

VR Exhibitions: Enhancing the Feeling of Immersion through Interactive Virtual Reality in Art

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Abstract

This thesis explores the impact of virtual reality (VR) in enhancing the feeling of immersion attributed to art exhibitions. The increased use of VR technologies in various fields has opened new possibilities of interaction within the art world. By studying the possibilities of the technology, and leveraging its capabilities, this research will explore how VR can be used in artistic contexts to create more immersive experiences between the audience, artist, and artworks. It will parallelly explore the marginalization of artists of color in the context of the Dutch artistic community because of the country's colonial history, and how VR can help to give voice to marginalized artists.

A VR museum exhibition was design and implemented alongside the Surinamese artist Remy Jungerman. A number of Remy's artworks are showcased in a virtual exhibition, allowing visitors to experience them in a completely different way.

To evaluate the effectiveness of the built system, a mixed-method evaluation is conducted, where both quantitative and qualitative data is collected and analyzed for several participants. After their interactions, participants respond to an immersion questionnaire which is used to assign an immersion score for their experience.

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Table of Abbreviations

VR	Virtual reality
VE	Virtual experience
HMD	Head-mounted display
RQ	Research question
3D	Three-dimensional
HMI	Human media interaction
PC	Personal computer
FPS	Frames per second

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1. Introduction

Art is one of the fundamental building blocks of human expressiveness. Carrying diverse shapes and forms for thousands of years, art has continuously evolved into what us humans categorize it as today. Art itself can be interpreted simply, but boundaries within the artistic world are mellow, and obscured by a constant change in perspectives. There is not one definition of what art is, but every individual has their own.

Despite art's pervasiveness, it is not so evident the types of functions that certain art pieces serve. Artistic functions are usually categorized into 3 layers, namely physical, social, and personal [1]. These categories help shape the way in which us viewers understand and interpret art, but also the process of creation of art. The three *functional layers* of art are not fixed, and there are different interpretations within this thought. In other terms, art can also be regarded as a multifunctional and multifaceted construct.

Societies and cultures have created art continuously, and as it may seem that art many times is simply a process of human expression, it is also an outcome of culture, then becoming the expression of societies, not individuals. This cultural expression of art can take different forms, ranging from visual arts, to music, to performing arts and folktales [2], and that is what defines the visible changes in culture around the world. Distinct cultures have passed through series of events, changes and epochs that have drastically changed the means by which societies have expressed themselves as a whole, resulting in unique art works that helped shape time periods. The extent to which different art works have emerged is largely a cause of contextual factors, resulting in the use of art as an instrument of resistance [3].

Art then becomes something more than a mere physical object of pure entertainment. It becomes a representation of suffering, challenges, power, protest, and so many others. This project addresses the marginalization in the art world, by exploring the lack of polyvocality in Dutch museums, which for many years has represented a small minority of the artists, institutions, and individuals in power, allowing for a narrow perspective of the Dutch colonial history. The common point of view comes from the people in power themselves, which have marginalized artists that previously did not fit in the agenda of the individuals sitting on the golden throne. The lack of attention and representation of different perspectives of Dutch history is evident, and Cecilia Uitermark reinforces that "this continues to this day, yet nothing has been written about these trajectories, demonstrating the lack of attention for Indigenous perspectives in the Dutch context" [4].

However, validating such artists, which have been suppressed continuously is powerful and needed, as more voices, which have often not been heard throughout the Dutch history, will be given the chance to express their perspective of history. What people fail to understand, is that the perspective of marginalized artists is not alien, it is part of history, but unfortunately it has been stripped out of the public's eyes.

The step of validating artists is not straightforward, as there is not one way to do it. However, I argue that Virtual Reality (VR) can be used to give voice to artists while allowing them to present their stories and narratives. By combining the potential applications of VR with the powerful meanings behind artists and their artworks, a system that tackles the issue addressed above can be developed.

To better understand the impact of constructing more polyvocal artistic communities, this research aims at investigating the extent to which an artist can provoke certain feelings and emotions on their audience by conveying their narrative effectively using immersive VR technologies. For this, a main research question (RQ) was formulated: ***How can immersive Virtual Reality increase the feelings of immersion attributed to a piece of art?***

In addition to the main research questions, four sub-questions will also guide the project:

How can immersive VR enhance the feelings and emotions that visitors attribute to a piece of art?

How can a virtual setting amplify the user's perception of art?

How can immersive VR allow interactions between visitors and art works?

How can a non-tangible space of art contribute to an artist's expression?

To address and combat the aforementioned issues and consequently answer the research questions, VR art exhibition was developed alongside the Surinamese artist, Remy Jungerman. The structure of the environment is 3D modelled, including a museum-like space, art sculptures, and appropriate details. The user experience will be enhanced through the application of VR, which will allow for unique interactions within the virtual environment.

This will be done by developing a solution which allows both the artist to display their work in a virtual setting where the physical constraints of museums do not pose any hindrances, and simultaneously allow the artist to express their own stories, perspectives, and opinions.

There are different ways that a visitor can experience and observe art, one where the visitor is presented with an artist's context, their works, and sometimes their message or goals, and another where the visitor first experiences and observes art pieces and then is presented with the artist's background and context. These two ways can drastically change the visitor's perception of the art, since in the first scenario, the visitor can expect something from the art because of the artist's interpretation of it, however, in the second case, the visitor's perception will proceed the artist's explanation or context. This research project will explore the second case, where the visitor will dive directly into Remy's art works without prior knowledge on what they represent, how they are made, and their underlying messages.

Because this project is and should be creative and "open", there is a substantial amount of room for discovery and implementation. The use of VR is not something novel, but the possibilities within the virtual worlds visited within VR is something completely malleable and worthy of exploration. By working closely with an artist, I will be able to explore their own visions, needs and points of view, while applying my own skills and knowledge. I will create a unique and interesting experience, with the help of 3D modelling tools and a social VR platform. The opportunities to explore ideas and interactions not possible in "real" life are possible through the implementation of immersive virtual reality.

This paper is structured into 9 chapters, excluding the References and Appendices, each covering a different aspect of the subject. In chapter 2, the *background research, related works, and state of the art* presents the reader with key technical terms and additional information in how the related works investigated similar research questions and challenges and what has been done in the area of VR and art. Chapter 3 encapsulates the *Design Method* followed during this research, the *Creative Technology Design Method* and the rationale behind this decision. Chapter 4 describes the Ideation process, which includes the chosen concept as well as the preliminary system design where a preliminary set of underdefined requirements of the system are explained following the MoSCoW Prioritization approach. Chapter 5 deals with the Specification phase, where the technical intricacies of the system are explained and described in detail prior to the building of the system. Chapter 6 covers this project's Realization phase, where I describe in detail how the planned idea presented in the Specification is worked out in an attainable way within the scope of this research. A more technical and detailed overview of tools, both software and hardware are presented. Chapter 7

covers this project's Evaluation Phase, where I describe the goals of this project's evaluation, the recruitment process of participants, the evaluation methods, and the results of the evaluation. Chapter 8 presents a discussion based on the results of the evaluation, including the result's strong points, areas of improvements and limitations, and how the results are effective in answering the RQs. After that, I dive into future work possibilities, where I explore ways in which this project could be taken further, for more extensive research and projects. Followed by chapter 9, where I present my conclusions to the project based on the evaluation. Finally, the last two chapters present this report's references and relevant appendices.

2. Background Research

The background chapter contains information and research about the topics related to this project, such as *Virtual Reality*, *Remy Jungerman*, *3D Modelling*, and *Digital & Virtual Museums*. It gives in-depth information on the relevance and connection that each of these topics has to the real-world problem addressed in this report.

2.1 Virtual Reality

Although Virtual Reality and its practical applications are not necessarily new topics to many, it is still important to define specific terms and definitions regarding the project. It is crucial to understand the basics of the technology to recognize certain aspects of this project.

In this project, I explore the effects of immersive virtual reality, an application of virtual reality that is extended through the notion of immersion. According to Biocca and Delaney, immersive virtual reality “refers to the degree to which a virtual environment submerges the perceptual system of the user in computer-generated stimuli [5, p.57].” They introduce VR as a technology that takes many shapes or forms, and there is not only one type of VR system [5].

Three important aspects of virtual reality are *computer technology*, *interactivity/immersion*, and *replication of real life*. The technological traits of VR lie in the tools in which the technology functions, such as Personal Computers (PC), head-mounted VR displays (HMD), headphones, sensory equipment, and input devices. When combined, such tools can enable the interaction between a human and the digital world upon which the virtual reality is built upon. Without the notions of interactivity and immersion, the experiences with VR would not be unique.

By replicating real life through artificial and digital environments, designers can enhance the user’s sense of immersion. The replication is accomplished through (re)creating real-world scenarios digitally by 3D modelling, 3D scanning, or by turning a real-life video into a 360 degrees VR experience. This recreation is an important factor that leads to the feelings of presence and telepresence highlighted by Steuer [6]. The sense of being *in*, as in inside an environment, is an important component of an VR experience.

2.2 Remy Jungerman

The artist with which this project is being made in collaboration is *Remy Jungerman*, a contemporary visual artist from Suriname. Jungerman is based in both Amsterdam and New York and has several art pieces dedicated to his ancestral heritage, which travels back to his home country of Suriname.

Cultural Reference has a strong presence in Remy's work, which tell stories about the Surinamese Maroons and connects history to art. Remy has exhibited several art pieces and has been present and numerous art events, including the Stedelijk Museum in Amsterdam, the 58th Venice Biennale, Kunstmuseum in the Hague, and others.



Figure 1: Remy Jungerman, *PROMISE IV*

Remy's exhibition, *Behind the Forest* at the Stedelijk museum highlights some of the artist's key characteristics and styles. During an interview for the Stedelijk Museum, Remy accentuates that the exhibition came about as a way to increase the *cultural reference* in his work, directly relating it to his ancestry. The title name given to the exhibition, *Behind the Forest*, translates to the name of Remy's ancestor from Suriname, the Bakabusi.

The works featured in the exhibition underline Remy's meticulous use of materials, which are typical from the region of his ancestors in Suriname. These materials include clay, textile, grit, and sand. Remy utilizes such materials in compositing the art pieces, which include collages, cubes and various shapes used in ritual practices.

2.3 Digital & Virtual Museums

Museums allow people to observe and admire artifacts, and most of the time these artifacts are supposed to be *real* [7]. However traditional museums face an issue when it comes to the notion of *real* and tangible artifacts. Some artifacts are just too big for the constraints of a museum, and the best solution most of the time is photographs of those artifacts, which can be boring [7]. Also, in the scenario where museums do display large artifacts, such as dinosaur fossils, the costs of maintaining these artifacts are high since most of the time they need special environmental conditions to be displayed [7].

Another barrier that physical museums face is obtaining the actual **display setting** itself. The physical space for displaying a piece can also be expensive, and that is why many times art pieces are never really displayed. Visitors need to **travel** to the museum to experience it, so locomotion is another restraint to be taken into account. Often pieces at museums (at least history and classical art museums) are not interactive and engaging.

Applications of virtual technologies, such as VR, can aid in easing the restraints of physical museums. Tschritzis [7] states that interactive 3D graphics in junction with devices such as a head-mounted display lets the user interact with objects and their surroundings [7].

The development of VR has led to the technology being used for the display of cultural heritage and art [8], which typically happens in museums and galleries. Different levels of immersion can be achieved through virtual technologies; however, VR helps achieve a level of immersion that leads users to feel a sense of control and freedom over their actions [8].

2.4 Feelings and Emotions in Virtual Reality

The experience of a user is greatly influenced by emotions and feelings, which can also be provoked through the use of VR. When a well-implemented system is met with positive feelings and emotions, the overall user experience is significantly better. However, according to Dozio et al [9], there are no specific guidelines when it comes to designing a Virtual Environment (VE) for a virtual experience. They state that any detail, asset, or interactivity within a VE will influence a user's experience. These include visual, auditory, tactile, and even olfactory feelings [9], which can be combined through different multimedia applications within the VR system. Tschritzis et al.,[7] argue that in contrast to physical museums where the visitors are often simple observers and spectators, virtual tours offer the visitors the feeling of active participation.

The enhancement of the sense of participation provoked by the system also increases the feelings of immersion, which contributes to the experience as well. Kalving et al., [10] state that an HMD provides the user with control over what they wish to observe inside the virtual space, enhancing the sense of control, and therefore immersing the user further into the experience. The feelings of immersion and control contribute to the participant's connectedness to the tour, as they can feel that their input and participation in the experience are important and meaningful. The immersion of a user associated with their experience is also related to the feeling of control they have over their virtual tour [10]. A higher feeling of control allows the user to actively make choices and decisions during their tour, which will translate directly to their immediate experience.

2.5 Related Work

The literature review below was written by the researcher during a course of academic writing in parallel with this research. It examines relevant scientific literature in the fields of VR, art, and emotions and highlights the ways in which VR can help increase visitor's museum experiences. It is divided into six sections, each dealing with a different aspect related to the literature review's research question. This research is relevant as it provides additional information about virtual reality technologies, contextualizes VR in museums, further explains the possibilities of implementation of VR, and which are the predominant feelings associated with VR in such contexts.

2.5.1 Literature Review

To what extent does Virtual Reality technologies enhance museum experiences through emotions?¹

Introduction

Art can be consumed in numerous ways and there is a vast range of venues available for it to be admired. Museums, art galleries, exhibitions, cinemas, and public spaces are some of the most conventional spaces where art is typically presented to the public, facilitating the overall access to such art. While these different venues allow people to observe and admire artifacts that sometimes could not be seen otherwise, they share a practical constraint that can be overlooked, the displayed artifacts must be **real** and **tangible**. Given that venues are bound to physical and tangible artifacts, many pieces are never displayed to the public, display spaces become expensive to acquire, there is

¹ I wrote this literature review for my course in Academic Writing, which happened at the same time of this project.

low overall interactivity, and there are 3-dimensional limits to the art being displayed [7]. These constraints, however, can be tackled through the implementation and use of virtual technologies such as VR.

The increased use of VR in different fields such as Education [11], Healthcare [12], and Art [13] has shown that it can be extremely beneficial in distinct contexts. The innovative nature of VR allows the development of creative and interactive installations which are not bound to the physical world. The integral use of VR has increased in the last few years, and this shows how this technology can be versatile, and the subsequent growth and spread of VR applications has increased the demand to improve further the technology's possibilities and functionalities [10]. This effect can show itself to be extremely rewarding, as it will steadily attract more investment to the area of VR.

The study of VR implementations in art is relevant in order to accurately portray the development of such technologies in the field of art. To further and concisely explore the possibilities of VR implementations in artistic scenarios such as museums, galleries, and exhibitions, the following question will be studied: *How does VR enhance a visitor's museum experience?* The goal of this review is to explore, analyze and synthesize the benefits of adapting VR technologies in artistic contexts, with expectations of increasing the overall user experience.

This literature review consists of four main topics surrounding the use of VR in museums. The first part discusses the implementation of VR in museums, the second part dives into feelings and emotions provoked by VR experiences, the third section deals with interactivity with art in VR, and the fourth section touches on the physical museum's constraints are eased by the application of VR. The first four sections serve to highlight how the implementation of VR allows art to be explored differently than the conventional face-to-face way.

Implementation of VR in Museums

VR technologies have been applied to diverse areas and fields, leading to a development boost, but their application in art especially has led to exciting discoveries that are relevant to this literature review. Over the last few years, VR exhibitions have been implemented by several renowned museums and galleries such as the *Louvre* [14], the *Helmut Newton Foundation* [15], and the *Tate Modern* [16], with each one providing the audience with unique and exciting experiences. Museums and galleries have implemented VR as a way to change visitors' experience by immersing them in the displayed art in non-conventional ways. The technology adopted by various museums allows visitors to visit exhibitions remotely, offering the opportunity for physically disabled individuals that cannot visit museums to observe and interact with art pieces. The possibility of remote attendance also facilitates visiting during busy hours and lets visitors choose visiting times more freely. Dozio et al [9] argue that virtual environments have gained popularity because it

reduces costs, increased availability of the technology, and because of user acceptance of virtual reality [9]. Museums can benefit wildly from VR in monetary and practical aspects; however, this paper will explore the practical aspects in more depth. It has also been researched that VR is a suitable tool for displaying cultural heritage by providing visitors with immersive experiences [17]. Carrozzino and Bergamasco highlight that the widespread of VR in various sectors has led it to be positively received in the field of cultural heritage [18].

Feelings and Emotions Provoked by VR

The experience of a user is greatly influenced by emotions and feelings, which can also be provoked through the use of VR. When a well-implemented system is met with positive feelings and emotions, the overall user experience is significantly better. However, according to Dozio et al [9], there are no specific guidelines when it comes to designing a Virtual Environment (VE) for a virtual experience. They state that any detail, asset, or interactivity within a VE will influence a user's experience. These include visual, auditory, tactile, and even olfactory feelings [9], which can be combined through different multimedia applications within the VR system. Tschritzis and Gibbs, [7] argue that in contrast to physical museums where the visitors are often simple observers and spectators, virtual tours offer the visitors the feeling of active participation. The enhancement of the sense of participation provoked by the system also increases the feelings of immersion, which contributes to the experience as well. Kalving et al., [10] state that an HMD VR provides the user with control over what they wish to observe inside the virtual space, enhancing the sense of control, and therefore immersing the user further into the experience. The feelings of immersion and control contribute to the participant's connectedness to the tour, as they can feel that their input and participation in the experience are important and meaningful. The immersion of a user associated with their experience is also related to the feeling of control they have over their virtual tour [10]. A higher feeling of control allows the user to actively make choices and decisions during their tour, which will translate directly to their immediate experience. Through VR, the feelings of immersion, control, connectedness, and enjoyment can all be augmented when users interact with art.

Interactivity with Art in VR

The feelings and emotions enhanced by VR are partially possible because of the interactivity allowed by the system. VR makes interactivity with art possible through tools that allow the user to alter and amplify aspects of the art pieces. Input devices, such as a *data glove* mentioned by Tschritzis and Gibbs [7] make it possible for users to reach out with their hands and grab certain objects. Such devices make it possible for the user to not only observe changes to the environment around them but also be part of the change. Another part of interactivity is being able to activate

certain functionalities by hovering on top of digital buttons and menus and selecting different settings. The possibility of selecting and changing different settings gives the user more freedom when shaping their experience. Since an integral part of a VR environment has to do with interactions, there also exists a space for the body-(virtual) environment interactivity. The emphasis between the body, its sensory systems, and the digital/virtual environment is highlighted by Yang et al. [19], which is a concept known as experiential learning involving feelings and mind-body interaction [19].

Eased Physical Constraints of Museums

The interactivity with art, made possible with VR, eases physical constraints posed by museums. A major physical constraint is a need for real tangible artifacts and physical space to display them, which in many cases is expensive and time-consuming for museums [7]. With the development of digital environments for VR, museums would no longer need to spend time and money in preparing physical spaces for their art pieces, which are not all displayed at one time due to space limitations. Maintaining a large number of artifacts that are not constantly displayed is also expensive, and the possibilities of creating digital artifacts with 3D technology is immense. Expensive and fragile artifacts, which are not usually displayed often, could be digitally recreated, and consequently be displayed virtually for a larger audience of visitors. This approach, despite lacking the physical essence of a grand artifact, also poses a safety measure that helps prevent such artifacts from being stolen or broken during museum visits. The use of VR by museums can greatly aid with exhibiting pieces that would not be displayed otherwise while easing physical constraints posed by non-digital settings. Since many times museum artifacts are not usually stored in their original locations, digital technologies can help overpass the gap between transporting artifacts to museums and maintaining them at their original sites [20]. This would ensure that historical pieces are maintained at their original site, holding they're historical in place while maintaining their physical integrity.

Conclusion

In this literature review, I explored different ways in which applying VR can enhance user experience in museums and exhibitions. The technology has gained increased popularity over the last years, which led to museums and exhibitions adopting VR for certain exhibitions. User experiences are greatly influenced by the feelings and emotions felt during an experience, and by using VR, feelings of immersion [10], control [10], and presence [6] can be provoked through design choices of implementation. The feelings and emotions associated with a VR experience are partially amplified by the interactivity offered by the system. VR enables the user to feel and be an active agent in their experience, rather than a simple observer. Participants many times have the freedom

to explore their surroundings and actively contribute to their experience inside the virtual environment that is being visited. However, the interactions go beyond what the user sees and hears while encountering the system, the participant also interacts with their body and sensory systems, further increasing their experience. The affordances of VR include eased physical constraints, which most of the time are matters of discussion with physical museums. With VR, many physical constraints that museums have can be eased, since the technology is mostly digital, with few electronic gadgets such as head-mounted headsets, hand controllers, and headsets.

Taking these aspects of VR into account, it can be argued that VR does have the potential to increase the overall museum experience of visitors positively. The extent to which the user's experience is enhanced is based on several factors, with some being more easily assessed.

Extensive research has been done in the field of virtual reality and its various applications in different contexts. It has shown to be a promising technology in the arts field, as it has been adopted by numerous museums for engaging exhibitions. Despite its popularity, it is still argued that there are no clear virtual environment validation methods for creating environments that arouse specific emotions and feelings [9]. The limit in methodological research shows that further scientific insight must be applied in this area, where such information is vital. While a methodological approach seems counterintuitive to be applied to a process that is so free and creative such as designing virtual environments, certain guidelines on feelings for specific contexts would aid the process immensely.

2.6 State of the Art

The related work presented above showed that there is huge potential for implementing artistic experiences in VR. The state of the art explores how different museums and galleries around the world have adopted the technology in their exhibitions. It is extremely helpful to research about existing products and solutions to analyse such systems as well current limitations.

Museums of Other Realities

Museums of Other Realities (MOR) is a free online VR space where artists, creators and explorers create and share immersive media with each other. It is a place where users can collectively experience art with others through a VR experience.

The main issue addressed by MOR is the difficulty that artists face in getting their work seen by a wider audience. They explain "the same 'newness' that gives artists the opportunity to experiment,

however, also means that it can be difficult for them to get their work seen by a wider audience as intended” [21].

Artists that present their works at the MOR also challenge the artistic bounds of the possible and impossible, and their gate to achieving the impossible is through MOR. The platform allows artists to express their works to a large audience in engaging ways, where the users can interact with works by stepping into ever evolving paintings while being surrounded by “fantastic sounds” [21].

The MOR platform was created to address the issue of artist visibility by **building a community** that revolves around **supporting artists**. The platform provides explorers and artists with regular events that foster and celebrate this new way of collective experience [21].

Mona Lisa: Beyond the Glass (Louvre)

The Mona Lisa: Beyond the Glass is an immersive VR experience was made as part of the Leonardo DaVinci exhibition in 2020. It is meant to take the visitor on an engaging historical tour of the painting, starting at the origins of where DaVinci originally painted the woman. The user is not only presented with the still painting, but with a digital representation of Lisa herself, who interacts and talks with the user.

The issue highlighted by the curators of the exhibition, Louis Frank, and Vincent Delieuvin, relates to the painting’s fame and difficulty of personal engagement. Since Mona Lisa is such an extremely well-known piece of art, their question when researching and creating the experience was “how can you engage with it on a personal level- get through the barrier of fame to discover its inner secrets?”

The solution found by the organizers and developers of the project was one where the audience is able to not only observe, but interact with the painting face to face, therefore aiming to tell the real story behind the painting. Vincent Delieuvin exclaims, “The Mona Lisa is fated never to be seen again the way she should be, i.e., face to face” [14].

Modigliani VR: The Ochre Atelier (Tate Modern)

The Ochre Atelier is a digital recreation of Amedeo Modigliani’s last atelier in Paris [16]. The environment is built from a reimagined interpretation of the environment in which the artist created his last pieces. Since the Ochre Atelier was an undocumented space, it was also unknown to many, a problem addressed by the VR experience.

The Ochre Atelier has been brought back to life, exhibiting over 60 pieces by using the actual space as a template, since there are no photographs of the original layout of the studio [16]. Careful research was conducted on each asset to accurately recreate it in a digital environment. The recreation of paintings was done with a high degree of accuracy after extensive research on the materials, textures, and techniques of the painter.

Digital Exhibitions (Helmut Newton Foundation)

The Helmut Newton Foundation makes available via their website eight VR tours of different exhibitions.

The experiences are composed of 360-degree videos where the user can look around by utilizing their mouse or trackpad via their phone or computer. The guided tours are commented by the editor and curator of the exhibitions who act as an audio guide. Differently from the previous examples, the digital exhibitions from the Helmut Newton Foundation do not make use of external VR equipment such as headsets and do not offer the user the freedom of exploring the environment [15].

Curious Alice: The VR Experience

Curious Alice is a VR experience that takes the audience on an immersive and interactive journey through a re-imagined Wonderland. The world is full of colourful landscapes, interesting characters, and loads of interaction.

The re-imagined Wonderland is highly interactive, where the user is actively participating to make the most out of the experience. As a part of the story, the user is constantly solving riddles, embarking on quests, and playing games.

3. Design Process Method

3.1 Creative Technology Design Method

The design method chosen for this research is the Creative Technology Design Method [22]. The method is separated into four different phases, namely the *Ideation*, *Specification*, *Realization*, and *Evaluation* phase, where several iterations between each phase take place, following a non-linear workflow.

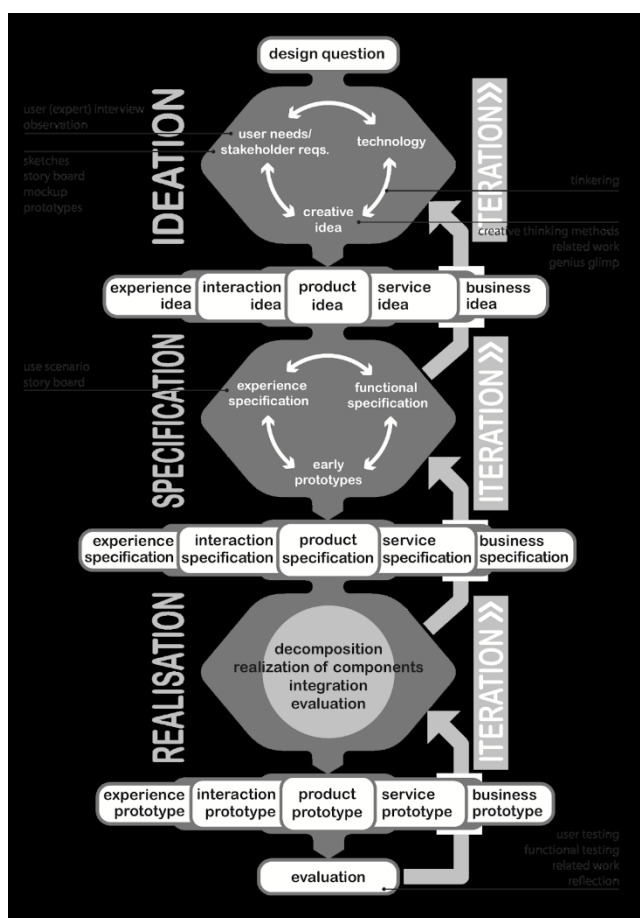


Figure 2: Creative Technology Design Process

This was the chosen method because it allows for an iterative process, where it is possible to go back and forth between phases, adjusting where needed, and re-evaluating areas which can be improved.

The final picture is clear, however the steps taken to arrive at the final phase are iteratively taken, in order to achieve a desired result.

3.1.1 Ideation Phase

During the Ideation phase, the main issue is addressed, the technology available is evaluated, and an idea is thought of.

The issue at stake for this project is creating a VR Museum installation that will accurately portray an artist's narrative while provoking feelings and emotions in visitors to enhance their overall experience. The researchers have been in contact with the artist, *Remy Jungerman* via online meetings to determine the needs and requirements of the project, as well as practical aspects such as the specific art pieces which will be displayed and the layout of the exhibition environment. Initial ideas were brainstormed through several brainstorming methods which include, *Brainwriting*, *Mind Mapping*, and *Round Robin Brainstorming*.

3.1.2 Specification Phase

During the Specification phase, different low-level prototypes will be built and evaluated, considering the user experience and functionality. These prototypes are not final ones, and will include storyboard, scenarios, and sketches of the product. To do so, preliminary evaluations with users, or done by the researchers themselves, will be conducted. According to the Create Design Process Method, the functionality of a product greatly influences the user experience, requiring a constant change in functionality during the Specification phase [22].

A large part of this phase lies in understanding the relationship between the technology and the user experience [22], and how this relationship can be adjusted through prototyping and evaluations.

3.1.3 Realization Phase

After the product is specified and has passed through several prototype iterations, the Realization phase will aid in decomposing the specification, realizing the components, integrating the components, and evaluating the system [22].

To realize the system, an explicit list of materials, tools, and programs will be elaborated and analysed, which the design researcher will use to create a list of requirements of the system, and consequently design and finalize the final iterations of the previous prototypes.

The realization phase serves as a guide to the reader on how the system is built and provides explanations for different choices taken in this process. It explains and shows the users how the

different tools are used in specific areas of the project, and how everything comes together in the final product.

3.1.4 Evaluation Phase

The evaluation phase encapsulates the relevant processes which will be used to evaluate the system and its integral parts. The functional testing done in the Realization phase will be extended to the Evaluation phase, ensuring that the system does work as intended and most of the previously established requirements will be tested to ensure that in part, they have been met. To test the system and its requirements, the researcher will apply user tests, which will allow the researcher to evaluate the user experience along with the functionality of the system.

In this research, users will test the Virtual Museum during individual sessions in which they will interact with the system and later fill out a questionnaire regarding their experience and how immersed they felt during their interaction. Both the questionnaire and observations taken by the researcher will be used to evaluate the final product and aid in the formulation of conclusions.

4. Ideation

This chapter deals with the ideation process of the project. Here, I explain how a collaborative brainwriting session was used to generate ideas, and how that lead to the chosen concept. I also present the system’s design through a preliminary set of requirements.

4.1 Brainstorming

Different concepts were explored through an online brainwriting session, in which me, and two other design researchers, Lilly Stelzer and Jesper Hoogenkamp, also participated. The session was based on a method of brainwriting where each one of us has ten minutes to write down ideas, and later one collaboratively discusses each idea and group them according to their context.

The main objective of the project is stated at the center of the canvas in figure 3, and different ideas were categorized between different aspects related to the **Provoking of Feelings and Emotions**. Each student’s idea is identified by a different color, which was assigned at the start of the session. At first, all the three students wrote down their ideas on post-its but did not necessarily fit them to any category, later, every idea was read over by all of them and categorized based on the type of interaction, feeling or media.

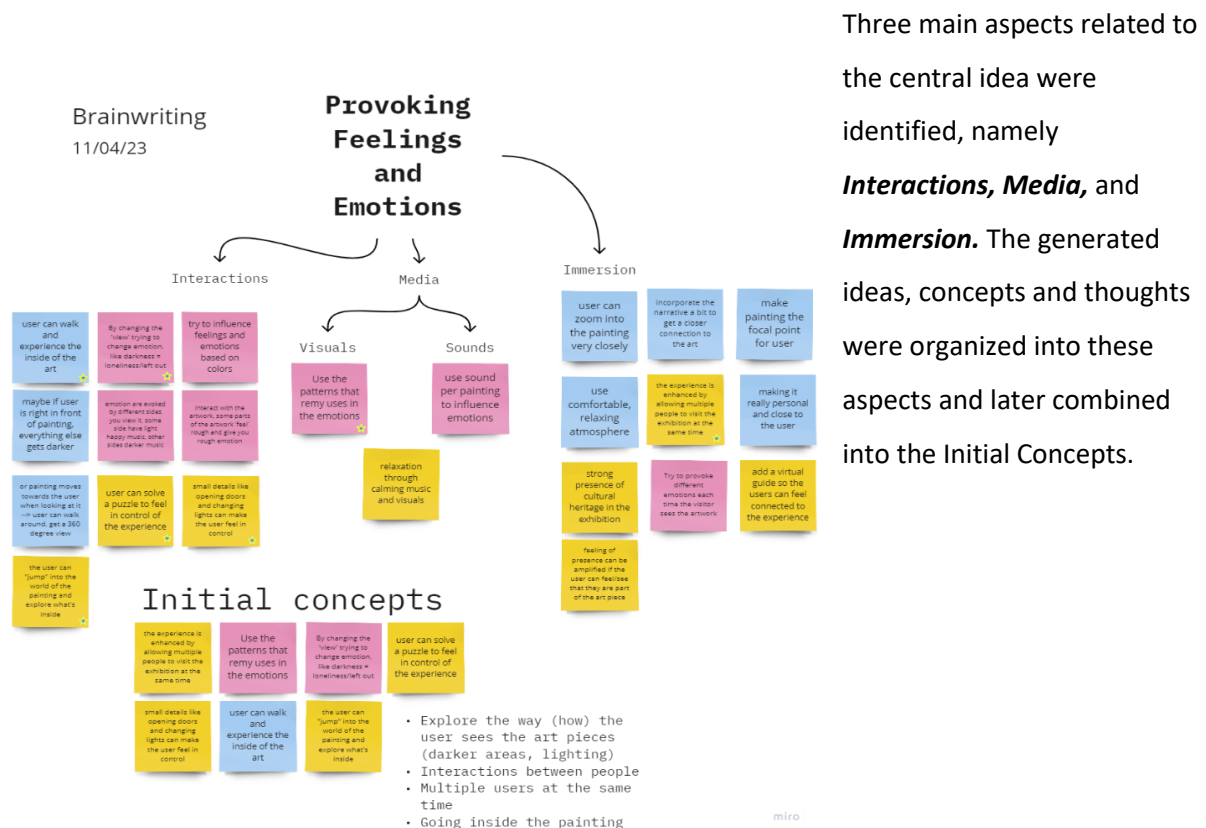


Figure 3: Brainwriting Session 1

Brainwriting was the chosen brainstorming method since it allows for the generation of multiple ideas from different viewpoints. All three participants could add to the canvas, and after each round, all ideas were discussed among us, and the best ideas were chosen collectively. This method allowed for an interactive collection and selection of ideas, where different inputs helped me understand areas of my project which I had previously overlooked.

4.1.1 Initial Concepts Worked Out

Following the brainwriting session, three initial concepts were thought of and worked out in more detail. The list below explains in more depth each concept based on the brainwriting presented above.

1. Multiple User Interactions within the World

The idea is not to gamify the experience completely but to add possible interactions between users that join the experience simultaneously. If multiple users join, they can feel connected with each other by engaging with puzzles (direct interaction with art pieces) or through gestures/interactions that happen between the users (handshakes, emotes, etc.)

Player-player interactions:

- Voice-chat
- Hand gestures (waving to another player)

Player-player-system interactions:

- Sliding tiles puzzle where the user can slide parts of a canvas around to arrange an art piece.

2. Going Inside the Painting/Transported into the World of the Painting

The concept of this idea revolves around creating specific scenarios (small different rooms/worlds) for different art pieces exhibited. Apart from the central room/hub where the user will spawn, they would be able to walk up to a painting, observe it naturally as they would observe any painting or sculpture, but also have the opportunity to “jump” into the painting and discover more about it. It is as if the painting would be dissected and each component of it could be explored.

The main world where the paintings will be exhibited is just a “hub” for transporting the users into the world of each painting. Each world will present specific characteristics of each painting, and the user will feel immersed in the rich history behind each piece of art. Inside each world, the user will feel immersed through sound effects, lights, and details about that specific piece.

The abstract paintings could lead the users to worlds where I explore their patterns, taking the piece further into the world by using the same patterns on the floor, etc.

This idea is greatly related by the Mona Lisa: Beyond the Glass exhibition at the Louvre [14]. The main idea behind this experience being the teleportation to a new world/scene or room, therefore learning something more about the piece of art. This concept revolves around extending the space of the sculpture and taking the visitor to the world of the sculpture, where the sculpture's structure is what plays the most important role.

3. Small Playable/Changeable Details around the World

The interactions and aspects players can toggle with do not necessarily revolve around the paintings, but the environment itself. Users can dim lights, open doors/windows, and toggle certain things throughout the experience that will engage them with the dynamics of the experience and make them feel in control of their surroundings.

4.2 Chosen Concept

After the Brainstorming phase, where various ideas were generated, I chose one concept to continue working on, concept number two. Based on my research about immersion in VR [10] and the different VR experiences that already exist like the Mona Lisa: Beyond the Glass [14], my thought was that by taking the user inside the sculpture, they could learn more about it by observing details more closely and feel higher levels of immersion.



Figure 4: Museum Scenario for Chosen Concept

Figure 4 presents a typical museum scenario, where visitors simply observe and react to art pieces around them such as paintings and sculptures. If the user feels drawn by a certain art piece, they can choose to move closer to it, and by either clicking on the painting, or by walking into the sculpture, they will be transported into the art piece. Figure 5 depicts what the users will be able to do once they are inside the art piece.

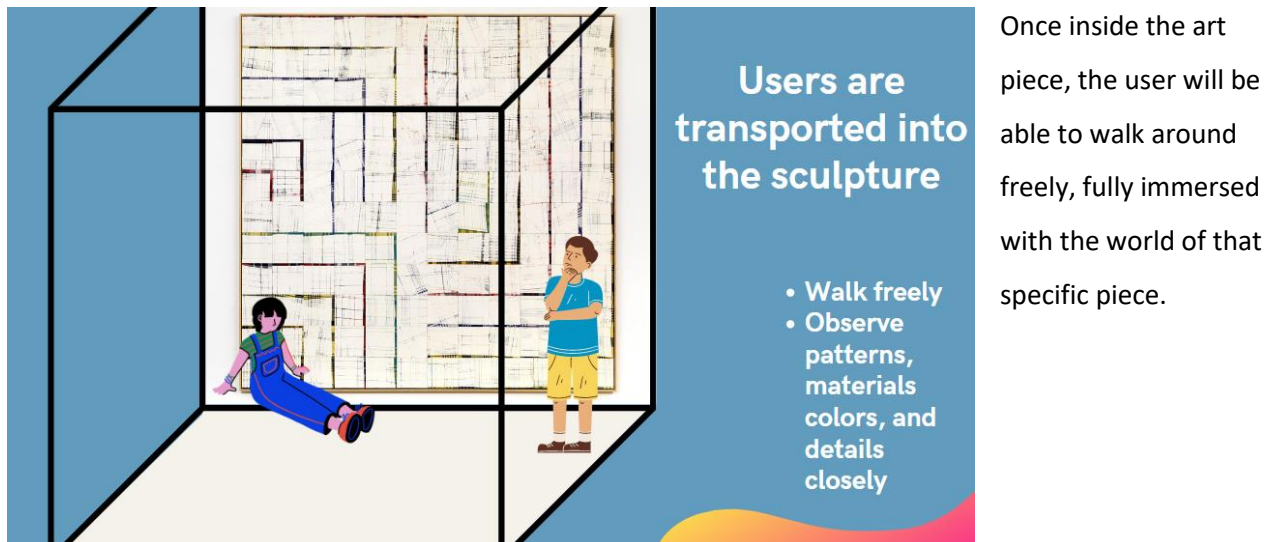


Figure 5: Users inside Sculpture

The chosen concept is meant to magnify the parts of Remy's art pieces which can feel small or unnoticeable when the visitor only observes them at a distance. By being taken into the piece of art, they can engage with it by walking around, noticing details and intricacies that could not have been noticed otherwise.

Based on the literature research on emotions in virtual reality, three emotions that can positively contribute to the user experience were identified, namely **immersion**, **control** and, **connectedness**. When provoked or amplified in an efficient way, the user can experience such emotions in a way that their overall experience with the system is increased as well.

4.3 System Design

This section deals with the system design through a preliminary set of system goals explained through functional and non-functional requirements categorized based on the MoSCoW prioritization list [23].

4.3.1 System Goals

Based on the MoSCoW Prioritization method, preliminary functional and non-functional requirements are presented below in tables 1 and 2.

Table 1: Preliminary Functional Requirements

Must Have ²	Should Have ³	Could Have ⁴	Won't Have ⁵
At least 2 interactable sculptures.	Maximum 4 users interacting at a time.	Audio guide throughout the exhibition	Non-playable character guide
At least 2 interactable paintings.		Programmed interactions such as opening doors to different corridors.	
Lights throughout the environment.		Grabbable objects.	

Table 2: Preliminary Non-Functional Requirements

Must Have	Should Have	Could Have	Won't Have
Environment must resemble a modern art museum	Noticeable details that add to the environment.	Ambient music.	
User should understand teleportation within 1	An immersive environment that the		

² Must: designer guarantees to deliver and is crucial for the system

³ Should: important for the system but not vital

⁴ Could: wanted aspects but less important

⁵ Won't: requirements agreed not to be delivered

minute of seeing the portal	user interacts with their body.		
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5. Specification

The specification goes a step further than the ideation by explaining more in details the aspects related to the system's functionality and design. A revised system specification is presented with more detailed requirements which will be used as basis for the building of the system in the next chapter. Here, I also explain the rationale for the chosen art pieces, and which assets will be possible included in the final product. The initial prototypes are explained through use scenarios, storyboard, and explanations of the target users.

5.1 System Goals

The goals of the system are to provide the visitor with an enjoyable museum experience by immersing them with Remy's art and to give Remy a unique space to exhibit his artwork.

5.2 Users

5.2.1 Target Users

The system will consist of a Virtual Reality Contemporary Museum Exhibition, attracting and directing different groups of target users. Four groups of target users have been identified, namely (1) appreciators of modern art museums, (2) appreciators of Remy Jungerman's art, (3) young people aged 16-24, and (4) physically impaired individuals that like/would like to visit modern art museums.

1. Appreciators of modern art museums.

This user group is primarily composed of regular visitors of modern art museums. Individuals that appreciate modern art, and enjoy physically visiting museums, could benefit from a VR Experience during their visit.

2. Appreciators of Remy Jungerman's art.

Since the artworks displayed through the project are Remy's, another important target audience is Remy's appreciators/followers. People in this target group will be able to experience Remy's work in an innovative and unique way, differing from what they have experienced before.

3. Young People (aged 16-24).

This target group was identified because my supervisor for this project, Carolien Rieffe is interested in testing such systems with adolescents and because the people in this age group can provide consent to interact with the system.

4. Disabled individuals that like/would like to visit museums.

Since this project will be implemented through a Virtual Reality system, and studies have shown that VR can be used to accommodate people with physical disabilities, the fourth target group approached by this project includes physically impaired individuals that like or would like to visit museums and artistic experiences.

5.2.2 Use Scenarios

The final product's function is to allow users to visit and engage with Remy Jungerman's artwork through a virtual reality digital environment.

1. VR Exhibition at a Physical Museum

Accessible for regular museum visitors, people that know of Remy's work and exhibitions, and museums that are equipped with accessibility features for physically impaired visitors. Since this project represents an existing artist and his works of art, it could be used during an exhibition of a physical museum where the artist has pieces displayed. The museum could set up the VR experience as a part of the physical exhibition where visitors could experience the artist's work differently.

2. VR Exhibition at an Educational Scenario (School, University)

Because of VR's many applications, the system developed during this project could also be used in an educational scenario, at schools or universities. Educational institutes could invite VR experts as part of their educational program to teach students about different topics in the area and how students can be better familiarized with VR.

3. VR Exhibition through the artist's own website

The artist (Remy) could embed the VR experience in his website as part of an online exhibition/display and his personal Portfolio. This would allow his appreciators to engage with his artwork remotely. However, a downside of this scenario is that it does not support virtual reality with head-mounted displays for all users. Since the system would be embedded into the artists' website, most users would access it through their computers and experience it through their screens only, without the full functionality of the system, which allows for more interactions and actions when used with a VR head-mounted display.

4. Online Website where the VR Exhibition can be remotely accessed (Museum's website, artist's website)

The VR Exhibition would become the most accessible and open to the public if it were exhibited on a museum's or Gallery's website. Such experiences are generally open to the public, and since they would be hosted online, it opens the door for remote access, a key aspect of accessibility and inclusivity. Similarly, to the scenario explained above, displaying the VR exhibition on a website would take away aspects that are important to the user experience if it were experienced with a VR head-mounted display. Only users who have access to a VR headset would be able to be fully immersed in it.

5.2.3 Storyboards

To contextualize the use scenarios described above, a list of possible user interactions is explained in detail in this section.

1. Paul, 50, is a follower of Remy's work for some years now, and he is up to date on most of Remy's exhibitions. Paul has found out that Remy will display some of his artworks during an exhibition at the X Museum in New York, however, Paul lives in the Netherlands and is not able to attend. Despite the huge distance barrier, Paul is still able to explore Remy's artworks on his computer via a VR Exhibition made in collaboration between Remy and Museum X, which is displayed on the Museum's website. Paul can remotely access the exhibition and navigate around the artworks all through his computer at home.
2. Amanda, 18, and Jessica, 20, are friends from university and occasionally like to visit museums together. They decided to visit one of the contemporary art museums in their city but are not familiar with the artists of the exhibition, they are visiting because they like art in general. Upon observing various exhibitions, they come across Remy's work, which includes paintings, silkscreens, sculptures, and panels. Very intrigued by the artworks, they become excited to walk around the pieces and observe them closely. While they are observing the various artworks, they stumble upon a VR setup, which is part of the exhibit. They are both able to simultaneously join the experience with two VR headsets and observe Remy's work in even more depth. A museum visit which both thought would be an ordinary one, was struck by an exciting VR experience that changed their view of Remy's works.

3. Mathew, 32, is physically impaired from his waist down, which prevents him from locomoting without his wheelchair. However, as Mathew is aware, unfortunately, many places he attempts to visit, such as malls, museums, public parks, etc., do not have the correct infrastructure to accommodate people like him. He is very fond of modern and contemporary art and is constantly looking for online exhibitions. After searching for art exhibitions in the fields of culture and heritage, he stumbled across Remy Jungerman's website. He became quite interested in Remy's works and dived deeper into Remy's website, which showcased many of his works through pictures and videos. To Mathew's surprise, a VR Experience of Remy's latest exhibition was available directly on his website, which allowed him to experience it through his computer.

4. Mary, 40, is a middle school art and humanities teacher that has recently started teaching her class of 15 students about modern and contemporary art. Mary is close friends with Remy and asked if Remy could be part of the class during one session. Remy is very excited to be part of the class and tells Mary that he has been developing alongside other developers a new way of experiencing his artwork, through VR. Mary contacted the school and was able to borrow 4 VR headsets to use during the class. The students were able to talk to Remy about his works and experience it in VR.

5.3 System Properties

5.3.1 Art Works

Based on the chosen concept of immersing the user within Remy's sculptures, five of the artist's sculptures were selected for this project. I selected artworks from different collections... Each sculpture is identifiably unique but carries traits reminiscent throughout Remy's art pieces. The following four sculptures will be recreated for this project in the 3D modeling software Blender 3D based on the available pictures found online and on Remy's website.



Figure 6: Promise V Sculpture

Promise V

This sculpture was chosen because of its interesting structure. The user's eyes are always observing something different and colorful. By walking around the sculptures, the visitor is met with different textures, materials, and interesting geometry.

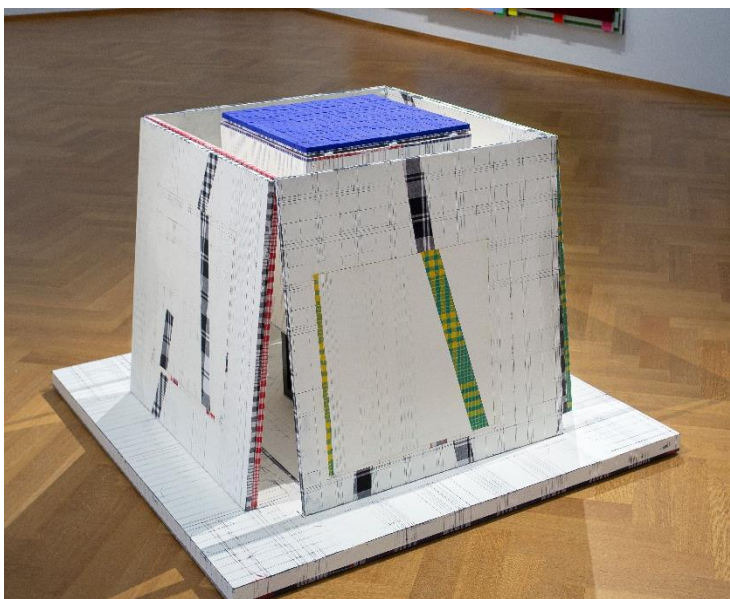


Figure 7: Omen Sculpture

Omen

Omen was chosen because of its bright colors and patterns. Aside from simply walking around the sculpture, the user wants to know what is behind each canvas.

NKISI PINDI



Figure 8: Nkisi Pindi Sculpture

This sculpture was chosen because of its interesting abstractness, geometry, and textures. The main structure is covered in patterns and textures which are prominent throughout Remy's work, reinforcing his cultural heritage.

Horizontal Obeah

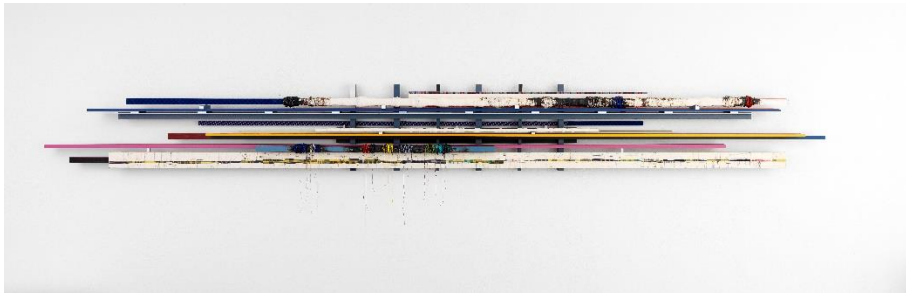


Figure 9: Horizontal Obeah Sculpture

This sculpture was chosen because it is significantly different from all other sculptures, adding to the variety of art pieces presented at the exhibition.

Ultimate Resistance

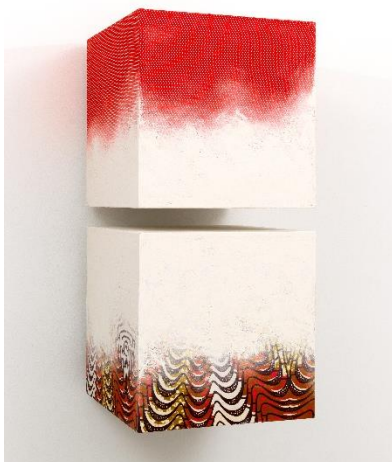


Figure 10: Ultimate Resistance Sculpture

Ultimate Resistance is vibrant and looks different from the other artworks, adding uniqueness and variety to the art exhibited in the virtual museum.

Fodu 1



Figure 11: Fodu 1 Sculpture

Fodu 1 was chosen because of its unique assortment of painted bottles, which differentiates it from other sculptures.

Pimba Beefi-IV

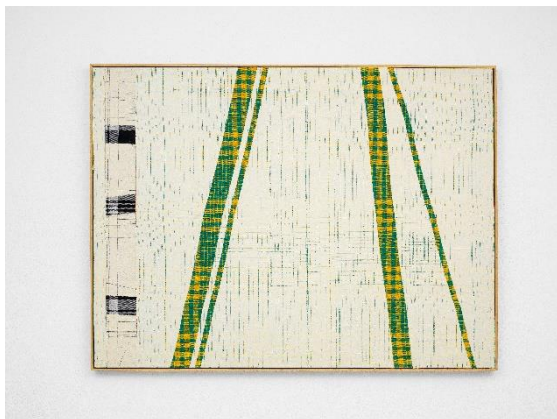


Figure 13: Pimba Beefi-IV Painting

Pimba AGIDA MADAFO III



Figure 12: Pimba AGIDA MADAFO III Painting

Pimba Beefi-IV and Pimba AGIDA MADAFO III were chosen because they have complimentary designs that go well together. Despite being from different collections, Remy's work often carries aspects from one to another, uniquely linking them.

5.3.2 Assets

3D Modelling

The Exhibition space, including its walls, floors, ceilings, details, and materials, Remy's sculptures with textures, and all assets of this project will be 3D modeled and textured in Blender 3D, a free 3D computer graphics software [24]. The version used throughout the period of the project is Blender 3.5 [24], with no addons installed.

The 3D modelling was accomplished with Blender's default tools and techniques. Simple geometry was created with 3D meshes such as cubes and cylinders. More complex geometry, such as the top piece of Nkisi Pindi was accomplished by adding a wireframe modifier to a cube.

3D Modelled Sculptures

All four selected sculptures that can be seen above (image x – z) were 3D modelled and textured in Blender 3D. The process followed a flow where first the basic building blocks of each sculpture were set, then adjustments were made to their sizes, details were added where possible, and finally, the sculptures were textured with images provided by Remy.

It is important to note that the 3D models are representations of Remy's artwork, and not exact copies since they were entirely recreated from scratch, taking as guidelines pictures from the original art pieces that were sent by Remy to us. At the start of the project, and once during it, we had a meeting with Remy where he expressed that we could recreate his artworks, therefore the artworks presented in my project are not exact copies of his work.



Figure 15: Fodu 1 3D Model

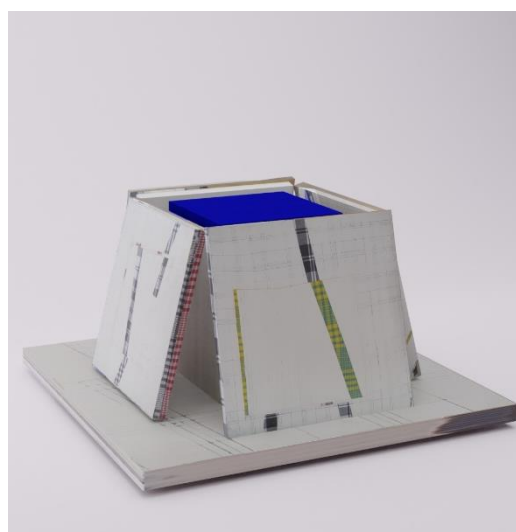


Figure 14: Omen 3D Model



Figure 18: Nkisi Pindi 3D Model

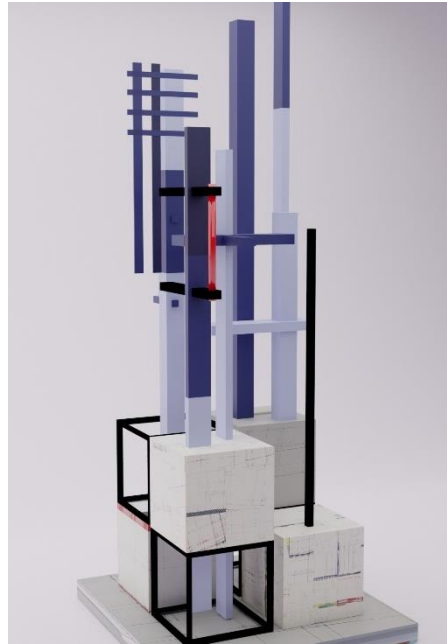


Figure 17: Promise V 3D Model.



Figure 16: Ultimate Resistance 3D Model

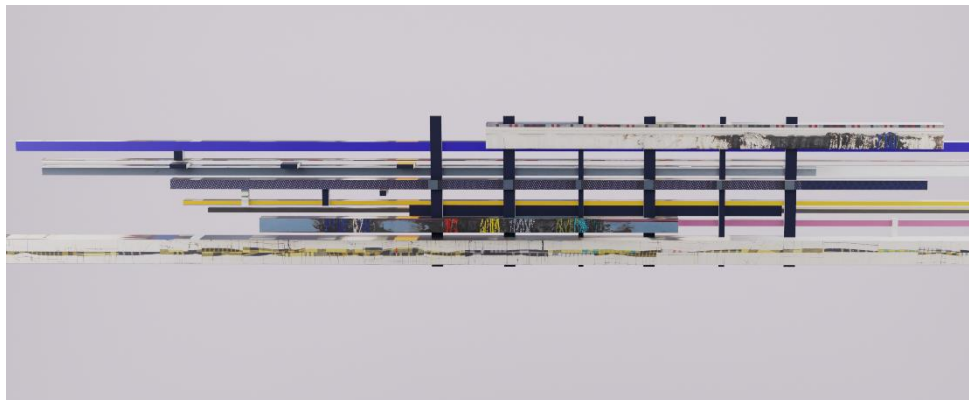


Figure 19: Horizontal Obeah 3D Model

The sculptures are textured based on high quality photographs of Remy's paintings that were sent from him. For each photograph, a normal map of the image was created in Photoshop and applied to the models in Blender.

5.4 Main Interaction

Walking into the Sculpture

The main interaction of the exhibition will happen when the user walks into a sculpture and is transported into it. I chose this version as, for me, it makes the most sense out of the ideas in the sense of immersion, as the visitor will be literally taken into the artwork. After early prototypes of scenarios and storyboard, this idea sparked the most interest among my colleagues and me.

This interaction allows the users to engage with art pieces in a way that is not possible in physical museums, thus tackling the lack of interaction with art that physical museums struggle with [20]. It emphasizes the aspect of immersion and adds to the experience of seeing the art piece, because the user sees things that are not visible when observing the sculpture from the outside.

By having the visitor walk into a sculpture, Remy can possibly tell more stories about them, focussing on their small details, by making them larger. Enriching his stories and letting visitors get close to the materials, colors, and vivid patterns throughout his work. It also gives the artists and designer freedom to create the environment that is supposed to represent the sculpture, as it is something that does not actually exist. A world that is unique to every sculpture can be built, a deeper layer within that art piece that expresses something that the art piece alone cannot.

5.4 Prototypes

Following the **brainstorming** of the Ideation Phase, a chosen concept was identified, which revolves around immersing the user in Remy's sculptures by transporting them into sculpture themselves. The concept follows the research done on immersion [10], connectedness [10], and presence [6], feelings that can be enhanced through VR which are explored in the background research.

Immersing User Inside Sculpture

To immerse the user, literally, with Remy's sculptures, this prototype will test a transportation mechanic where, when interacting with a sculpture, the user is transported into the sculpture itself. Being able to walk around, observing details and materials that were not possible when observing it in its original size.

Three main ways in which the visitor can be transported into Remy's sculptures were thought of. Each way carries different aspects that can change the user's reaction to the interaction, which are explained below.

1. Visible Transportation Portal

The transportation portal which takes the user inside the sculpture is positioned directly next to the sculpture and is visible to everyone visiting the exhibition. In this way, the interaction with the portal is completely voluntary, as the user has the choice to visit the sculpture or not.

2. Invisible Transportation Portal

In this scenario, the transportation portal is an invisible box which is placed around the sculpture itself. Whenever a visitor gets close to a sculpture, they will be automatically transported into that sculpture. The user cannot choose if they want to transport or not, it happens as they get closer to the sculpture.

3. Luring user to Portal gradually

This scenario mixes aspects of both scenarios described above. The portal will not appear visible to the visitor; however, they will know the portal is there through an indication. In this case, the objective is to make the user want to be transported into the sculpture, after they have seen it closely.

5.5 System Requirements

To understand the user's, designer's, and stakeholder's needs, a list of requirements was developed. The requirements are shown using an adapted version of the atomic requirements shell from the Volere process [26] and two types of requirements are defined for this research, functional requirements, and non-functional requirements.

Functional requirements describe *what* the system does, and non-functional requirements describe the system's *constraints* and *aspects* for its development [27].

5.5.1 Functional Requirements

Table 3: Functional Requirement # 1

Requirement #: 1	Requirement Type: Functional
Value: Learning more about the artworks.	Attribute: Blue portal located at each sculpture.
Description: The visitor can teleport inside determined sculptures without external explanation	
Rationale: This is exhibition's main interaction, and possibly the factor that will increase levels of immersion. The visitor will not be instructed about the teleportation, which will increase the element of surprise.	

Table 4: Functional Requirement # 2

Requirement #: 2	Requirement Type: Functional
Value: Visitor has more choices and can experience different scenarios, learning more about the art works.	Attribute: Sculptures positioned throughout the exhibition.
Description: The museum has at least four sculptures that visitors can teleport into.	
Rationale: By having at least four different sculptures, visitors have more opportunities to explore different art works and therefore learn more things about Remy and his stories.	

Table 5: Functional Requirement # 3

Requirement #: 3	Requirement Type: Functional
Value: Visitor has more choices and can experience different scenarios, learning more about the art works.	Attribute: Sculptures positioned throughout the exhibition.
Description: The artworks are detailed and suitable for visualization levels like their reference images.	

Rationale: By having detailed art works, the pieces look more real, and participants can observe details that they would if they saw the original art piece.

Table 6: Functional Requirement # 4

Requirement #: 4	Requirement Type: Functional
Value: Visitor has a smoother in-game experience and can observe details. This can also prevent the user from feeling motion sickness and related conditions.	Attribute: Stable connection between HMD and laptop computer.
Description: The gameplay in NeosVR + Oculus Quest 2 should run at least at 70 frames per second (fps).	
Rationale: Following research on the recommended fps a VR experience should run one, I encountered that the recommended fps is 120 [28], however the maximum fps I recorded when connecting the oculus to my laptop running NeosVR was 72 fps, making 70 fps the benchmark for my study.	

Table 7: Functional Requirement # 5

Requirement #: 5	Requirement Type: Functional
Value: If the difference between the scale of the sculpture inside the museum and its size when the visitor is inside it is larger, this can increase the visitor's excitement when going in.	Attribute: Smaller scaled sculptures in the museum.
Description: The sculptures are scaled down from their original versions in the virtual museum.	
Rationale: The sculptures will not be scaled exactly like their physical references because I want to add an extra layer of surprise once the user is teleported into it.	

Table 8: Functional Requirement # 6

Requirement #: 6	Requirement Type: Functional
Value: Freedom of choice for the user.	Attribute: Art pieces are equally separated throughout the space.
Description: The visitor can visit the museum in any given order.	
Rationale: Since the artworks are not necessarily connected to one another in a way that a user must visit one before the other, they are free to choose which art piece to visit at any point in time.	

5.4.2 Non-Functional Requirements

These requirements are related to the overall look and feel of the system, such as aesthetics, design, and overall aspects that do not hinder the usage of the system but contribute to the user experience. Non-functional requirements explain *how the system completes (does) its functions*.

Table 9: Non- Functional Requirement # 7

Requirement #: 7	Requirement Type: Non-functional
Value: Understanding the mechanics will ensure the visitor knows what to do.	Attribute: Blue portal at each sculpture.
Description: The visitor understands what the teleportation portal is within 1 minute of encountering it.	
Rationale: If the visitor does identify the teleportation possibility, they will not have a full experience of the museum.	

Table 10: Non- Functional Requirement # 8

Requirement #: 8	Requirement Type: Non-functional
Value: I can better leverage my skills in Blender to create the art pieces and museum environment.	Attribute: 3D Models exported in Blender.
Description: The 3D assets of the museum environment are modelled in Blender	
Rationale: The rationale behind using Blender as the selected software comes from my experience with the software and because it is free to use.	

Table 11: Non-Functional Requirement # 9

Requirement #: 9	Requirement Type: Non-functional
Value: The visitor will feel as if the environment is realistic, adding to their sense of immersion [10] and presence [6].	Attribute: White colored walls, wooden floors, and high levels of lighting.
Description: The exhibition environment is reminiscent of a contemporary art museum.	
Rationale: Based on Remy's preferences, he stated that he would like the exhibition space to be inspired by simple and "clean" modern art exhibitions.	

Table 12: Non-Functional Requirement # 10

Requirement #: 10	Requirement Type: Non-functional
Value: User will make most out of the experience without distractions.	Attribute:
Description: The teleportation should happen automatically once the user steps onto a blue teleportation portal.	
Rationale: The user should not be worried about which buttons to press, since some users are intimidated by controls. By automating the teleportation, the user can interact with the sculptures in a smoother manner.	

Table 13: Non-Functional Requirement # 11

Requirement #: 11	Requirement Type: Non-functional
Value: This gives us designers more freedom to incorporate prominent details and also saves times on details that are not seen by the visitors.	Attribute: Sculptures that are similar to Remy's but not exactly alike.
Description: The 3D modelled artworks are representations of Remy's work and are not intended to be exact copies.	
Rationale: Since 3D scanning was not an option to recreate the art pieces, we had to come up with a way to recreate the art pieces so that we could balance what is actually Remy's work and what is ours.	

Table 14: Non-Functional requirement # 12

Requirement #: 12	Requirement Type: Non-functional
Value: Body and Vision integration, increasing sensory systems [19].	Attribute: Head movements and joystick movements.
Description: Visitors move through the environment through natural body motions.	
Rationale: The visitors can look around and walk throughout the exhibition space freely as they would physically with the HMD and hand controllers.	

Table 15: Non-Functional Requirement # 13

Requirement #: 13	Requirement Type: Non-functional
Value: Body and Vision integration, increasing sensory systems [19].	Attribute: Head movements and joystick movements.
Description: The immersion score of each participant should be of at least 80.	
Rationale: The visitors can look around and walk throughout the exhibition space freely as they would physically with the HMD and hand controllers.	

6. Realization

The Realization chapter covers the technical intricacies of this project, which includes the tools used in the process of building the system, both software and hardware. It presents the final system, how the functionalities are worked out, aesthetics, and technical details.

6.1 Technical Details and Tools

This section explains the software and hardware used to build the system and the specific techniques and details behind it.

6.1.1 Software

Blender 3D

The 3D modelling of this project, which includes all assets presented in the virtual VR environment was entirely done in Blender 3D; no external addons were used. Blender was the chosen software because it is free and open for commercial properties, and I have previous experience with the software. After each asset was modelled and textured in Blender, they were exported as an fbx file, then later imported into the NeosVR environment.

Modelling

The 3D modelling of all assets was done through simple modelling in Blender. Most assets are a combination of different shapes such as cubes, rectangles, and triangles. The paintings were simply modelled as a 3D rectangle that serves as the painting's frame, and later textured with the painting's picture.

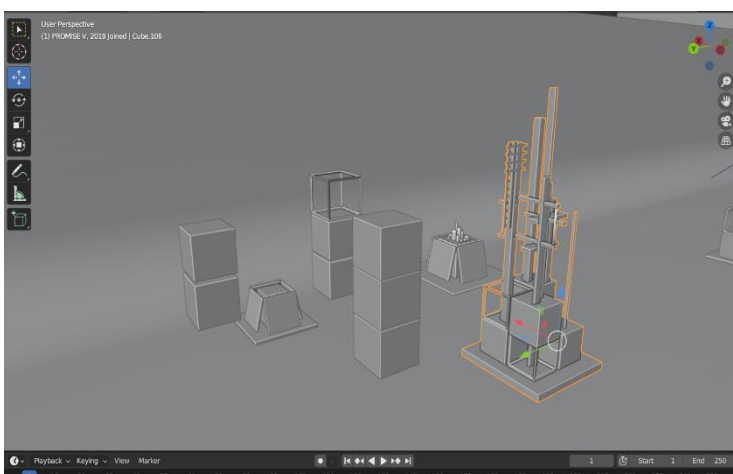


Figure 20: 3D Modelling of Sculptures in Blender

Sculptures were modelled from scratch based on reference pictures provided by Remy and found on the internet. It is important to note that while the sculptures do resemble Remy's sculptures, they are not exact copies, and some of them can deviate slightly from the photographs of the actual sculptures.

The Exhibition space was entirely modeled and textured from scratch in Blender 3D. The space is supposed to represent a modern/contemporary art exhibition room, with a large area where most of the sculptures are exhibited. Different existing art spaces from modern galleries and museums were used as inspiration when modeling the museum environment for this project. Such inspirations led to the color choices from the walls to the painting supports, the position of the various light sources, the material of the floor, and the size of the space.

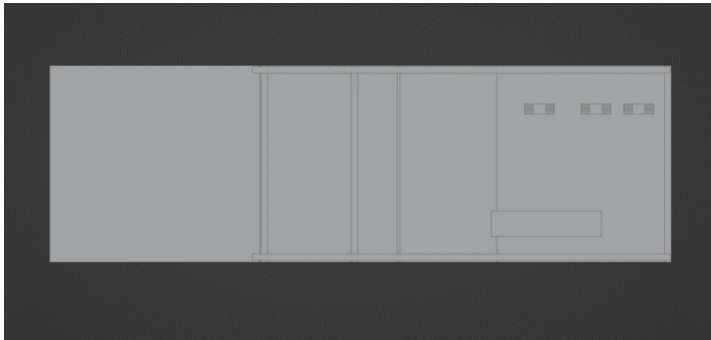


Figure 21: Floorplan Solid Top View

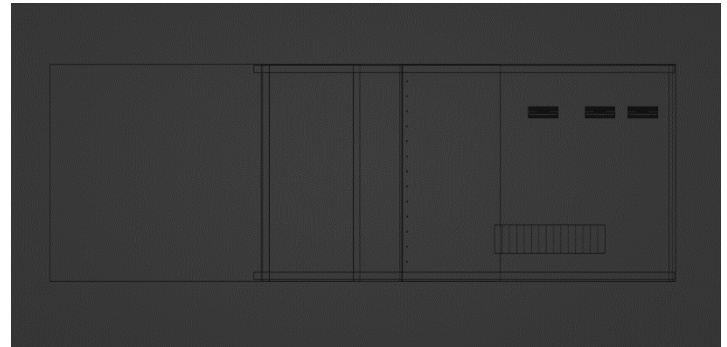


Figure 22: Floorplan Wireframe Top View

The exhibition space created takes inspiration from contemporary art museums and galleries. With modern touches to the room, spacious ambient, and pops of color.



Figure 23: Exhibition Render 1



Figure 24: Exhibition Render 2

Decorations

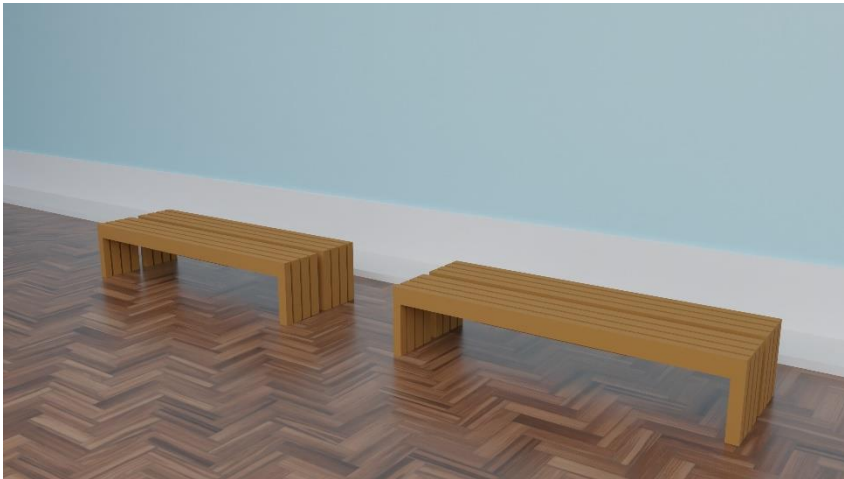


Figure 23 displays wooden benches which were modelled as a decoration piece for the exhibition.

Figure 25: Wooden Benches

Texturing

The texturing of paints and sculptures was done through different steps. For paintings, since Remy shared high quality pictures of them with us, it was possible to map them directly to a simple rectangle model. By UV unwrapping the painting “frames” (rectangle which holds the paintings), it was possible to directly project the images to the frame. UV unwrapping is a method where the 3D model is mapped onto a 2D version of its shape, making it possible for images and photos to be applied directly to its structure.

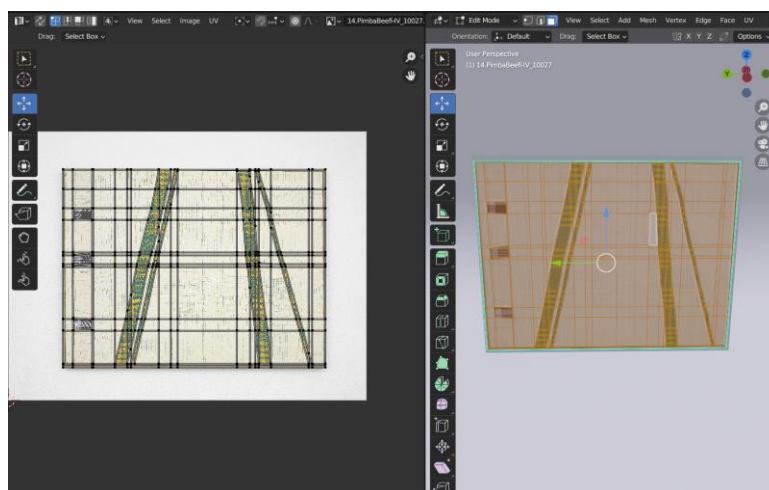


Figure 26: UV Editor & Textured Painting in Blender

For sculptures, the texturing was done differently. Since most sculptures are composed of many different pieces, and their geometry is not symmetrical in many cases, the unwrapping faces is not as simple as of a simple cube. The sculptures were textured based on reference pictures, and each

side was aligned following the same method as used for paintings. The normal maps that give texture to Remy's paintings were created in Photoshop.

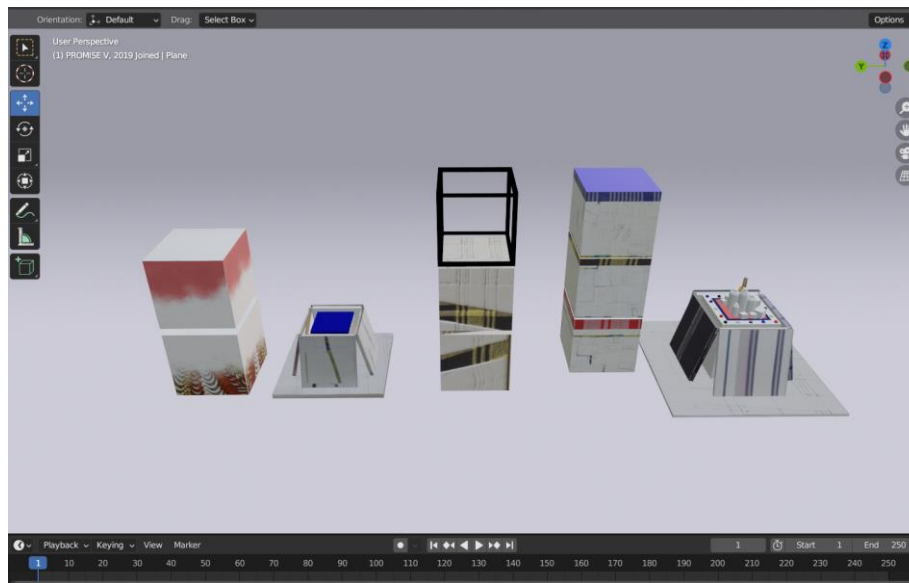


Figure 27: Textured Sculptures in Blender

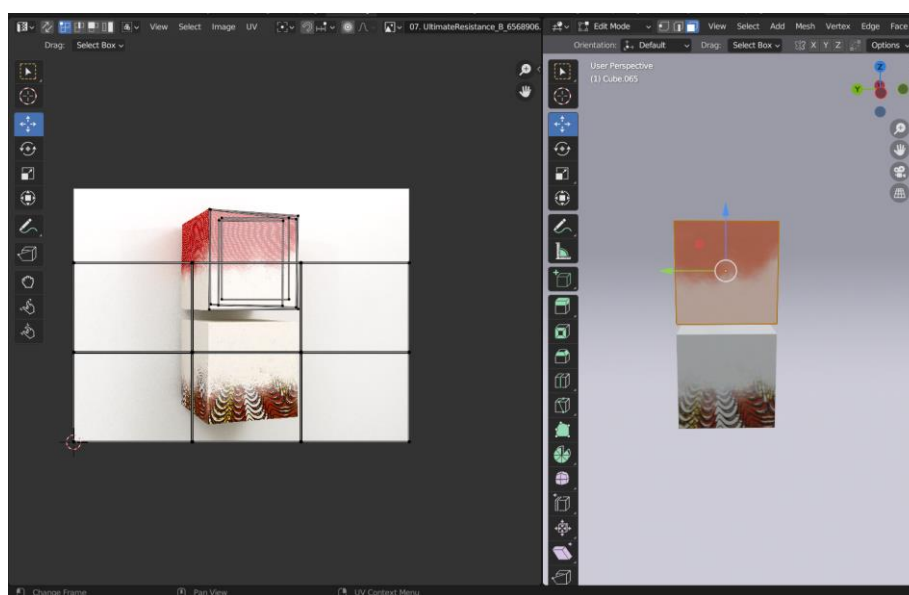


Figure 28: UV Editor & Textured Sculpture in Blender

All assets were exported in an fbx file which included both the object's mesh and their assigned textures.

NeosVR + Steam

NeosVR was used to assemble the environment exported from Blender, arrange the scene's lighting, and the programming and construction of interactions. NeosVR was chosen as the social VR platform for several reasons, first because it was introduced to us at the beginning of the project, and we decided to follow up on it. The look and feel of Neos caught my attention as it seemed more intuitive to use in comparison to Unity for example, which at a glance looks more complicated. NeosVR was also chosen because of the possibility to create interesting and meaningful interactions, like easily adding portals to different objects and easily incorporating text, images, and audio.

Placement of objects

After being imported into Neos from Blender, all the assets were arranged into an exhibition layout. All assets that had been previously textured in Blender maintained their texture when imported into Neos, and assets which were not textured beforehand were given a texture in Neos through Neos Materials tip.

Lighting

Light sources were not exported from Blender; therefore, they were all created in Neos. The environment, as default has a skybox, which essentially lights up the entire scene, however in enclosed spaces, like the exhibition space, more sources of light were added. On top of sculptures, spotlights were added, which highlight and gear the user towards them. Spotlights were also added to the ceiling and rotated to point at paintings and sculptures that hang from the walls.

Interactions

All interactions that make part of the system were created in Neos. For each sculpture, a copy was made, and largely scaled up, so when the visitor is transported to it, their relative scale to the painting makes them feel as if the painting was extremely large compared to their size, giving them the impression that they are inside the sculpture. The scaled-up copies of sculptures were placed outside of the exhibition space, in places of the map where the user is not able to access or see.

The user transportation happens through empty objects placed on two different parts of the world with a Locomotion component called TransportUser attached. By default, the transportation is one way, so two sets of portals are added to each sculpture and their scaled-up copy so that visitor can go into them and back to the museum space.

Avatars and User Choices

An important topic discussed in media applications [insert source from research] is the sense of user identity. Who you are online can reflect who you are offline, however it can also be totally different and diverge from your physical self. Such thoughts are important to consider when developing a system which will be used by different people. Who they are online also influences their action and reactions.

The chosen avatar was the default Neos avatar, where only the hand and VR goggles appear visible. The avatar has no visible body, wears modern gloves, and has a visible VR goggle.

Websites for Textures

Some of the textures used throughout the project were downloaded from websites which provide 3D textures, such as textures.com, poliigon.com, and freepik.com.

For most textures such as the exhibition's wooden floor, walls and ceiling, an albedo, normal and roughness map were downloaded and applied.

Textures used:

- White paint texture [29]: used on Remy's sculpture Fodu 1.
- Wooden texture [30]: used on the exhibition's floor.
- ccO texture package embedded in NeosVR.

6.1.2 Hardware

VR Headset

The VR headset used during this project was the Oculus Quest 2. This headset was chosen because it was available for the entire duration of the research and because I had previously been instructed on how to connect them by a staff member of the Interaction Lab at the University of Twente. Therefore, I decided that using this headset would be the easiest in terms of connectivity and troubleshooting.

Computer

The laptop used during the project is an Acer Nitro 5.

6.2 Final Exhibition Space

After all 3D assets were modelled, including the exhibition space, sculptures, furniture, and paintings, the exhibition was arranged in NeosVR. The final exhibition arrangement counts with six of Remy's sculptures and two of his paintings.



Figure 32: Final Exhibition Space Overview



Figure 29: Final Exhibition Space - paintings

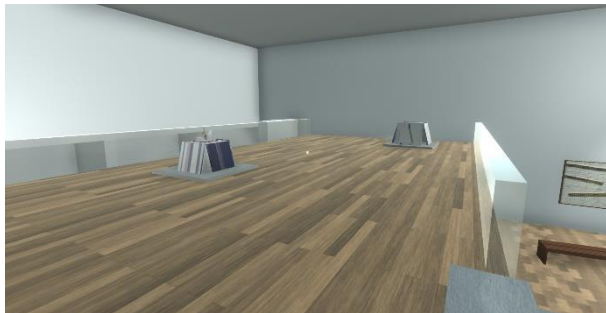


Figure 31: Final Exhibition Space - upper floor



Figure 30: Final Exhibition Space - upper floor

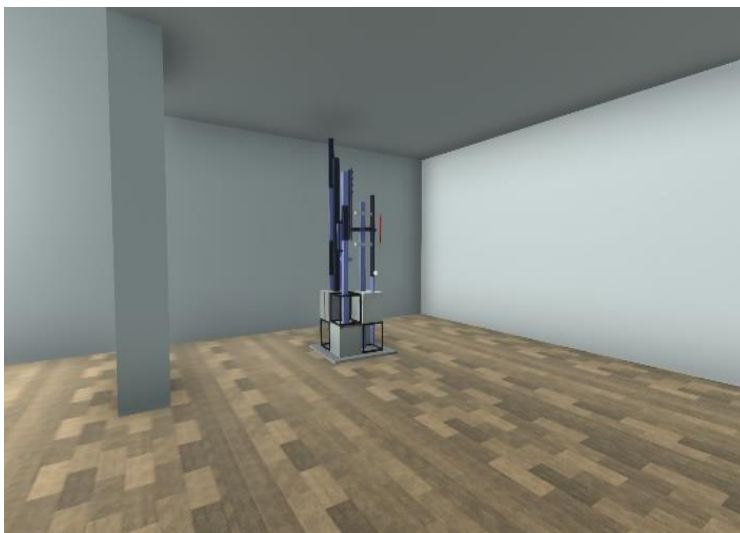


Figure 33: Final Exhibition Space - promise V

Changes to the exhibition space were constantly made, following an iterative process that led to the final exhibition space. Notable elements include the height of the ceilings, which were increased because of the user's height and its translation into VR. The art works are positioned in a way that the visitor moves through the entire space and can observe all art works. The figures in this page show how the final space was arranged, and the materials added in NeosVR.

7. Evaluation

The evaluation chapter explains in detail all steps taken during the Evaluation phase of the project. To properly evaluate the interactive virtual museum, participants were recruited to test the system and provide the researchers with feedback and data. The evaluation chapter includes the goals of this project's evaluation, followed by the evaluation plan, the recruitment process, the methods of evaluation, and the evaluation results. I will test if the system I have built is effective in increasing the levels of immersion felt by the users, and the extent to which the pre-established requirements are met. This will be done through two types of testing, first tested the requirements myself through usability tests, effectively identifying which requirements were met. After I conduct user tests with different participants, where the main goal is to collect data on their levels of immersion through a questionnaire and my observations.

7.1 Evaluation Plan

Prior to the users testing done for the evaluation, several steps were taken to ensure that little to no problems would arise during the testing sessions. This section explains the experimental setup, including all the materials used during user tests and how each of them was arranged.

7.1.1 Apparatus and Experimental Setup

Equipment used:

- Wireless Oculus Quest 2
- ASUS Rapture Router
- Acer Nitro 5 Laptop

The Oculus Quest 2 and Asus Rapture Router were reserved for the duration of the testing from the Interaction Lab at the University of Twente and the Acer Nitro 5 laptop is owned by the researcher. The router was needed to establish a wireless connection between the headset and the computer, since both need to be connected to the same network. Prior to the Evaluation, the researchers found that a cable connection delivered low fps and continuous connection issues, therefore, a wireless connection was chosen.

Arrangement:

- Interaction Lab at the University of Twente Campus
 - o Dedicated area for participant movement with VR of approximately 2 x 2 meters
 - o Dedicated area for researchers with table and chairs

Two rooms were booked during the evaluation week, which were divided between the three researchers. One headset was stationed in a smaller room, and the remaining two headsets were stationed in a bigger room, which could accommodate 2 simultaneous tests.

Software and Computer Systems

- Neos VR
- Steam VR
- Oculus Rift
- Windows 11

The VR headset was first connected to the laptop through Oculus Rift, and once the connection was established, Neos VR was launched through Steam VR.

Testing Schedule

The testing took place between the 12th and 16th of June 2023. 10 timeslots were assigned for each day, each timeslot was scheduled for 30 minutes, however not every slot of the schedule was taken, there were some empty slots. Some participants that tested my installation also participated in other user testing on similar subjects with similar setups as well.

Table 16: Example of Evaluation Schedule

Time	12/6	13/6	14/6	15/6	16/6
9:30 -10:00	...	...	...	...	...
10:15- 10:45	Participant x	Participant y	Participant z	Participant a	Participant b
10:45 - 11:15	Participant c	Participant d	Participant e	Participant f	Participant g
11:15 – 11:45	...	....	....	...	...
11:45 – 12:15	...	...	...	...	...
12:15 – 12:45	...	...	...	...	...

7.1.2 Testing Conditions

Two testing conditions were setup for the evaluation, condition A and B, making this a between-subject test where a participant only tested one condition.

A. Interaction

Condition A is identified as the interaction condition, essentially what tests the research questions. Here, the users will walk around the museum environment and be able to interact with the sculptures, like teleporting into them.

B. Constant

This condition is identified as the constant condition, where the interactions (transporting inside the sculpture) are not present for the users. The users will walk around the same museum environment; however, they are not able to interact with the art pieces, only observe them.

The pool of twenty-nine participants was divided semi-randomly between the two testing conditions, each day of the 4 days of evaluation were devoted for testing both conditions. At the beginning of each testing day, a condition was assigned to a side of a coin, which was flipped and indicated the starting condition for that day.⁶ The first slot of each day was determined through a coin flip, and each slot that followed was alternated between the two conditions.

⁶ I forgot to apply this to the first testing day, so I tested 6 participants with the interactive condition and none for the constant condition. On the remaining days I tried to compensate for this.

7.1.3 Procedure

The numbered list below presents the different steps taken prior to, during, and after each evaluation session. It provides a detailed explanation of each step, and a detailed presentation of the methods used during the evaluation are presented in the following sections.

Prior

1. Connect Router, VR headset, and computer.

- Make sure all devices are properly connected with cables and have power.
- Connect the VR headset with the computer through a wireless connection (Air-link)
- Position all equipment in a table where they can easily be handled.

2. Setup testing space

- Prepare the testing space the participant will be standing on by defining boundaries within the VR environment which are translated to the physical room.

3. Print Information Brochures and Consent forms

4. Welcome participant

- Greet the participant and follow by explaining more about the project and their importance in participating in the evaluation.

5. Both sign consent form

6. Debriefing of VR controls

- Explain the movement controls and how to properly handle the hand controller.

7. Adjust HMD

- Tighten or loosen straps of the HMD depending on the participant's preferences.

During

8. Participant starts interaction

9. Researcher writes down observations

- Write down observations specific to each participant based on previously established guidelines.

After

10. Participant fills out Immersion questionnaire

- The questionnaire was loaded in my computer, so participants could quickly fill out the questionnaire through a form. Their responses were collected and arranged in a google sheets file.

11. Thank participant for being part of the project

12. Participant exits

*15 minutes break between each participant

13. Repeat steps 4-11 for following participants

7.2.4 Hypothesis

The level of immersion participants experience in condition A is higher than the immersion experienced by participants of condition B.

7.2 Selection of Participants

7.2.1 Inclusion and Exclusion Criteria

Participants were included based on the following criteria:

- The participant is of 18 years of age or older.
- The participant has dominance over their upper body and can effectively control their movements with the VR controllers and headset.
- The participant does not suffer from epilepsy or conditions that are affected by swift digital movements, changes in lighting, and motion sickness.
- The participant can make choices independently without the aid from a guardian/second party.

7.2.2 Recruitment and Selection

An google form was sent out to different WhatsApp groups, where possible participants indicated their interest in participating on the evaluation. The interest form includes a brief explanation of the project, a picture of the VR environment, and the available dates which can be chosen by each participant. The form was distributed among different WhatsApp groups and between friends.

Apart from the interest form being sent digitally, a flyer was printed out and spread across the University of Twente's campus. The flyer contained information about the testing days, what the participants would be doing, and a QR code to the interest form.

In total, twenty-nine participants were recruited for this study, some of which also participated in Lilly Stelzer's and Jesper Hoogenkamp's research, which also deals with VR installations with the works of Remy Jungerman.

7.3 Methods

7.3.1 Participants

Twenty-nine (29) students participated in this research. The mean age was of 21 years old (SD = 1.99), ranging from 18 to 27 years.

At the start of each evaluation session, each participant was greeted by me (the researcher), followed by a brief introduction to the project, what their participation entails, and I thanked them for their participation.

After the verbal introduction, the participants received an information brochure with more specific details about the research, which apart from diving into the project's context, it also explains the participant's rights within the research, and what will be asked from them. After the participant has read the information brochure, they are handed a consent form, which explains the specifics involving the participant's involvement, and how the collected data will be handled. Both the researcher and participant sign the consent form with their names and signatures, and after that, the evaluation can begin.

Before each participant equips the VR headset, I ask them if they have used VR before, since some are already acquainted with the technology and don't need an explanation, but some are completely new to it, and require a more thorough explanation.

If the participant wants a brief explanation on how to use the controls, I quickly provide them with an explanation on the basic controls which include the two joysticks and buttons. However, moving around the virtual museum only requires the participant to use the joysticks on both controllers, and no button press is needed, which avoids confusion since accidental button presses could open menus. If a button was pressed, I aided them into closing the opened menu.

Finally, I help the participant with final adjustments to the head-mounted display, ask if they are comfortable, and tell them that they may begin exploring the environment. As mentioned before, I do not give the participants any context on Remy or on his artwork, and let the participant explore and analyse on their own.

The Information Brochure and Consent Forms used during the evaluation can be found in this paper's appendix.

This approach was approved by the faculty's (EEMCS) Ethical Committee under the application number: 230093.

7.3.2 Observations

Descriptive data was collected from the participants based on observational methods of their actions, reactions, and expressions, both vocal and physical. During each participant's interaction session, observations on their reactions, gestures, and on-screen interactions were written down based on topics of interest that I paid specific attention to, which go in line with the evaluation goals mentioned above.

The following list present guidelines that were considered when noting down observations for each participant.

Actions

- How long does each participant (condition A) spend inside each sculpture?
- Are they able to make their way around the exhibition?

Observable expressions

- Do they laugh?
- Do they say things while the interaction?
- How do they react to the art pieces?
- What do they say out loud?

Observable movements

- How do they physically react to the system?
- How quickly do they get the hang of the controllers?

Based on these guidelines, observations on each participant are written down to be further analyzed in the Results section. Since the participants pool is divided between conditions A and B, some observations are dependent of the condition, and cannot be analyzed for both conditions, like the time spent inside a sculpture for example. However, general observations can be used to take overall conclusions since they are independent of the condition the participant is in.

The participants will not be asked to speak during their interaction, however, they can, and their expressions and reactions will be written down. Verbal expressions are valuable as they are not subjective to the researcher's views and express what the participant intended to express.

7.3.3 Questionnaire

Measuring and Defining the Experience of Immersion in Games [31]

At the end of every participant's interaction round, they were asked to fill out a questionnaire related to the immersion they felt during the time they were in the virtual museum. The questionnaire used is derived from a journal article from Jennet et al. and is part of a set of often used questionnaires familiar to the human media interaction (HMI) community, which defines a measurable ground for immersion in games [31]. The paper present two questionnaires developed for measuring participant's immersion during different tasks in games; the second questionnaire is an extension of the first developed questionnaire because the researchers found that the positive and negative wording of the first questionnaire was confusing to the participants, therefore, creating a new questionnaire with simpler wording [31].

This questionnaire was selected to evaluate the immersion each participant felt during their interaction with the system. It is divided into different sections, concerning different aspects related to "attention (4 questions), temporal dissociation (6 questions), transportation (6 questions), challenge (6 questions), emotional involvement (5 questions), and enjoyment (4 questions)" [31]. Participants assign a score to each question based on a Likert scale numbered 1-5 and the total immersion score for each participant is calculated by summing all the scores assigned to each question. The hypothesis H1, states that participants that interact with condition A, will feel more immersed than participants that interacted with condition B.

The questionnaire constantly asks participants of their experience in *game*, which fits the context of the research done in the paper. It measured immersion in different game tasks, therefore, the wording used in it refers to the game each participant interacted with. However, there are no gamified interactions in this project, and it is not considered a game. Despite this different, the experience in the context of this project will be considered a *game*, in the lens of the questionnaire. Because of that, the questionnaire was deemed usable and was applied to during the Evaluation.

After participants finished interacting with the system, they were asked to score the 31 questions of the Immersion questionnaire through an online form provided by the researcher. The questionnaire's wording that referenced the "game" was pointed out to them, and it was explained that they could think of the game as their experience in the virtual museum, and not necessarily as a videogame, therefore, making the term interchangeable with the virtual museum.

The 31 questions from the Immersion questionnaire can be found in Appendix A at the end of this paper.

7.4 Results

7.4.1 Requirements

Before the user testing was conducted, the system requirements were tested.

Assessing the requirements previously established on the Specification chapter aids in evaluating if the built system works as intended, contains specified functionalities, and the areas of future improvement of the system.

The tables 12 and 13 below present the requirements which were satisfied.

Functional

Table 17: Functional Requirements Results

Requirement #	Result
1	Every participant that teleported inside the sculptures did so without external explanations.
2	The virtual museum has three sculptures that the user can teleport into.
3	Most participants had remarks about how the art works were very detailed and realistic.
4	While testing, NeosVR was running at a constant 72 fps, which meets the fps requirement.
5	The sculptures are scaled down in comparison to their original version to fit the exhibition space.
6	Users were able to visit the museum in any given order, but most of them usually followed the same pattern of first visiting the ground floor and later the upper floor.

Overall, the functional requirements previously established were in most cases met, with the exception that there were three sculptures the user could interact with, not four. The main functionalities were present, and there were no major issues with the interactions of the system.

Non- Functional

Table 18: Non-Functional Requirements Results

Requirement #	Result
7	The users that tested the interactive version did go inside a portal within 1 minute of seeing the portal. After the first try, every user understood what the blue portal were.
8	All 3D assets were modelled in Blender.
9	Participants pointed out that the environment did resemble a modern art museum. "It looks like a modern art museum I've been to (p4)"
10	The teleportation was completely automatic. Once the user stepped into one of the blue portals they were teleported into a sculpture.
11	The art works displayed in my virtual museum are not exact copies of Remy's work, but 3D modelled representations.
12	The required physical movements for interacting with the system were only head movements, as the user could virtually move through the museum with the joystick on the hand controllers.
13	There were only three out of the twenty nice participants with an immersion score lower than 80, namely 76, 76, and 78.

The non-functional requirements were mostly met, with the exception of the last requirement, where three participants did not have an immersion score of 80, however this is a small part of the sample. Overall, the requirements were met, showing that the built system did work and look as it was intended to.

7.4.2 Qualitative

The qualitative results were collected through observations written down during each participant's interaction. Observations on their reactions, speech, expressions, and their interactions in-game were written down. These include how they walked through the environment, how close they observed the art pieces, how fast they moved through and their easiness to learn the controls.

A table containing the detailed annotations of observations can be found in this paper's appendix B.

The observations are separated between conditions A and B since for each condition, participants experienced different things, therefore they cannot be analyzed together. However, the observations are later used to further analyze and support the quantitative results of this research and can help explain some results further. Aside from the condition specific observations, there are general observations on behaviors that participants from both conditions demonstrated.

1. **Getting up-close to the paintings on the wall.**
2. **Notices details on paintings and sculptures and points them out.**
3. **Expressed that the "paintings look realistic."**
4. **Felt excitement when first entering museum.**
5. **Virtually walking slowly around museum space.**

Participants from both conditions were, overall, very fond of Remy's artwork and expressed excitement when getting up-close to the pieces. Participants expressed their excitement over Remy's art by highlighting the interesting details and patterns, vivid colors, and by verbally expressing phrases like "wow" (p 4,7,9,22, and 26), "very cool" (p 3, 4, 6 ,13, 15, 27), "nice art pieces" (p 9), and "love this" (p 7). Remy's prominent pattern work, involving bright colors and minute details was almost always noticed by participants. Participants would sometimes ask to know more about Remy and his art, indicating that they not only enjoyed being in the virtual setting, but that the art itself was interesting to them.

Participants from the interactive condition were more impressed by VR and the interactions, while participants from the non-interactive condition were more impressed by the details in the artworks and focused more on the art itself.

7.4.3 Quantitative

The internal consistency of the questionnaire answers of both conditions was calculated through Cronbach's alpha. Based on the calculations of internal consistencies, given by the alpha coefficient, both conditions have an acceptable inter-correlation amongst their items.

Cronbach's alpha

Interactive Condition = 0.794

Constant Condition = 0.833

The immersion scores for each participant were calculated following the method mentioned in Jennet's et al. journal [31], where the score is calculated by adding all the individual questionnaire questions, 31 questions in total, with a maximum immersion score of 155.

For each condition, the immersion score for each participant was calculated, and the sum of all immersion scores. With that, the mean immersion score for each condition was calculated, as well as the standard deviation.

Table 19: Descriptive Statistics for Immersion Scores of Conditions A and B

	Condition means (and standard deviation)	
	Interaction Condition	Constant Condition
Immersion Score	98.47 (11.74)	95.71 (13.23)

Based on the calculations of immersion scores for each condition, the immersion score for condition A indicates that participants that tested that condition felt more immersed on average over participants that tested condition B. However, the difference in mean immersion scores is not significant, and indicates that for both conditions, participants felt immersed. The low difference in mean immersion scores is further explored in the Discussion chapter.

8. Discussion

The evaluation results were overall very positive, with data that supports my hypothesis, and observations that can be used to further improve my project.

Based on my observations, all the participants felt some level of interest and excitement when moving through the VR museum. However, I noted something interesting between the two tested conditions. Participants from condition A were more excited about going inside the sculptures and being inside them, therefore less focused on the details of the actual space. While participants from condition B were more excited about observing sculptures closely and about the actual art pieces themselves, being more focused on details of the actual space. This can be the case because the interactive condition allowed participants to do something that they would not be able to otherwise, thus turning the focus from the art pieces away and focusing it at the teleportation. However, I do not think this is necessarily bad, since the participants were still excited about the details on the art pieces, but for future work, a balance between these two aspects can be further investigated.

Participants that evaluated the interactive condition (A) were more immersed overall (3% more immersive), despite the low difference in immersion scores. This means that even though these participants indicated that their immersion during game was higher, the small difference tells us that participants from the constant condition also felt immersed. Without a doubt I think that the interaction of teleporting inside the sculptures added to the participants sense of immersion, since they could feel as if they were inside the sculpture, however, I do think that most participants felt immersed because they felt present in the museum. The realism in the art works and to some extent the museum space translated to a physical museum. This translation from the digital to physical is reinforced by such details, and since most participants were constantly observing these details closely, I think that this was the factor that increase their sense of immersion.

The virtual museum contributed to something that ultimately, visitors would not be able to experience in a physical museum space. They were able to walk extremely close to the paintings and sculptures, and most interestingly, go inside some of them.

Some of the participants also tested other projects with similar topics and setups, because of this, there is a possibility of a learning curve effect between the participants of all three projects. If a participant tested 3 projects consecutively, they could have experienced things in each installation differently, leading to slight changes in reactions, or their level of experience in movements could have increased from one test to another.

Some points of improvements were mentioned after the testing was completed and can be helpful for future improvement. One of the discussed points relates to paintings presented in the virtual museum space, where some participants highlighted that two out of the three paintings seemed too flat in comparison to the painting which contained a normal map. This could be easily adjusted in a future iteration, with the addition of a normal map to the remaining paintings.

It was also discussed that Remy's narrative was not entirely clear to visitors as there were no introductory texts provided at the start of the exhibition. This was previously discussed in this project's introduction, where I chose to implement the system without much context on Remy nor his artwork, this way the visitor would have as much of a subjective visit as possible and be able to formulate their own thoughts to some extent of what the artwork represents to them. More context can be given, however, about the artworks themselves, with texts that include their names and a short description. Despite not having any given context on the art pieces, participants seemed to have enjoyed Remy's artwork, something that is also meaningful for this project.

On the topic of interactions, some participants noted that they wish there were different types of interactions. Initially, I wanted to include interactions like buttons to open doors and light switches but did not include them as I thought they would distract the user from the main interaction of teleporting in the sculptures. I do agree that maybe one type of interaction might be less engaging, so different types of interactions can be explored that are still meaningful to the goals of the exhibition.

Lastly, this project contributes to the growing body of research on the intersection of art and technology. Focusing on the applications of virtual reality in transforming traditional art experiences in more immersive experiences, it can provide valuable insights to artists and technologists that focus on building more captivating experiences. Artists can use of this research to understand and explore ways that their art can be presented through non-conventional ways.

9. Conclusions

This project has explored how immersive VR can be used in art to increase the feeling of immersion visitor's attribute to their experience and how this technology can tackle marginalization in the art world. Based on the results of the evaluation, the system I have built contributed to increasing the feelings of immersion that visitors attributed to their experience by enhancing their sense of presence and connectedness with the artworks and the environment.

The virtual museum showcases Remy's artworks in a novel and exciting way and provides him with a space to present works to a broader audience. The highlighted issue of marginalization is tackled by providing this space to artists, where they can focus on different aspects of their artwork, providing new experiences to visitors.

Meaningful Interactions are extremely important, as it was shown that participants that interacted with the interactive condition were more immersed than the participants that tested the constant condition. The interactions contributed to the participant's sense of immersion by adding a layer of interaction that added more meaning to the sculptures and Remy's work.

The system fulfills the established requirements, and there were no major flaws identified, but there are limitations to the system. Despite the system functionalities, there are some aspects which can be further improved for future research. More meaningful interactions will engage the visitor with the artwork while providing artists the choice to deepen their stories. More work needs to be done concerning the building of such VR environments, however this project has shown that the visitor's sense of presence and connectedness is extremely important and should be considered during the process of creating such environments.

VR has shown to be a promising and useful technology in the field of art. As explored in this project, in combination with 3D assets, social platforms, and physical gear (HMD, controllers), VR can be used to increase artistic experiences in many ways. Through meaningful interactions, engaging mechanics, and interesting stories, art can be presented in a different way than it has been shown before.

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Appendix

A. Immersion Questionnaire Questions

Please answer the following questions by circling the relevant number. In particular, remember that these questions are asking you about how you felt at the end of the game.

To what extent did the game hold your attention?

Not at all 1 2 3 4 5 A lot

To what extent did you feel you were focused on the game?

Not at all 1 2 3 4 5 A lot

How much effort did you put into playing the game?

Very little 1 2 3 4 5 A lot

Did you feel that you were trying you best?

Not at all 1 2 3 4 5 Very much so

To what extent did you lose track of time?

Not at all 1 2 3 4 5 A lot

To what extent did you feel consciously aware of being in the real world whilst playing?

Not at all 1 2 3 4 5 Very much so

To what extent did you forget about your everyday concerns?

Not at all 1 2 3 4 5 A lot

To what extent were you aware of yourself in your surroundings?

Not at all 1 2 3 4 5 Very aware

To what extent did you notice events taking place around you?

Not at all 1 2 3 4 5 A lot

Did you feel the urge at any point to stop playing and see what was happening around you?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel that you were interacting with the game environment?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were separated from your real-world environment?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel that the game was something you were experiencing, rather than something you were just doing?

Not at all 1 2 3 4 5 Very much so

To what extent was your sense of being in the game environment stronger than your sense of being in the real world?

Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you were unaware you were even using controls?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were moving through the game according to you own will?

Not at all 1 2 3 4 5 Very much so

To what extent did you find the game challenging?

Not at all 1 2 3 4 5 Very difficult

Were there any times during the game in which you just wanted to give up?

Not at all 1 2 3 4 5 A lot

To what extent did you feel motivated while playing?

Not at all 1 2 3 4 5 A lot

To what extent did you find the game easy?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel like you were making progress towards the end of the game?

Not at all 1 2 3 4 5 A lot

How well do you think you performed in the game?

Very poor 1 2 3 4 5 Very well

To what extent did you feel emotionally attached to the game?

Not at all 1 2 3 4 5 Very much so

To what extent were you interested in seeing how the game's events would progress?

Not at all 1 2 3 4 5 A lot

How much did you want to "win" the game?

Not at all 1 2 3 4 5 Very much so

Were you in suspense about whether you would win or lose the game?

Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you wanted to speak to the game directly?

Not at all 1 2 3 4 5 Very much so

To what extent did you enjoy the graphics and the imagery?

Not at all 1 2 3 4 5 A lot

How much would you say you enjoyed playing the game?

Not at all 1 2 3 4 5 A lot

When interrupted, were you disappointed that the game was over?

Not at all 1 2 3 4 5 Very much so

Would you like to play the game again?

Definitely not 1 2 3 4 5 Definitely yes

B. Evaluation Observations

Table 20: Evaluation observations per participant

Participant	Condition	Observations
1	A	<ul style="list-style-type: none"> - Excited about teleportation. - Did not see portals (blue boxes around sculptures) initially. - Gets very close to sculptures and paintings → observing of details. - Pointed out that it “felt like a game.” - After first teleportation, figured out what the portals were. - After teleporting inside all sculptures, they highlighted that it offered a “new perspective to details.” - Demonstrated excitement when going inside the sculptures
2	A	<ul style="list-style-type: none"> - Observed every art piece very closely. - Noticed details (rough parts of paintings, patterns on sculptures) and pointed them out loud. - Looked at portal, got close, but did not go through → I had to tell them about the portal. - Looked around very slowly when inside Promise V. - When inside Fodu 1 and Horizontal → fell of the platform a lot and had difficulty walking from one side to the other.
3	A	<ul style="list-style-type: none"> - At the very start exclaimed “it looks cool” → referring to the whole environment. - Asked “can I interact?” - Noticed portal and pointed it out. - Was excited about going in the portal, even without knowing where it would take them. - Figured out how to jump with the controller, jumped around inside Fodu 1. - Looks like is having fun, by smile and movements inside the sculptures. - Pointed out that they wanted to interact more with the art. - Noticed details more when going inside → “I can really see details now.”
4	A	<ul style="list-style-type: none"> - Looking around at the beginning, hesitant to walk around. - Got very up-close to the paintings. - Excited when going inside Horizontal → “wow!” - Asked about materials and showed interest in art pieces. - “It looks like a modern art museum I’ve been to”. - Fodu 1 - Looks around first, then goes through portal. - Jumps on top of boxes. - Gets the hang of the controls. - Promise V - Looks around after going inside → “very cool.” - Got motion sick and asked to stop.
5	A	<ul style="list-style-type: none"> - Took longer to get the controls → was first time using VR. - Points out “realistic paintings.”

		<ul style="list-style-type: none"> - Looked closely at paintings and sculptures. - Noticed details and pointed out that “from up close they are very detailed.” - Noticed materials more when going inside the sculptures. - Talked about the materials and colors. - Promise V - Reminded them of Mondriaan. - Really liked going inside. - “Looks like you’re really inside the sculpture.” - “Looks like a (video)game.” - Fodu 1 - Surprised about being inside → was not expecting it. - “I feel like Antman.” - Jumped onto blocks. - Looked at all art pieces very closely.
6	A	<ul style="list-style-type: none"> - After getting up-close to paintings, they noticed the normal maps and bumps of paintings. - Horizontal - “Very cool” - Fodu 1 - Highlighted that making a ramp instead of stairs would be easier for the user to go up to the mezzanine. - Hard to maneuver with controller. - Promise V - Felt dizzy but liked the scaled-up sculptures.
7	A	<ul style="list-style-type: none"> - “Love this!” → first thing they said when starting. - Looked closely at details. - “The art is very nice.” → liked Remy’s art. - Observed patterns and pointed them out. - Felt dizzy and wanted to take a break → I asked if they wanted to stop but they said they wanted to continue. - Walks around the entire space. - Fodu 1 - “I’m in!” → excitement after teleporting in, unexpected. - Jumps around blocks. - Promise V - Slowly walks around and notices details. - “Wow!” - Horizontal - Looks down at avatar’s hands and points it out. - Turns head to see things around them. - Jumps around. - Highlights that they enjoyed the experience even though they felt dizzy.
8	A	<ul style="list-style-type: none"> - Likes the smooth turning. - Found portals and noted them.

		<ul style="list-style-type: none"> - Notices that the image was a little blurry, got better after adjusting the HMD. - Horizontal - "Pretty sick!" - Laughs and enjoy being inside sculpture. - Confused about going back to the main space. - Promise V - Jumps around and looks up at scaled-up pieces. - Fodu 1 - Jumps on top of boxes. - Looks closely at all details. - Walks in between boxes and places which others had not been before. - Explores.
9	B	<ul style="list-style-type: none"> - Looks first at paintings, then goes to sculptures. - "Nice art pieces." "Wow!" - Went back and forth between paintings.
10	B	<ul style="list-style-type: none"> - Noticed avatar's hands. - New to VR but got controls easily. - Liked how each art piece had their own space → doesn't feel cramped. - "Very interesting." - Liked being able to walk around sculptures up close. - Pointed out that it is nice that there is one bench for each painting → liked the details of the museum.
11	B	<ul style="list-style-type: none"> - Noticed avatar's hands. - "Interesting textures." - Liked the space's architecture. - Wanted to interact with pieces. - Got up and close to paintings. - Wanted to change locomotion to be able to fly around → got dizzy. - Had throwback memory because of the exhibition space's architecture. - Felt immersive even though no interactions. - Liked that they could see the avatar's hands.
12	B	<ul style="list-style-type: none"> - Shocked when looking around. - First time in VR - Choppy movements but later got smoother. - Noticed a continuity on paintings and similar patterns throughout pieces. - "Surreal" → very excited. - Liked the amplitude of the space/exhibition. - Asked about the relation of pieces with each other. - "Loved it!" "Reminds me of buildings" → Promise V. - Noticed patterns in Remy's works. - Liked the avatar's hands.
13	B	<ul style="list-style-type: none"> - Observed paintings closely → "interesting." - Wants to go all around the space.

		<ul style="list-style-type: none"> - Looks and sounds excited → “super cool!”
14	B	<ul style="list-style-type: none"> - Curious about sculptures → “this is nice.” - Asked about Remy and art pieces. - “I liked being in the museum in VR” “Liked the actual experience, not the art.”
15	A	<ul style="list-style-type: none"> - Swift movements - Saw portals and pointed out what they were → interacted early on. - Horizontal - “Interesting” “so cool.” - Talked about colors and materials. - Promise V - Looked around, not very intrigued. - Fodu 1 - Interested → “cool colors and shapes.” - Noticed that it is different from the rest. - Starts confusing and hard.
16	B	<ul style="list-style-type: none"> - Excited when jumping → got controls easily. - Got close to sculptures and observed details closely. - Walked around all the sculptures. - Interested in the art but did not really understand it.
17	B	<ul style="list-style-type: none"> - Walked around the space first before going to the art pieces. - Got very close to the art pieces. - Expressed excitement when being able to go up close.
18	B	<ul style="list-style-type: none"> - “Beautiful art” - “Looks like the art is actually here in front of me.” - Got up close to the paintings → liked the textures when looking from the side. - Moved painting around while grabbing it → knew controllers. - Kneeled to see details more closely. - Rotated sculptures with controllers. - Went “inside” even in the non-interaction condition.
19	A	<ul style="list-style-type: none"> - First time using VR. - Closely observing details. - Crouched to see details better. - Went into portal without knowing → then discovered what it was. - Promise V - “Holy shit!” - Walked around entire piece. - Looked at portal for horizontal and knew what it was. - Horizontal - “Crazy!” - Jumping around and interested in the details.
20	A	<ul style="list-style-type: none"> - Got close to paintings and said, “this is cool” “nice.” - Crouched and ducked to see details through a different perspective.

		<ul style="list-style-type: none"> - Horizontal - "that's cool!" "that's amazing!" - Was excited about seeing colors and patterns up close and standing on top of them. - Promise V - "Became so cool!" - Fodu 1 - Jumped on top of blocks.
21	B	<ul style="list-style-type: none"> - Liked their shadow casted on the wall. - Attentive to details, slowly walking around and away from sculptures. - Observing art pieces from different angles.
22	A	<ul style="list-style-type: none"> - "Didn't image the blue box was a portal." - Interested in the story that the art tells → wanted to know more. - Asked about Remy and the art pieces. - Liked hands of the avatar. - "Cute environment." - Noted that there could be more paintings on the white walls. - Fodu 1 - "Incredible!" - Pointed out that they liked seeing the textures and materials up close. - Promise V - "Wow!" → excited - Changed locomotion to fly around → "So cool!" - Horizontal - Can really see the details up close → "very nice."
23	B	<ul style="list-style-type: none"> - First time in VR - Noticed normal maps on paintings → "looks cool." - Went super close to the art works. - Liked the remodelling of the pieces.
24	A	<ul style="list-style-type: none"> - Liked the hand movements. - Asked about the materials when getting up close. - "Textures look 3D." - Fodu 1 - "More interesting" → more interesting when going inside. - Jumping on top of blocks. - Motion sick because of jumping around. - Promise V - "Very nice" → when going inside. - Horizontal - "interesting" → looking at patterns. - Unexpected. - Went mainly for portals → did not observe other art pieces so closely.

		<ul style="list-style-type: none"> - Experienced physical sensitivities.
25	B	<ul style="list-style-type: none"> - Asked about Remy → wanted more context. - Virtually walked to paintings straight away and got very close to them. - Expressed that they liked the environment → “modern looking environment, I like it.” - “Very nice sculptures” → found sculptures interesting and aesthetically pleasing. - Expressed that they wanted to jump using the controllers. - Physically crouched to see the sculptures from a different angle.
26	A	<ul style="list-style-type: none"> - Before moving around museum they looked at the avatar’s hands - “So cool” → first impressions. - Physically crouched and sat down to observe details from more closely. - Was trying to “touch” paintings through their hand gestures. - Horizontal → “wow! So cool!” - Promise V → flew around the scene and looked at a lot of details. - Fodu 1 → flew around the scene as well.
27	A	<ul style="list-style-type: none"> - Textures “look real.” - Goes very up close to paintings. - Promise V → went inside on accident, “very cool!”, “lots of interesting elements.” - Horizontal → Observes details, feel a couple of times from the edge, did not comment. - Fodu 1 → Liked bottles and how it made them look tiny. - Constantly crouched to see different details.
28	B	<ul style="list-style-type: none"> - Asked about Remy was interested in knowing more about him. - Walked quickly past sculptures but said that they look very interesting in VR and even possibly more interesting in VR than in real life.
29	B	<ul style="list-style-type: none"> - Asked if they could interact with the art pieces, asked if I would eventually add interactions. - Virtually walked very slowly around the sculptures. - Was surprised at the level of details of the art pieces.

C. Information Brochure

VR Exhibitions: provoking feelings and emotions through immersive art in museums

Dear reader,

In this letter, we would like to inform you about the research you have applied to participate in. This research focuses on a Virtual Reality (VR) exhibition created by the researchers which displays the works of Remy Jungerman, a Surinamese artist who creates unique pieces to tell stories and display feelings of the Maron culture and traditions. The goal of this research is to test and evaluate if the design choices in building the VR environment enhance the user experience in line with the researcher's questions. As a participant, you will interact with the system by equipping a VR headset and walking around the virtual exhibition. During the process, the researchers will take notes on observations. After the interaction, you will be asked a series of questions related to your experience, what aspects of the interaction were meaningful, what could be improved, and overall feedback. This will help determine if the VR experience enhanced the feelings and emotions of the participants.

Your participation is and will remain voluntary at all times and you can withdraw from the research and end your participation at any point during the research. You can also withdraw from the research after you have initiated it, within 24 hours of the starting point. During the experiment, we will observe your interactions with the system and take notes on it. After the experiment, you will be asked a series of questions, and your answers will be digitally written down. No Personally Identifiable Information will be gathered, and any transcribed information which might lead to your identification will be removed from the transcription. The information gathered will consist of age, occupation, and responses to questions.

Since this research deals with VR, there are possible risks involved. If you have had previous experiences with VR in which you experienced any sort of motion sickness, dizziness, or any side effect, we advise you not to participate. If you choose to participate, the researchers will monitor you (the participant) during the whole duration of the experiment. If you still experience any sort of sickness, you are free to back out of the experiment at any time and the researchers will assist you if necessary.

Yours sincerely,

Research leader: Felipe de Andrade Ramires

Email: ⁷

Research assistant:

Lilly Stelzer

Email:

Jesper Hoogenkamp

Email:

Coordinator:

Carolien Rieffe

Email:

⁷ Emails have been omitted for privacy reasons.

D. Consent Form

"I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure. My questions have been answered to my satisfaction. I agree with my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my expressed permission. If I request further information about the research, now or in the future, I may contact Felipe Ramires."

If you have any complaints about this research, please direct them to Felipe Ramires, email: f.deandraderamires@student.utwente.nl.

Signed in duplicate:

Name subject

Signature

I have provided explanatory notes about the research, I declare myself willing to answer to the best of my ability any questions which may still arise about the research.

Name researcher

Signature