements did stimulate you?
5 responses

- Music
- Basketball and 3d painting
- seeing drawings in 3D and picking stuff up, also music
- Drawing, looking at fun objects
- Breaking objects

And which elements did not stimulate you?
5 responses

- all other elements.
- VR makes you feel unsure where you are in physical. Moving your headset moves the hitbox of the player giving weird effects.
- nausea
- Non-interactable objects, for example the laptop
- Having to move around with the joystick

Which elements did you find distracting from the experience?
5 responses

- nothing, the remote combined with the one hand limit was annoying
- Vr headset chord. Paint cans falling
- nausea
- Bugs
- Motion Sickness

What was the most frustrating moment or aspect of what you just played?

5 responses

changing the music, not being able to save the creations, 2d drawing without courser

Grabbing small objects, the paint brush mostly as it never goes into a natural position. Accidentally pressing the joystick. Rendering of lines from the paint brush

nausea, visual fatigue, objects hard to pick up, throwing was hard

Bugs

Motion Sickness

Hitbox was a bit iffy sometimes so objects were sometimes annoying to pick up

Physics (I couldn't throw stuff up in the air)

What was your favourite moment or aspect of what you just played?

5 responses

drawing in 3d,

Yeeting the basketbal into orbit. Putting hats on everything

3D drawing

The drawing is very mind-consuming and therapeutic. Because it's in 3d, you can more easily express yourself without being able to draw well.

The sparkling particles when you drew stuff

Was there anything you wanted to do that you couldn't?

5 responses

go higher, draw outlines define spaces, copy and paste, move, selecting, grouping lines

Put a hat on. Throw stuff with momentum

throwing, sense depth(for drawing, but also made me move more)

Animate the drawings

Mix the colors

If you had a magic wand to wave, and you could change, add or remove anything from the experience, what would it be?

5 responses

add the above, add an inventory, prefabs, sketching tool

More moving objects like the basketball.

reduce nausea, throwing and catching, rainbow color, throwing color

Fix the interaction bugs, make a way to animate the drawings

Make the birds more lifelike. Would have been super cool if one of the birds from the environment outside landed in the room

What were you doing in the experience?

5 responses

drawing a transformer, a ladder and a spaceship

Making weird art mostly. trying out if everything did something and if i could break it.

mostly drawing

Mostly drawing, a lot of walking around and grabbing random objects

Breaking a lot of objects and trying to make an army of dabbing golden statues

How would you describe this experience to your friends and family?

5 responses

cool drawing in 3d makes more creative instead of sitting in front of a screen, can be a great first step for big 3d projects

Fun creative room to interact with (poggers)

very fun and something they should try

Therapeutic

A lot of fun, but not for the ones with a weak stomach.

Would you use this application as a tool during the design process?

5 responses

maybe without the nausea, and with more functionalities in specific scenarios, like designing 3d models for games or for some 3d projects like model planes/ the hydrogen car of the UT

Needs more features for designing but overall pretty fun and creative

no, but if depth sensing for drawing was better I would try it. I would use for brainstorming, explaining, making rough sketches

In explaining and brainstorming yes, though not for drawing up formal designs, due to the lack of precision

I guess yes, if you could add some tools that would draw straight lines. It's a bit hard to draw in 3D. Brainstorming. Explaining how a product works. For an exploded view.

Did you feel more creative while using the application?

3 responses

Yes. It looks playful and stimulating

yes for sure

Yeah. Especially after I got the hang of it.

How do you usually draw? (this refers to your drawing outside of the virtual experience)

3 responses

First big movements and shapes and then smaller details and refinement

mostly on paper with pencil, both doodles and sketches, also paintings

Repetitive strikes to get the countour of the thing that I'm drawing and then I add in the details.