USING VIRTUAL REALITY TO ENHANCE SOCIAL MUSEUM VISITS

Bachelor thesis

Lisemijn Presser
Supervisor – Shenghui Wang

Abstract

Museum learning environments are constantly evolving in the ever changing modern world. The possibility of innovative technologies such as virtual reality could add an additional layer of understanding to the origin story of the displayed cultural heritage. Such technologies could further open up the possibilities of increasing the engagement of the user beyond the possibilities of the real world. Often such implementations are solely focused on single player usage, however the addition of a second user within the virtual environment could increase the communication and cooperation within the experience, allowing for the sharing of knowledge between users. In the context of this graduation project, such implementations were explored in the past art installation HERE, Black in Rembrandts Time by the Rembrandts Huis. The goal of the project was to investigate how the engagement of the user could be influenced using virtual reality, and how the usage of this technology can optimally involve the user into the story of the installation. From the researchers side this meant that a prototype had to be created where multiple engaging elements were incorporated. After the completion of this installation, the used design tactics and multiplayer elements were evaluated in the form of a user testing, allowing for the collection of data on the users behaviour and understanding of the exhibition. The results lead to the discovery that both single player as multiplayer variations of the installation could aid in the optimalization of the users engagement, depending on the preferred method of processing in the user. However, future testing with an improved version of the installation should be done to ensure that a definitive conclusion can be constructed on this matter, ensuring that variables such as the unstableness of the virtual reality hardware does not impact the results. For now, the conducted research serves as the opening of a doorway for the conveying of the story of cultural heritage in virtual reality, creating a museum learning environment beyond the borders of reality.

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Chapter 1 – Introduction

The usage of virtual reality has become increasingly popular in museums throughout the years. This fairly new technology allows for new forms of interaction using innovative ways of conveying the story behind an art object. The usage of such technologies will shift the focus of a museum from an object based visit to a more experience based user environment, creating situations that would not be possible in real life [1]. However the opportunities of such technologies are still vastly unknown. The prioritization of certain aspects of virtual reality could lead to optimal engagement and communication, conveying the intended message of Cultural heritage. These elements, together with the story of the object, create a new and appealing learning experience in museums. When looking at the currently available virtual reality museum visits, it becomes clear that the main focus of the installations lies on enhancing the experience of the user while stepping on the borders of reality. However, said visits often focus on creating an immersive environment for one user only. The current market VR installations has a gap when it comes to multiplayer experiences, with yet to discover possibilities of this as an additional design element.

The Rembrandts huis in Amsterdam has stated its goal in creating such an installation, by reworking the older physical installation 'HERE black in Rembrandts' time into a virtual museum visit. This installation was created with the aims of displaying portraits of people of colour with respect and dignity, outside of the usual stereotype. However, problems arise when moving an exhibition into the digital world as it removes the tangible element of a museum, making it more difficult for the audience to experience engagement, or immersion in virtual reality. The multiplayer aspect of the installation is aimed to add human interaction within the digital environment, opening up the possibility of the user to connect with another person.

Thus, this graduation project will focus on creating a multiplayer based VR visit for the Rembrandts huis in the upcoming software NEOS. This software serves as a platform for online VR creators and opens up the possibility of exploring virtual worlds with multiple people around the world at the same time. The final installation aims to create an interactive learning environment that presents a new way of conveying the story of the displayed cultural heritage, optimizing the users immersion and understanding. The exhibition will incorporate design techniques intended for full engagement, taking advantage of aspects that a multiplayer environment can offer, in contrast to a single player VR visit.

To support the process of this project questions are formed to aid the design process and scope out the intended goal of the thesis. These questions are divided into one main research question and two supporting questions, digging deeper in two specific design elements:

- **How can virtual reality enhance engagement of the users during a social museum visit, presenting cultural heritage?**
- What design tactics can be implemented to help convey the story of the artist in a way that will leave an impression on the users?
- How can a multiplayer environment encourage the users and thus each other to look deeper into the meaning behind the object at face value, as an alternative to a single player VR visit?

The thesis at hand is divided in multiple chapters, leading up to a fully finalized design and product. The decision that were made along the way will be build up by research done in the first chapters, leading to conclusion on the research questions that were previously presented. This will be followed by a detailed methodology and ideation into the first user testing. A finalized concept of the virtual museum visit will then be taken into the specification and realization chapter, where will be developed into a working prototype. Additionally, the installation will be tested by a group of participants, where the collected data will be taken into the last chapters, discussing the findings and conclusions of the conducted research. In the

end it is aimed to give a clear overview on the process of designing a multiplayer virtual reality visit and give insight on future design and research work that can further improve this branch of product in the world of cultural heritage.

Chapter 2 – Background Research

To build on the research that will be conducted during this graduation project and aid the design process of the installation, the following background research will shed light on a handful of topics relating to the stated research questions. This chapter is divided into three sections. The first being a literature review on the engagement of the user and how it can be enhanced using specific design elements. The second section will provide relevant literature on the subject or surrounding the focus of virtual museum visits. The third and last will consist of a detailed state of the art, giving an overview on the current available virtual reality visits and its varieties.

2.1 Literature review

To understand when certain design tactics result in optimal engagement and immersion, designers must first gain knowledge on this feeling and how it can be influenced. Thus, this literature review is aimed to give insight on how virtual reality can enhance the engagement of the user during a museum visit. The gained knowledge will help future designers understand how virtual reality can change the world of storytelling in current museum settings. For clarity, a division into three sections is made. The first section of the review will define the feeling of engagement and how it can be measured to use during the design process of future virtual installations. The second gives an overview of the effect certain design choices can have on the experience of the user and which aspects should have priority in order to achieve optimal engagement. Lastly the limitations of virtual installations in a museum based learning environment will be listed, giving clear insight on the current gaps of this technology that should be considered in future design processes.

Understanding user engagement

Understanding the feeling of engagement can help discover how a museum visit can be optimized to leave an impression on the user. Prior knowledge on the human response to activity will help unravel the ways of optimizing a user′s engagement. The usage of measuring methods specifically designed around this feeling can give insight on what elements leave an impression on the user in a museum learning environment. According to [1: 510], "Audience engagement at its most inclusive level covers any activity where the visitor interacts with a display beyond just a walk through.". A user is fully engaged with the installation at hand when they are immersed within the story that is told and are able to connect with the cultural heritage through interaction. Engagement is deemed as vital in the design process of virtual installations and creation of an immersive experience for the user, although it is often not clear how to measure this feeling amongst the user in the first place. It should be noted that since the act of engagement will be conceived differently depending on each user, making it difficult to find a method that can objectively measure the user′s actions. However, as optimal engagement is deemed a desirable aim for museums, it can be seen as highly important to gain more knowledge about this matter before developing future installations [1].

Even though there is a clear gap in the current knowledge on engagement, there are a number of possible measuring methods. This opens up the possibility of comparing data between users in the aims of creating an optimal learning experience. These methods can be divided into two clear categories, with the first being subjective measurement methods. In this category the subjective characteristics, such as the feelings and

emotions of the user are measured, often done using questionnaires or interviews [2]. In some situations the Geneva Emotion Wheel (GEW) method can be used, detecting the emotions that were felt during the exhibition, their intensity and valence (positive or negative) [2]. Another possible method is the usage of the Uses and Gratification theory (U&G) as a theoretical lens during user testing. According to Shahab *et al.*, "U&G research provides an opportunity to examine gratifications sought (GS, i.e., expectations) and gratifications obtained (GO, i.e., experiences)" [3: 3]. U&G measures the motivation of the user and helps create designs that meet the users expectations without overfilling them. It is thought that within the balance of expectations and experiences, optimal engagement can be achieved.

The second category is objective measurements, focusing on the usage of heart rate monitoring, EEG, eye tracking and body sensitivity mappings. EEG highlights different brain waves of the user, measuring the active parts of the brain during the exhibition and the amount of stimulation [4]. Of most importance are the alpha waves and beta-band oscillations, which play a role in the multiple sensory processes of the user. These elements together can suggest increased cognitive processing as a sign of engagement of the user [4]. The same can be achieved using heart rate monitoring and body sensitivity mapping, only here the focus is put on the user's bodily reaction during the installation. This reflects how the emotions evoked by the installations affect the user's body [2]. Lastly, eye tracking can give insight on what parts of the presented cultural heritage attract the attention of the user. This can give an overview of the most viewed design elements, giving information on which parts of the objects should receive the most attention when creating the installation [2].

Opting for only one measuring method, can have a major disadvantage in the researching process. For example, when only a subjective measurement method is used. The results of such tests are written by the users themselves, making the data self-tested which sometimes leads to incorrect conclusions. Vice versa, only using objective measurements might result in a lack of insight in the feelings of the user that were felt during the exhibition. For this reason it is always recommended to use both measurement categories, giving a rich insight into what factors lead to optimal engagement of the user during a virtual exhibition. Usage of these methods in future research will close the gap on the current lack of knowledge on engagement, helping to evolve current installations and increase the user experience in a museum learning environment.

Conveying a story using design

The use of design tactics can aid the process of creating an exhibition that conveys the story of the artist while immersing the user in the experience. Such tactics aim to create optimal engagement of the user in the exhibition, putting the focus on involving the user in the story of the cultural heritage. Thus the main goal of the type of design tactics used should be to involve the user in every aspect of the experience. Rahimi *et al.* stated that the use of the theoretical perspective of spatial experience could serve as a good base structure for designing a virtual museum exhibition [5]. This theory follows a simple three step process that would ultimately lead to an optimally designed installation with maximal user involvement: "(1) people need to be sufficiently encouraged to get involved in the experience, (2) be enabled to connect with the context, and (3) be triggered to perform a behaviour." [5: 1472]. The usage of this theory could serve as a baseline when starting the design process of creating a virtual installation.

To increase immersion into the virtual environment two main design tactics can be defined. The first element would be the involvement of senses that would not be stimulated in a real museum, giving a whole new layer to the user experience. The digitalization of the objects opens up the possibility of handling them which would normally not be possible due to safety and the fragility of the object. This lets the user investigate all its details, really getting the chance to get involved [6]. This also adds a tangible element to an

intangible experience, making the installation feel more realistic. Objects from museums are more easily distributed this way, opening up the possibility of using cultural heritage that would not be safe for travel or handling from other museums [6]. Other senses like hearing can be advanced through sounds, helping to further convey the emotions of the object, increasing the understanding of the user. When adding all senses, a new world can be created around the object, possibly recreating the original surrounding of the object. This would give the user further insight into the history of the cultural heritage, adding an additional storytelling element. This method has been proven to increase engagement in the user as it adds context to the object, allowing the user to make a connection with the object and creating opinions while the story is taking place [5]. The inclusion of all senses increases involvement of the user with the installation, changing often passive users to active, further enhancing their learning experience [7]. This coincides with the second design element, which is to encourage the user to make their own decisions in the installation's story. Implementing the freedom of choices in the installation will allow the user to make their own connections, giving them a feeling of autonomy [5]. This way, the user can decide how they would like to experience the installation, as not everyone processes information the same way. This would make the installation more inclusive for a broader user target group, increasing the overall understanding and effective learning of the user.

The implementation of the above discussed design tactics can be used to create an optimal experience and learning environment for the user. Thus, the installations should be focussed solely on interacting the user and immersing them in the story of the cultural heritage. To achieve this a few key focus points can be noted that have been proven successful. First and foremost, the installation should make ways for the user to interact with the cultural object, perhaps giving the possibility of manipulating it. This gives the user an opportunity to explore the object themselves ,creating their own opinions on the object and the feelings it's meant to convey [8]. Another implementation could be letting the user step into the object, thus experiencing the story of the object's origin. In [1] Neher states a virtual exhibition where the user was able to step into a photo of the Holocaust, letting the user see beyond the borders of the picture. Here, photorealism and 360° storytelling are top priority as this gives the user freedom in which matter to experience the story, passive or active. Furthermore, incorporation of storytelling by the usage of human actors will give the user a realistic human interaction, increasing their cognitive functions [9]. Lastly, the intended emotion of the object can be incorporated into the digital environment [10]. Enhancing the emotion of the object's story throughout the installation in the forms of immersive sounds or colour theory would stimulate the user to take effort into understanding the material, thus increasing their learning [8].

Virtual reality and its challenges

The lack of knowledge on the limitations of virtual reality due to the novelty of the technology, can lead to future obstacles in the development of virtual museum visits. When looking at possible limitations of implementing virtual reality into museum exhibitions, two key problems can be found. The first problem, safety of the user, can be seen as the main issue in future implementations. Since the user will be closed off from the real world they can't sense the environment, opening up the possibility of accidents [5]. Thus, in cases where the users have no prior experience with virtual reality, such visits should always be accompanied by employees, ensuring safety of the user. Another coinciding problem might be unfamiliarity with the technology, possibly causing confusion or motion sickness [9]. This further stresses the need for an instructor or employee aiding the user. The third key problem that might occur entails a more design based limitation. The change from real life to virtual reality has the disadvantage that the presented objects are no longer real. When the presented objects are no longer tangible it might be difficult to give meaning to them

[11]. Thus it is even more important to increase immersion in future virtual exhibitions, possibly taking the creation of a digital world to an advantage and using this to make up for the lack of reality.

Conclusion

This review aimed to give more insight into how the act of engagement can be incorporated into the design of virtual museum visits to optimize the user experience. This reaction proved difficult to define and measure due to its subjective nature, leading to virtual installations that optimized immersion of the user. However, more and more measuring methods for engagement have become available, ranging from subjective to objective. A combination of these methods has been deemed as most effective, giving rich data on the user's engagement during the virtual visit on both mental and physical levels. The resulting data can aid when deciding what type of design methods are deemed effective in a museum learning environment. Tactics like the incorporation of senses or the inclusion of storytelling with human actors led to high engagement in the user. Depending on the virtual installation, such elements can be incorporated in the form or sounds, handling of the object or the ability of choosing a path of exploration. The focus here is on stimulating the cognitive functions of the user while giving them autonomy of their experience.

Due to the novelty of virtual reality the scope of implementing engagement is still quite unknown. Common limitations such as motion sickness and the intangibility of digital environments can make the design process difficult. Due to a clear gap in research on such limitations and the definition of engagement, the creation of an optimal installation design can be deemed as challenging. Thus, further research needs to be done in order to create a clear overview of the impact of engagement on the museum world. Furthermore, even though a clear list of immersive design tactics are available there are still many parts of virtual reality left unexplored. Most virtual installations still follow the 'rules' of the real world bounded by the recreation of real life. However, as virtual reality knows little to no limits design wise, using this as an advantage might result in the creation of a new horizon, leading to a world on the border of reality.

2.2 Related research

Handling sensitive heritage.

When it comes to displaying cultural heritage and its origin story, it can become apparent that sensitive subjects must be communicated in order for the user to understand full context. Thus when designing an installation that handles such sensitive heritage, one needs to take into account how to best communicate the matter in a respectful way.

This too applies for the installation that will be created for the graduation project, as the installation 'HERE. black in Rembrandts time' talks about racism and stereotypes in the past. The installation is aimed to give new viewpoints on wrongfully assumed stereotypes during Rembrandts time, hoping to change the current assumptions surrounding the history of people of colour. Thus the focus in the installation is put on people of colour with ranging backgrounds, displaying the actual diversity from around Rembrandts time, that people often have little to known knowledge on. The intended goal with this installation is thus to educate and inform people on the sensitive history surrounding racism in the 1600s. Additionally this exhibition is hoped to encourage people to be more open and willing to learn about the past, proudly showing people of colour from ranging backgrounds as the main focus in paintings. As discussed in [12], sensitive subjects in a society's history are often not acknowledged in the hopes of erasing a difficult past, often resulting in making

the underlying issues more apparent. It is thus important that these subjects are thoroughly presented, giving full insight on society and its history.

When looking into possible design tactics or ways of presenting used for sensitive heritage, the literature available on such subjects is quite scarce. It was thought that explored literature could possibly aid the design process making sure that the focus optimally remains on the story being conveyed while additionally engaging the user. It was found that the handling of a sensitive subject in a museum can be quite challenging. Depending on the subject that is being dealt with it might be difficult to incorporate immersion in the overall experience as it might result in emotions that do not fit with the intended story. Thus, one might then become more hesitant in the development process as the goals of respectfully conveying the intended story and increasing the engagement and immersion of the user are not easily balanced. Wrongfully presenting new and sensitive information can put the user in a stage of 'wilful ignorance', impairing there learning process. Though according to [13], this the incorporation of emotions should not be feared, rather taken as an advantage when handling such difficult heritage. The atmosphere of a museum combined with the sensitive subjects handled in the exhibition can increase the users learning and understanding [1]. However, here it is additionally stated that this often results in provoking unsettlement in the user during the experience as a design tactics., resulting in rethinking and increased learning in the user.

However, even though this tactic might be effective and commonly used around sensitive heritage, this does not quite fit with the intention of the installation HERE. Black in Rembrandts time. As this installation aims to shed positive light on the subject of assumed stereotypes surrounding people of colour, emotions like unsettlement are often negative in nature and do not correspond with the intended message of the curator. The incorporation of said emotion will quite drastically change the overall message of the installation, which is not the goal of the project. Thus, the current found design tactics surrounding sensitive heritage will not be taken into account during the next steps of development, rather put on the side as an indication on how other museums handle the conveying of sensitive stories. The final installation will therefore not include any design tactics specifically created for handling sensitive heritage, rather put the main focus on incorporating the usual strategy for engaging the user additionally putting respectfully handling the installations intended message as a main focus.

2.3 State of the art

As a building block for the research and development that will be done during the graduation project, a thorough research will be done to set a scope of the current state of the art of virtual museum visits. In this chapter the current assortment of virtual museum visits will be compared and categorized with the aims of creating a clear overview of existing designs in the virtual museum world. This overview will give insight into the type of design elements and implementations that are repeatedly used, and thus are deemed effective for the desired goal of creating an engaging virtual museum installation.

Even though the final installation for this graduation project will be created for a multiplayer setting, the research mainly focus on the design and current state of the art of single user virtual art installations, as multiplayer virtual installations are still in the development stage. Focussing on multiplayer exhibitions only would result in a very small selection of installations and would thus not provide a rich amount of data where one can see or conclude similarities. However two multiplayer art projects will be highlighted as these might provide new design elements that come into play when engaging multiple users at the same time. These cases might also form a clear gap on multiplayer virtual museums visits, giving some insight on what

elements can be put as the main focus of the graduation project, leading to new and unexplored paths in the world of virtual museums.

Modern single player art installations

When it comes to the current range of available virtual reality museum visits, a clear categorization can be made. Virtual museum visits are often divided into two types, both displaying cultural heritage however each containing a specific type of content.

The first category references to virtual installations containing broad content [14]. Here, installations take on the form of digital museum spaces or art galleries, displaying a range of cultural heritage with different origins. These museums are aimed to create an experience similar to normal museum visits. Objects are displayed in realistic environments, sometimes replicating the museum or surrounding of its current housing, thus replicating a normal museum experience. Such museums give the opportunity of sharing the museum experience in a digital world, making the installations more inclusive. This opens up the opportunity for experience for people with a disability or people from different countries to view cultural heritage in a similar matter compared to real life. Installations like these can easily be produced as museums often allow for open access to pictures or information about art objects. Digital art galleries can thus easily be created by anyone, easily distributed using platforms such as Steam and Oculus. This adds onto the argument of easy accessibility, however also opening up the chance of mistakes.

Such art galleries often contain errors, wrong units or bad quality of the displayed art, reducing the immersion felt by the user [14]. To add to this, the type of installations often create a passive experience for the user. Often due to the lack of interaction with the object itself, or added on experience into the installation apart from the possibility of walking through the exhibition, audiences are less prone to be fully engaged. In digital museums it is often difficult to immerse the user as the tangible object have become intangible in the digital world. Interaction is needed, to give the user context and experience, giving meaning to intangible environment [1].

The second category of virtual art installations makes use of software with specific content [14], focussing on a single art object or artist throughout the museum exhibition. This decision allows for the creation of a more customized environment that coincides with the story of the displayed object. This further opens up the possibility of adding more context and information to the installation as there is room for one object or artist to be the centre of the experience. Installation such as The Eye of Owl by Bosch VR [14] go beyond presenting objects, transforming the whole world around it and emphasizing emotion by including all senses into the experience. This can include music, interaction with the objects or animated parts in the installation itself. In some cases, the user might be able to jump into the object, experiencing the art from the inside instead of looking at it.

Using this approach of displaying art in a digital world, the virtual aspect is used as a way to go beyond real life, compared to using the technology as an add on into the experience. This way, the user is more engaged and immerged in the story, increasing the learning experience and the ability to understand the context of the museum. A small downside could be the length of such installations, as they are often shorter than the first category. However, due to the increased immersion and additional elements, a longer duration of such experiences could be perceived as overwhelming to an unexperienced user, thus a shorter timespan might fit in this specific situation.

Multiplayer virtual experience

The addition of a multiplayer element in art installations is very new and thus unexplored. To get an idea of the current stage of this added element a few cases will be discussed. A combination of the approaches that were used in these situations will give insight into aspects that might need further research or development, finding the gap that this graduation project can fill. In the first case that will be explored [15], the virtual environment opens up the possibility of two players experiencing the same exhibition at the same time. In the second [6], users are stimulated to experience the world on their own, however can see other players in the same environment. This case also has the addition of a virtual tour guide, an element that will also be explored in the graduation project. Both world use the addition of a multiplayer element differently, however both give insight on how the added elements perform with the aim of increasing engagement within the user.

The case of hybrid worlds

The first case presented at hand is the hybrid virtual and augmented reality environment created by Li and Ch'ng. In this environment two users are able to socialise between two different worlds of reality technologies. One user will be immerged in a fully immersed virtual world, whereas the second user would make use of augmented reality (AR). AR combines the real world with the virtual, adding augmented objects to the physical world [15]. In this case the users were presented with a handful of objects in a museum setting. The AR user can interact with an app on their phone. Using a cube that is connected to the software on the phone the user is able to tilt the cube, resulting in the tilting of the art object on the phone. This augmentation is synced with the same of object in VR meaning that interactions between the worlds result in changes in both environments. During the study the communication that took place between the users was observed together with the interactions and engagement with the objects.

From the study results of this story it was found that conversations were initiated between the users to indicate both were matched with the same objects [15]. Furthermore, in the interview that took place after the testing, users commented that the addition of seeing each other's head and torso movements in the environment contributed to their experience. When it comes to the communication between the users, the test resulted in the sharing of personal experiences or relations with the object, contributing to each other's learning experiences. Subjective interpretations were shared, stating relevant information or personal experiences, giving insight on the differences of understanding of the material at hand between both users. This gives another point of view when it comes to interpreting given information with specific context. In the interview the users stated that the exchange of information and difference in interpretations added on to their experience and their understanding of the presented objects.

Furthermore, cooperation was observed, even though the installation was not specifically designed for said interaction. During the testing the VR user tried lifting an object to view the back size, however it was deemed impossible due to its size. The AR user however had the added possibility of rotating the object, and used this cooperation technique to aid the VR user, allowing for the viewing of the back of the object.

This case study gives great insight into the changes a multiplayer environment can make when it comes to the engagement and learning of the user in a virtual reality visit. The addition of a second user allows for communication and cooperations as was seen during the testing, adding a new layer to the possibilities of virtual museums.
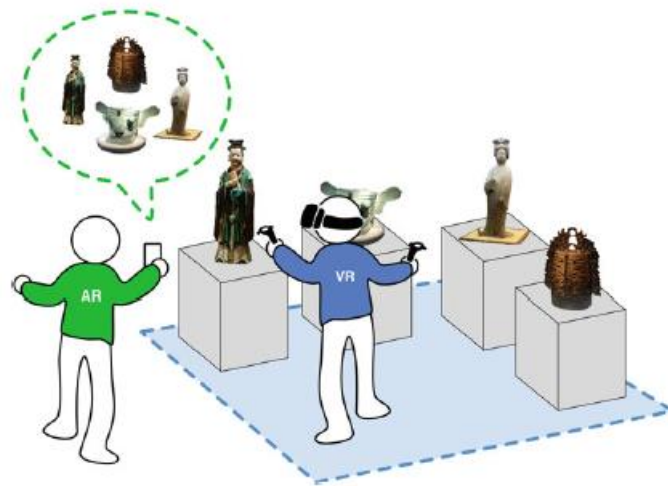
Figure 1. A scenario of use in the hybrid virtual and augmented reality environment (Li and Ch'ng [15]).

The case of the 2Gether museum visit

In the 2Gether museum different objects from different geographical locations are brought together with the aim of creating an digital exhibition. By using both 2D and 3D objects, different types of interactions and animation can be created in order to engage the user with the installation. Depending on the objects the user can interact with a replica or look at an animation of said objects. Furthermore, a Points of Interest (PoI) activity is created for each object. These activities can be done by users if they want to delve deeper into the object and learn more about its meaning [6]. Lastly, here an embodied virtual tour guide is also present, giving additional information of each object to the user. While in the installation other users and the tour guide can be seen in the same environment. To add to the realism of the installation realistic 3D models are used as representation.

When analysing this case however, one can view a lot of points are lacking in order to create an optimized multiplayer environment. Even though the users can view other visitors in the virtual world, the installation is not created for interaction or communication between users. This installation is set in a real life museum giving the possibility of the user to jump into the world using VR at every art object that is displayed. A few sets of VR headsets are available and attached to a computer, opening up the possibility of a second person viewing the digital world outside of VR, however the experience can only be done in a fixed space. Users in VR can see each other but cannot interact, this leaves space for possible future improvements to further engage the users. Furthermore, even though a tour guide is used in the installation, adding a human factor to the environment, the guide has a fixed amount of information that will be given when the user triggers a threshold for specific object. The user is not able to further interact with the guide, however this can be improved in the future by implementing a real person as additional virtual guide.

When setting the case of the 2Gether museum and the hybrid world case side by side, one can see that the implementation of multiplayer to a virtual museum visit can differ drastically. This can often depend on the goal and intend of the installation. The first case was specially designed for social interactions, meaning that this was taken into account during the design as the main goal. However in the second case, the multiplayer effect was not the focus point. Here it was aimed to enhance learning amongst the user, resulting in a very different outcome.

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Figure 2. The presented guide for the 2Gether museum (Tsita et al. [6]).

Comparison with the graduation project

When comparing the current state of the art of virtual cultural heritage installations with the virtual visit that is aimed to be developed during the graduation project, a few key differences can be found. First of all, most art installations are focused on single player experiences only. The decisions and paths that can be taken during the virtual exhibition are carried out by a single user. Interactions created during the experiences are between the user and the virtual world or the cultural heritage that is on display. However, as seen in the case of the hybrid world, the addition of a multiplayer element can drastically change the interactions and experience of the museum visit. This element opens up the possibility of interaction and communication between users increasing their learning and understanding while also attaining the different views of the other users. However when implementing this, it should be taken as a main priority during the designing and development process of the installation. As seen in the case of the 2Gether museum, when handled as an additional element without priority the multiplayer element will not seek out its full potential. This creates a missed opportunity when it comes to the design and the optimization of the users engagement. Thus with this project, elements of the first case will be used. The focus will be on creating an interactive multiplayer environment such as in case one, with communication being the main driver of engagement and immersion. The inclusion of a second user stimulates allows for the sharing of knowledge on art presented at hand and stimulate the use of cognitive skills during the museum experience.

Chapter 3 – Methods and Techniques

To start up the design process of the graduation project, a clear method must be selected. Said design method will give a coherent structure and steps that can be followed during the engineering of the aimed final product. As these methods can range depending on the field and the nature of the product development often a combination is used. For this project the chosen design method will be a balance between the Divergence Convergence [16] and Spiral methods of design process, specifically designed for the study Creative Technology by Angelika Mader and Wouter Eggink [17].

The design process for CreaTe emphasises the steps of the design process that are specific for the study Creative Technology. This method is split into four phases, where each phase includes a divergent stage of multiple ideas and a convergent phase where the design space is reduced until one final solution is reached [17]. The first phase *ideation* consists of definition of the problem and collecting the relevant knowledge surrounding it. Using this data a variety of ideas will be generated, sharing the similarity of approach, leading to the desired goal. The next phase *specification*, a number of prototypes used and evaluated with a feedback loop, aiming to further explore the design space of the project. During the *realization* the product specification will be dissected opening up the possibility of realizing components needed for the engineering of the product, followed by the integration of said components. Lastly, the created prototypes will be tested during the evaluation phase and requirements that were stated during the ideation phase are carefully examined, checking if they are fully implemented in the design.

For this project specifically the emphasize of this process will be on the user testing. As the installation aims for optimal immersion and engagement for multiple users at the same time, the optimalization of the product for the user is the projects main goal. Thus, as is often done with Human-Centered Design (UCD), the development of the product will be an iterative process. The goal here being the creation of fully understanding the users, their needs and their context in all stages of design and development [18]. These consideration will be carefully taken along the whole process into developing the product.

Furthermore, during the fourth phase user testing will be done by letting two or more people interact in the same exhibition at the same time. However, in addition an investigative tool used in UCD will be used, namely in the form of a survey. Here, the users will be asked to fill in a survey with questions about their experience and engagement. These survey will hopefully give insight on whether the implemented design techniques help convey the intended story and result in the desired emotion in the user. Furthermore, this survey can give insight into any negative or positive aspects the user might have experienced during the museum visit. These aspects could apply to the overall design of the installation or possibly problem with elements of the technology used. As virtual reality is a fairly new concept, it still needs tweaking to result in a user optimized product.

Chapter 4 – Ideation

Following the first phase in the creative technology design process [17], this chapter focuses on narrowing down the problem statement, specifying the needs on goals of the product and using these to create the initial designs. These designs will be generated by combining results from a brainstorm session with the elements of the background research that were found to result in optimal engagement in the user. Using online questionnaires, the concepts will then be presented to the user target, aiming for feedback on specific design elements and developing a scope of what is deemed as a desired virtual installation design according to the user. The collected data will be implemented in the initial designs creating new and improved concepts that incorporate user feedback into the goal of optimally creating a virtual learning environment.

4.1 Defining the problem

A detailed definition of the problem statement will help understand the scope of the design for the graduation project. When starting the ideation into the development of the product it should be clear what elements should be taken into account and arranging in order of importance. By combining gathered information from the client with the background research done in chapter two, the following aspects define the current scope of the problem.

First and foremost an addition of a multiplayer element should be incorporated into the installations design. This could be in the form of a tour guide or a second user. The priorly conducted background research showed that the implementation of these two options both lead to a different result when it comes to user engagement and learning. The implementation of a tour guide can give the user more information on specific details of the presented cultural heritage, additionally allowing them to ask questions about any parts of the context that might be difficult to understand. The implementation of a second user in the environment opens up the possibility of communication between peers and cooperation in the experience, which was found to increase learning and engagement in the user [15].

However, both of these implementations have added downsides. As each user learns differently, active or passive, such implementations won't fit everyone. A passive user might find the communication with a tour guide bothersome and would rather experience the installation solo. However an active user might want to learn each and every detail and would enjoy the company of an expert. Different conversations will take place depending on the relationship of the people in the virtual environment, a relation of two peers is different than the professional relation between a user and a tour guide or expert. Thus when implementing it should be taken into account that options for both active and passive users are available.

The second element would be increased immersion. The goal of the final virtual installation is to rework the physical installation of 'HERE. Black in Rembrandts time' adding new ways of interacting with the given cultural heritage and information that was lacking from the original exhibition. Since virtual reality removes the tangible aspect of the experience, additional design elements should be implemented into the installation to keep the users entertained and increase their cognitive skills [11]. Thus the focus should be on creating ways of interaction that would catch the interest of the user. However, here it should be kept in mind that such implementations are often done by the 'gamification' of the exhibition. For this specific situation, this should be carefully looked into as a difficult subject, racism in the time of Rembrandt, is incorporated into the story. The aim of the immersive elements should not be on the enjoyment of the user but more the learning, making sure that all implementations are done respectfully.

Lastly a few restriction should be kept in mind during the creation of the design. It was noted by the client that for this project a digital version of the original exhibition would be used as a base. This was decided as a conservator had carefully planned and designed all its little details, meaning that the erasure of such would remove the incorporated story the installation was meant to convey. This meant that the layout of the environment should stay the same, also counting the placement of the paintings, lighting fixtures and given information. Furthermore, the way the presented information was worded should preferable also remain somewhat identical. These limitations can somewhat narrow down the possible implementations of the installation as the main environment cannot be changed. Thus, unconventional ways must be discovered to develop an immersive environment without changing the story as told by the curator.

4.2 Initial creation of design concepts

For the development of the initial design concepts, it was decided to have a brainstorm session in the form of an organized mind map to roughly get an idea of all the implementations for the project. The initial ideation session was done simply with paper and pen, however for clarity a Miro board was created of the final elements and concepts. On the Miro board, the possible design choices were divided into the development of the multiplayer aspect in the installation and the inclusion of enhanced immersion of the user.

Figure 3. The Miro board of the initial ideation session.

Following from the brainstorm session, two main concepts were developed. These concepts arose from elements mentioned in the discussed research and information discussed with the client during past meetings.

Initial ideation session concept 1

The first design would be the creation of a second world behind a presented painting. Here the user would be able to open up the object, resembling a door of some sorts, letting them step into a new environment.

Following this interaction it was thought that there would be three variations on what would be shown in the world behind the canvas. The first version would show an environment resembling the 1600s. The user would be taken back to Rembrandts time, creating a environment that would fit with the mood and depiction shown on the presented painting. Here the user has the possibility of looking around and possibly interact with object from that time, giving them context on what was deemed normal around that time.

The second version would put the user in the shoes of the painter. Here the user would be seated as if they were creating the painting, however now being able to see beyond the borders of the canvas. This could be compared an animation created for an exhibition about the Holocaust as was presented in the Background information. Here the user was able to step into the picture, experiencing an animated version of the object.

The last version, would take the user into the process of creating a painting from start to finish. This could entail a small story where it is shown how canvas or paint medium was created in the 1600s, giving the user more background information while also learning about the artifacts materials. All these versions would have the incorporations of multiple senses through sounds and touch while also adding in storytelling elements. These are the two main design elements found in the literature review as effective for the users and where though to increase learning and understanding. The implementation of two different design techniques in the form of combination could possibly be even more effective in the goals of creating optimal engagement.

Initial ideation session concept 2
The second concept would be to let the user interact with certain elements or details of importance to the paintings importance. This would entail that the user could 'pick up' objects and take them out of the painting, allowing them to take a closer look. Objects taken out of the object could be presented with additional information to the user. This could be about the type of material, how an object was made, symbolism or cultural significance. This implementation would focus mainly on incorporating touch as its main sense, however other sense could be included when it comes to conveying the additional information. The information on the object hold by the user can simply be presented using text, however audio or animation could also be a viable option. Another addition to this concept could be the inclusion of a tour guide. The tour guide could then form the way of communicating the additional information on the artifact. Here another element could be the changing of the avatar when a new object is picked up from the painting, changing it to fit a person of the same level of wealth or a craftsman that would have knowledge on the object. This concept incorporates both senses and the addition of the user to make choices in how they would like to experience the installation, giving them a feeling of autonomy.

Multiplayer elements
One thing to note with the presented concepts is that although the incorporation of a tour guide is possible, there are no multiplayer specific design elements included. The reason for this is that so far, no specific implementations were found to increase immersion or communication in social virtual reality. As this is still quite a novel concept, there are currently no proven ways of influencing engagement in a multiplayer format. One could understand however, that since engagement is a subjective matter, it cannot easily be grouped or enhanced for multiple users at the same time. It could very well be that design tactics used to engage individual users, are just as effective in a social virtual environment. It should thus be noted that even though the current concepts might use design tactics created for the individual user, the addition of social environment might still result in the aimed level of engagement and learning in the user. However, this should then first be tested before one can conclude such hypothesises. Therefore, a goal for the next phase would then be to test the current concepts and see how these would function in a multiplayer setting.

4.3 Collecting user data

Using the format of a questionnaire possible future users were asked questions divided in three separate categories, ranging from past museum experiences, knowledge on virtual reality and feedback on initial design concepts. The user target here are people who would be interested in learning more about cultural heritage, varying in age groups and genders for optimal inclusivity. Furthermore the group included a set of people currently studying the minor of conservation of Cultural Heritage. Because of the close relation of these users with museums, with often weekly museum visits, this group gives interesting insight on frequent elements or lacking elements in a variety of museums in the Netherlands.

The three categories will shortly be discussed together with some reasoning on why certain questions were asked, however the details and full questionnaire can be found in appendix B. Starting with the first category 'Museum Behaviours', the 14 users were asked about aims to get insight on the users average behaviour in physical museum visits. These ranged from whether the user had visited a museum before to how they would like to experience an exhibition. Additionally it was asked if the user preferred making use of the available guided tours or if they would rather roam free and experience the museum on their own. If the first was preferred, users were asked if they would hesitate in asking questions or would easily exchange words with the tour guide. In case of the latter, it was then asked if company of other people would improve their experience or if they prefer to visit the installation individually. These follow up questions were included in the questionnaire following a discovery done during the research phase, also touched upon in the problem definition section. From the research it was concluded that all users learn differently, ranging from passive to active [1]. Furthermore, it was understood that the relation between two users or a user's relation with the tour guide differ. Some users are more hesitant asking questions or sharing information with an employee or expert on the field of cultural heritage [19]. Thus, these questions were asked in the hopes of getting insight on whether this can indeed be the case, hoping to include this in the future installation designs.

The second section 'Virtual Reality' asked the users some general questions about their prior, if any, experience with virtual reality. If prior experience with virtual reality is found a follow up questions about any experienced problems is asked. As was found in prior research, it is often found that users experience motion sickness or problems with orientation during their experience with virtual reality. It is hoped that this question will give insight into what problems are experienced most often, additionally giving the users the possibility to report personal problems that were not listed.

The last section of asked questions were about the design concepts created in the previous subchapter. Here the user was presented with both ideas separately giving some feedback on the elements that make up the total experience. In the case of the first concept users were asked their opinion on the three different versions and which one, if any, would have their preference. Furthermore, additional elements that could be implemented in both designs were listed, giving the user opportunity in stating their opinion on what elements they thought would be most effective in their personal museum experience. Again, here the option of the addition of their own ideas was given, possibly resulting in components that were not thought of in the initial ideation session. The feedback given in these questions will be taken into the next step of reiterating the initial design concepts.

4.4 Reiterating the initial concepts

In the last section of the ideation process the initial concepts will be reiterated using the received feedback from the online questionnaires. For clarity this process will be divided into two sections, the first discussing the results from the questionnaires and the second using the data to further develop the installation designs. The incorporation of the user into the design process will hopefully aid the creation of an engaging installation and lead to inclusion of elements into the design, that were missed in the initial brainstorm session. The following will be a summary of the collected data, putting the focus on the most important items. The detailed results of the questionnaires can be found in included files within this graduation project.

Museum behaviour

In this first section, users were asked about their preferences when visiting an exhibition. It was found that the majority of the users, 13 out of the 14, asked preferred to experience the installation on their own without the addition of a tour guide. Here, 9 users preferred to roam around the museum individually whereas the rest would enjoy the company of friends or family. Furthermore, with the addition of a guided tour only 5 users would feel comfortable asking questions, 4 stating the possibility of asking questions in private tours only and 4 preferring to not instigate conversation at all. It can be seen here that the implementation of a tour guide in this specific group will not increase the engagement and learning of the user, possibly meaning that this set of users would fall under the 'passive' type of museum visitors. 90% of the users did however agree that the normal form of information presentation via text is not preferred, stating that an alternative form of data representation would help them understand the context of the cultural heritage.

Virtual reality

When looking into the results on the users knowledge on virtual reality a few key points can be found. From this specific selection of users 11 out of 14 had prior experience. This might also be cause by the majority of the user group being around 20-23 years old. The younger generation in the society often having more prior knowledge on cutting edge technology. When asked about any presented problems during their experience, motion sickness, blurry vision and disorientation or the feeling of unstableness were experienced most often. Here the user was additionally given the option to list any additional problems that were missed. Two users added a significant problem with virtual reality in combination with glasses, making the experience nearly impossible. Some virtual reality headsets do not open up the possibility of use combined with glasses, thus eliminating a person with vision problems from optimally experiencing the installation. Thus it should be taken into account that an inclusive type of headset is used, allowing all users to equally experience the exhibition. Luckily, currently there are multiple types of headsets available that allow for this, often additionally allowing the user to alter the distance of the lenses, which can decrease any blurry vision that the user might experience. The inclusion of this option might then help with the elimination of the stated problem of impaired vision found in the results of the questionnaire.

Concept feedback

The last category in the questionnaire presented the two initial concepts created during the brainstorm session, allowing the users to state preferences and give feedback. Here it was found that in case of the first concept, versions 1 and 2 were equally preferred over version 3. Furthermore the users stated favouring the stylizing the environment of the virtual world around the painting style of Rembrandt. This would add to the feel of being inside a painting instead of a real environment adding the element of a scenario that would be impossible compared to real life. Such elements often pique the interest of the user as it creates a new and

unfamiliar experience, leading to possible increase in engagement and enjoyment. One user questioned the possible addition of the modern world in the case of version 2, allowing them to see the differences in the changes between now and then.

When looking into the data on the second concept, the biggest feedback was the scope in which the objects could be handled. The respondents wondered how possible breakage or damage to the presented paintings could be prevented. Clear limits should thus be implemented into the installation, making sure that any negative behaviour cannot effect the presented cultural heritage. Furthermore when asked on the preference on how any additional information would be presented, most users opted for data presentation in the form of audio or some type of visual presentation. In the case of audio the addition of subtitles should additionally be explored. This would make the installation inclusive for people with hearing problems, allowing all users to equally experience the exhibition.

Lastly the users were asked to choose one of the presented concepts based on personal preference, where 11 respondents choose the first concept over the second. However when asked their thoughts on incorporating a single concept over the inclusion of both, 60% stated that the inclusion of both designs into the installation would help optimize their experience and understand the presented information. Thus, rather than eliminating one concept, both ideas will be taken into the next step of the design process. It is hoped that the final prototype can include elements from both ideas, creating an optimal combination of preferred design elements.

The final concepts
Using the feedback given in the questionnaires the first two initial ideas were further developed into more detailed concepts. Both ideas will shortly be explained with some argumentation on the choices made during the finalization of the ideation session. It is however possible that in the next step of the CreaTe development process it is decided that one concept is more feasible then the other, possibly due to time restrictions. This could then result in the development of one concept only or the recombination of elements that were thought to create the optimal learning experience for the user.

Concept 1
The revised version of concept 1 includes a merging of the three available versions presented in the initial concepts sub-chapter based on the preferences given in the online questionnaire. The possible new worlds the user could have explored are merged into one, recombining the preferred elements into one scenario. Thus, in this concept, the user is able to open up the painting resembling a door as seen in figure 2, allowing them to 'step into the painting' and enter a new world. The user is then taken to the 1600s, stepping into the shoes of the painter during the creation process of the presented portrait. The user can view an unfinished version of the painting and the person painted in the portrait in the same room, viewing the world beyond the borders of the canvas. Additionally the user is able to ask the person a set of fixed questions getting some insight and details on their life and status in that time. On specific locations of the room the user is able to paint a 'window' to the modern world using a given paint brush. This allows the user to compare the environments and explore possible changes between the two. To further increase the immersion of the user the world will be stylized in the painting style of Rembrandt, as this was found to be preferred in the online questionnaire. This mains objects presented will have a impasto layer (thick application of oil paint) and the use of triangular lighting (two light sources in opposite directions) will add a dramatic feeling to the environment. This concept includes the incorporation of multiple senses and incorporation of storytelling

through the addition of a character into the environment. Furthermore, the user is able to choose their own way of experiencing the installation, giving them a feeling of autonomy. Here, it is additionally possible to include a tour guide, giving them insight on the environment and any additional information regarding the 1600s.
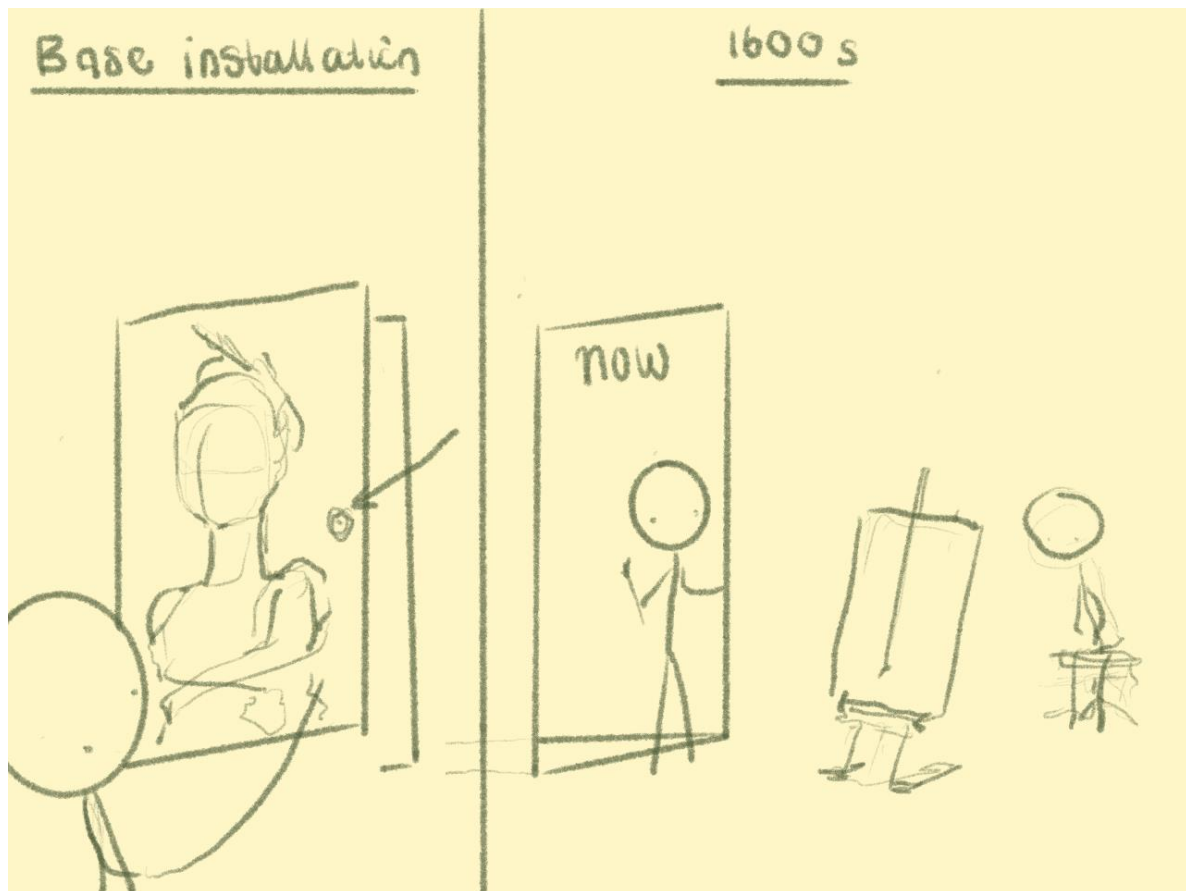
Figure 4. A sketch of the finalized version of concept 1.

Concept 2

The second concept only has some minor changes compared to the initial version priorly discussed. As in the first version, the user is able to pick up objects or elements from the presented portrait (figure 3), allowing them to view them up close and explore it details. All elements that are available for exploration are highlighted in the portrait to clearly give the user indications on which objects have additional meanings. When picking up said object, the user will be given information in the form of narration and visual representation in some form of text bubbles. For inclusivity, the narration will be accompanied by subtitles possibly available in a range of languages. The information given about the object will range from material details, cultural significance, symbolism or double meanings of the object presented surrounding power or wealth. This gives the user additional insight on who the person presented in the portrait was, and what they represented. Furthermore, by holding certain objects the users avatar will change into a person of the same status as someone that might own such an artifact or a craftsman involved in the objects creation. This would add an interesting multiplayer element to the environment as this allows two users to explore changes in avatars together and communicating with each other on what they think the clothing represents. Another multiplayer addition might be the inclusion of a set of quiz cards. The cards would include prompts such as

'What object in the presented portraits do you think symbolizes health?'. By communicating with each other and exploring all the possible objects the users can decide which object they think represents this description and pick it up to check if they were correct. Lastly, to prevent any forms of vandalism or messing with the installations, objects that are dropped are directly removed from the environment. Furthermore the ability of throwing said objects is removed.

Figure 5. A sketch of the finalized version of concept 2.

Chapter 5 – Specification

In this phase of the Creative Technology Design Process [17], the concepts created during the ideation phase will be refined and taken into the next step of the product development. Possible new perspectives will be considered, and additional feedback received between the end of GP I and the beginning of GP II will be implemented. Here, a range of prototypes will be created as an aid to explore the designing space and allowing for a clear representation of the final product. By evaluating these prototypes, the concept will be redefined and reworked until a final version is developed, which adheres to the preliminary requirements stated in chapter 4 and allows for a good mental image for the stakeholders as to what the envisioned product will do.

The following chapter is divided into two sections. The first section of this chapter the preliminary requirements will be divided into 3 categories. The first, functional requirements, will focus on what the virtual installation actually does. The second category will discuss the non-functional requirements, which describes how the museum visit intends to carry out the functional requirements. Additionally, in the last category the stakeholder requirements will be discussed. In the second section of this chapter a well-defined specification of the envisioned virtual installation will be developed. This final version of the concept will give a clear overview of what functionalities are need to fully implement the created design. To help visualize the installation a storyboard will be created, showing the full user experience. Additionally stills of the digital installation will be made, showing the details of the design in the final virtual installation.

5.1 Functional requirements

The final product created in this graduation project will present additional information on the presented cultural heritage. The installation will give the user context on what symbolism can be found in objects worn or held by the People of Colour depicted in the portraits. Additionally the installation will include multiple interactions based on the design tactics found in the conducted research that were deemed to increase engagement and immersion. The users will be presented with a realistic museum environment allowing for the recreation of a normal museum experience. During this experience the user should be able to move around freely and look at the objects in the desired order of their liking. This would mimic the setting of a normal museum where artifacts can be viewed and explored in no particular order. The presented objects should clearly be displayed and the given information should be given in a readable format as so it would not distract or frustrate the user, taking away from the overall experience and the ability to process the presented information.

Additionally the installation should allow the user to roam freely as would be done in a normal museum without any correct order or tasks to be completed, as this would optimally mimic the real life museum environment it is intended to recreate.

The focus of the installation should be on the presented story and informing the users on People of Colour during Rembrandt's time. It is thus evident that any included interactions should not take away this focus, however rather adding to the story and context of the installation.

The models that will be used in the installation will be created using the blender software and implemented in the Neos social virtual reality program. The Neos program will be used for the programming of the interactions and the installation of the final product.

In the exhibition the user should have the ability to pick up objects with the virtual hands of the user. The mechanics should allow for the holding of products using both triggers as this would imitate the real life motion and holding placement of grabbing objects, increasing a feeling of mimicked reality.

Lastly the exhibition should allow for an organized way of completing the interactions as to not confuse or disorient the user with possible messy mechanics or design. The nature of virtual reality might already be perceived as disorienting, thus lousy design could emphasize such feelings in the user.

5.2 Non-functional requirements

When it comes to the non-functional requirements of the installation, the main importance is the optimalization of the users engagement and cognitive skills. The user should feel a sense of immersion within the virtual environment stimulating their engagement. A set of design tactics that were found to influence this feeling will be implemented into the environment with the aims of impacting the user and thus increasing their learning in an interactive way. As it was found in [1], not every visitor processes information in the same way. Thus, a variety of interactions should be available, including both passive and active users into the experience.

The installation will make use of an extensive set additional information on a variety of subjects as a way educating the user on all aspects of the people depicted in the portraits of the installation. Said information will mainly be focused on the symbolism and material characteristics found in the paintings, often unnoticed at first glance. However, the inclusion of these details can tell a great lot about the story of the depicted person and their life during the 17th century. It is hoped that this information will make the user more involved in the artifacts origin story and the overall lives of People of Colour in Rembrandts time. Additionally, another category of information should be presented focusing more on the artist of the portraits and the materials and techniques used during its creation. Such information would attract a different category of visitors mostly interested in the technical aspects of the artifact rather than its story. By including a variety of available information to be discovered in different ways of experience, the installation aims for optimal inclusion of different users and their preferred path of exploration.

In addition to optimized learning, the installation is designed for a multiplayer format as a way of stimulating communication and the sharing of knowledge between users. For this reason the installation should be designed in a way that can optimally accommodate multiple users, both for close cooperation and for separate puzzling in the same environment. It is thus important that all aspects of the environment can additionally be experienced individually as some users might prefer a less strict and thus more free exploration of the interactions. Forced cooperation could lead to the decrease of the users engagement and learning, thus clashing with the overall goal of the installation. Thus every interaction should be possible for both users at the same time allowing for a feeling of autonomy with possible inclusion of cooperation between users if or when desired.

Lastly, it is important to acknowledge the users expectations of the experience. Due to the nature of the installation and its story, the user expects to learn more about People of Colour and their lives in the 17th century. As the installation is branded as an interactive learning environment for cultural heritage of the Rembrandts Huis, some expectations might arise in possible visitors prior to the actual experience. It is important that such expectations are met or even over fulfilled as this will lead to continues use of a product, as stated by Shahab *et al.* in [3]. Contrary to this, not fulfilling the expectations of the user might lead to a decrease of learning and engagement or the overall feeling of boredom during the exhibition. Thus, it is

important that the interactions in the installation will peak the interest of the user in a way that was not foreseen. This could be done by taking advantage of the virtual environment, allowing for the creation of situations that are not possible in real life. As the users expectations can only go as far as their imagination in the real world, the inclusion of the 'impossible' will add a new layer of experience and gratification in the user.

5.3 Stakeholder requirements

Aside from the (non)functional requirements of the product, possible requirements from the stakeholders should additionally be kept in mind. The listed requests, as stated by the client should be taken into account during the product development as they form the base of the intend and story the product will represent. Though some requests between stakeholders might clash with one another, a middle ground should lead to an optimized product.

The first stakeholder would be the Rembrandts Huis museum itself, presenting a number of different requirements. First of all it is desired that the installation will increase visitations and motivate the visitors. the installation should teach the users on the given matter in a way that is informative but also stimulating, as to result in an experience that will be memorable. The final exhibition could open up the path for a new group of visitors for the museum. In addition, the installation should give a good representation of what the museum stands for, possible using common designs often used and the information should be relevant the museum van the here in Rembrandt's time installation.

The second stakeholder, the curator of the installation itself, would be more focused on the actual details and story told within the installation. Certain choices within the method of displaying the artifacts and overall design of the environment were made as to increase or aid the story it is meant to convey. Thus, all elements in the installation should fit with the story and not distract from the artifacts. Furthermore, it is not deemed desirable that the installation would be perceived as some type of game. Even though the overall experience should be entertaining, the goal should not be to 'finish' or 'achieve' something. The main focus of the installation should be the education of the users on the matter of People of Colour in the time of Rembrandt.

A last stakeholder would be the visitor or user themselves. The user requirements would be to make an understandable and enjoyable installation. The information should be presented in an interactive matter as to pique the interest of the user on the subject of the 17th century. Additionally, the amount of stimuli should not be distracting and all elements should feel coherent and in place. The environment should include possible instruction for mechanics or elements that could be deemed confusing or harder to understand. This could prevent the possible arising of frustration in the user when a handling is not working as planned, decreasing the enjoyability of the installation and thus the learning and understanding in the user.

5.4 Defined specification of the envisioned product

The following will include a detailed description of the final product concept and its design. After careful consideration it was decided that both concepts presented in chapter 4 will be used as a recombination of design elements to optimize the user experience and engagement.

After the final evaluation of all the concept designs it was decided that, given the timeframe for this graduation project, the inclusion of a realistic environments and settings from the 17th century was not feasible. The mechanics for making such implementations, such as the inclusion of a 'world bubble' or window into another world in Neos, would not be the biggest problem. Instead the actual creation of said world and its surroundings would require a lot of 3D modelling and highly realistic rendering. As found in [source], to effectively incorporate such implementations, the environment should closely mimic the real world. This would include background noises, possible cracking of the old wooden floors, and animated surroundings. Excluding such elements from the interaction would result in less immersion of the user, possible dismissing its goal of inducing optimal engagement.

Thus with the exclusion of the discussed interaction, the final product will mostly follow the story and design of the second concept presented in the ideation chapter. This being the creation of questions on symbolism and material characteristics found in a selection of objects in the presented paintings. In this concept the users are given prompts which they were to match up with the correct object, stimulating their cognitive skills in the form of a puzzle. This form of interaction will additionally open up the opportunity for communication between users in the multiplayer environment, allowing for an open discussion on the topics presented in the prompts.

To help the users with the matching the correct card and object they can pick up a selection of artifacts from the paintings. When doing so, the user will receive a 3D object which additionally includes a detailed description of its material values and its symbolism. This information can then be used as a hint for the prompt cards. The statements, given on a set of separate cards, are presented in a vague riddle format. This format, often purposely worded a bit vague, aims to stimulate the user. Such play on words results in a puzzle format which would not be solvable without communication or the usage of the information from the 3D objects. This additionally discourages possible 'quick solving' tactics in the user, where the prompts are matched without using the available information, resulting in the complete dismission of the story and context of the installation.

In addition to the prompts and 3D objects the users are given the possibility to interact with 3 categories of additional information on the painting itself. Here additional information on the painter, the story and context of the painting or the material and techniques are presented for further insight on the artifacts. The information is given in the form of a node tree where the user can unluck each branch using a presented brush. The unlocking of the node branch will activate a brushstroke animation that will lead into the next subsection of information. Each section gives the possibility to look into a number of subsections surrounding the chosen subject. This allows for the user to decide their own learning path based on their interest, giving them a feeling of autonomy [source]. Additionally this design element can be seen as a more passive way of experiencing the installation in comparison to the prompts. This inclusion of both passive and active interactions allows for the inclusion of more users. As found in [source] not every museum visitor processes information the same way. By allowing the users to choose how they would like to learn about the installation they are more likely to immerse within the presented story and actively understand the subject matter.

In figure 4 the final story board of the installation is shown. In the final installation the prompts will be presented on a table located in the middle of the second room in the installation. On the table 8 prompts will be presented together with a button in the middle of the table. The button can be pressed at any time during the museum experience and will light up any correctly placed object, allowing the user to check their process during the interaction. Each prompt card includes a vague statement that correlates with an object in one of the five paintings that are incorporated into the interaction. The included paintings were chosen based on the amount of objects that were presented in the paintings and whether enough information could be found on them. It was decided not to include all paintings in the exhibition as this would increase the workload on modelling and programming, thus focusing solely on the second room. The included portraits are: *The Head of a Boy in a Turban, King Caspar, Dom Miguel de Castro, Diego Bemba* and *Pedro Sunda*. For these paintings no information will be presented in text form on the wall, all information will be given via the 3D objects and the three additional exploration paths included in the installation.

For the three paintings, *King Caspar, Dom Miguel de Castro* and *The Head of a Boy in a Turban* additional information will be given on the earlier discussed categories. This decision of only including three paintings in the interaction was made based on the amount of information that could be found on the artifacts as little to no information would result in minimal interaction.

Figure 6. The storyboard of the final product.

Chapter 6 Realisation

The last phase of the Creative technology design process [17] includes the realisation of the final product. Here, all concept prototypes and requirements are implemented in the development of the final product. This phase makes use of proven methods of engineering design such as the Waterfall model and the V-model. Said methods often include a decomposition of the start specification, realisation and integration of the components and evaluation, carried out in a rather linear path that allows for possible backtracking. The evaluation done during this design phase is not focused on user testing but rather the validation on whether the finalized product matches the specifications and requirements that were determined beforehand.

The following chapter is divided into three subsections. The first section will focus on the decomposition of the product, analysing all necessary components needed for the realization of the prototype. The second focusses on the realization of the components, including the building and the programming of the needed elements in the final exhibition, making sure they are all separately accounted for. Lastly, all elements will be combined and finetuned into one coherent prototype which will then be carried into the next step of user testing and evaluation.

6.1 Decomposition

When it comes to the virtual museum visit created in this graduation project, multiple components can be deemed necessary for the development and realization of the final prototype. Such components can range from hardware to software elements which together, combine into the final prototype. Arranging the necessary components before the actual construction of the prototype will make sure that all possible complications are taken into account beforehand, allowing for a smooth development process.

The first set of components necessary for the museum exhibition would be the virtual reality hardware needed for the actual immersion of the user. For this specific prototype, two sets of headsets and computers are needed to ensure the creation of a multiplayer museum environment. Each user would use their own set of hardware connected to the same virtual environment. The users would then meet in the Neos program where the installation will be presented.

When it comes to the type of virtual reality headsets, it was decided that opting for an Oculus quest or HP model would be best. The main advantage with these models over a headset such as the Vive would be that no additional tracking equipment is needed, as all tracking is imbedded in the headset and controllers. Even though the HP and Oculus quest would still require a cable connection with the computer, their usage would make the selection of the location needed for the prototype easier, as no additional requirements such as size or height are needed.

Due to the nature of virtual reality, the demands for the selected computers are quite high. Not all laptops or pc's are capable of running software such as SteamVR, often used to stream a program to a virtual reality headset. This is often due to problems with the CPU or the graphics card. To ensure that the hardware can be utilized for the museum visit a steam performance test can be executed. This test will inspect the selected laptop or pc and decide whether it is capable of handling the selected steaming software based on its specifications.

Furthermore, communication via the Neos software should be made possible. Neos allows for the communication between two users via virtual reality in the forms of spatial audio. The location and distance between users in an environment impacts the volume and direction of the sound. This element helps the users of the software locate each other and adds a feeling of reality to the digital environment. This can thus

be deemed as an important element of the museum installation as the inclusion of spatial audio can aid in the optimization of the users engagement and immersion. It should be ensured that the prototype and used headset allow for the incorporation of this element in the final product. In combination with the supportive hardware, an accommodation should be made when it comes to the product location. Since the installation will be used by two people at the same time, different locations or rooms should be available to ensure the possibility of digital communication. In case these rooms are allocated next to each other, testing should be done to ensure the rooms are soundproof.

Lastly, for the actual design, programming and development of the museum installation two programs will be used. In the first program, Blender, the 3D models of the objects available for inspection in the installation will be created. Here, the portraits and additional information on the objects will be used as reference. The objects will be sculpted with the aims of replicating the 2D depiction as closely as possible to allow for a historically accurate model. Said objects will then be imported into Neos where they will be implemented in the base installation designed by Caspar Sikkens, a replica of the real life exhibition of HERE, Black in Rembrandts Time. Using the Neos programming language LogiX, interactions such as the grabbing of objects and matching of prompts will then be implemented into the environment. Additionally, information on the presented objects will be collected in the form of an extensive research on its historical and symbolic value, which in combination with the 3D models and programming, will form the total experience of the museum exhibition.

6.2 Component realisation

In the second section of the realisation process the necessary components for the virtual museum visit will be individually realised, where each components will focus on a specific section of the final product. Separating all elements into sections, will allow for an ordered development process and easy backtracking in case complications might arise. The realized components will be combined in the last section, creating the installation as a whole.

Research

As preparation for the development of the installation, extensive research was conducted on the 17th century fashion and symbolism. The selected objects from the paintings, as seen in appendix C, are prime examples of objects often depicted in 17th century clothing or portraits as to represent a level of power or tell a specific story. Additionally the book on the installation HERE, Black in Rembrandts time [39] was used as main reference on identifying the depicted objects and its year of origin. Objects such as the hat in the portrait of Dom Miguel de Castro took some additional research as to define the specific style of headwear and its purpose. This hat was found to be a cavalier hat, a commonly worn fashion piece, often paired with an ostrich feather.

In appendix C all the descriptions of the objects are listed, however here the description of the Cavalier hat will be given to paint a picture on the wording and depth of the information presented with the object. Here the text is made up from information found in multiple sources surrounding 17th century fashion, all included in appendix C.

The Cavalier hat
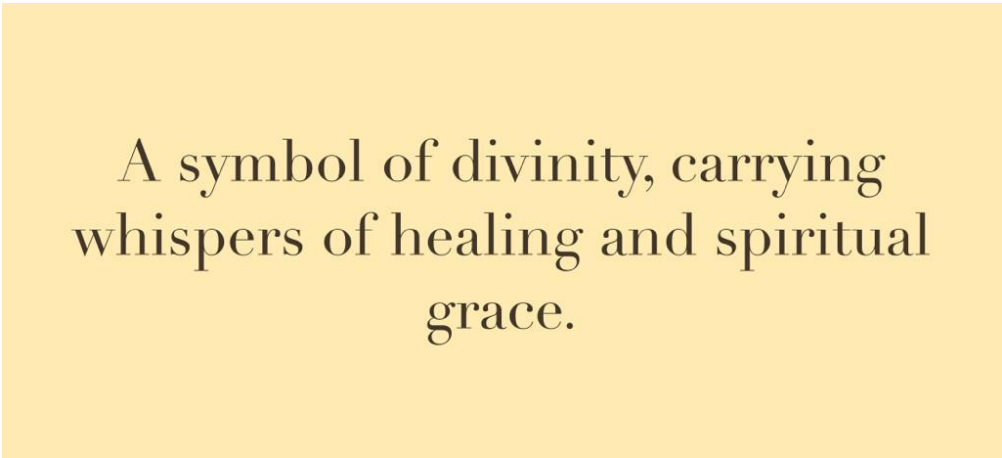
The cavalier hat was a commonly worn wide-brimmed hat from the 17th century. The name of this hat originates from supports of King Charles I, known as the Cavaliers, who were known for wearing extravagant garments. The hats were often made from felt and accentuated with ostrich feather, secured on the hat with a broach. One side was often pinned to its base, creating an asymmetrical look.

The information that was in the conducted research will be presented in the form of text, together with the correct 3D objects from the presented portraits. The user can access the objects together with its information by 'grabbing' into the painting, resulting in the spawning of its smaller 3D version. This allows the user to closely inspect the artifact and gather information on its material context at the same time.

Based on the research and the context of the object 8 prompt cards were then created with a cryptic description of the matching artifact. The prompts were made to stimulate communication between users, intentionally worded quite vague to encourage users to look deeper into the presented information. It should be noted that only 8 descriptions are presented on the painting, even though 10 different objects are displayed in the installation. This was done on purpose to moderately increase the difficulty of the matching and discourage any matching of the orbs with random slots as a quick solving technique.

The following are the 8 descriptions presented on the prompt cards:

1. This delicate adornment adds a touch of grandeur to the attire of the affluent. - *The red ostrich feather*
2. Known as a shining ruler, this object radiates power and brilliance. - *The golden accessories*
3. As a gesture of goodwill, I arrive bearing symbols of harmony. - *The diplomatic gift*
4. I ascend the throne of self-esteem, a hue of majestic depth. - *The blue garment*
5. A symbol of divinity, carrying whispers of healing and spiritual grace. - *The incense pot*
6. An artefact adorned with shimmering grace contrasting the snowy backdrop. - *The gilt silver garment and collar*
7. This prized substance represents commanding force within the depths of its engravings.- *The ivory tusk*
8. Worn on top, this arrangement is customary in a variety of cultures. - *The turban*

Figure 7. The prompt card for the incense pot.

Lastly, in addition to the information presented together with its corresponding object, three categories of additional information are available for further exploration for three selected paintings. These paintings *King Caspar, The Head of a Boy in a Turban* and *Dom Miguel De Castro* include further details on the artist, the story of the portrait and its materials or techniques. Said information will be included in the node tree as discussed in chapter 5, granting the user additional ways of exploring the portraits origin story. All additional information available in the installation is listed in appendix C, however for clarity the text for the portrait of King Caspar is presented to give an idea of the nature of available information.

A02 – King Caspar

Painting description: The portrait of King Caspar was created by Hendrick Heerschop, a golden age artist, in 1654, depicting King Casper in full glory.

More about the story: The painting represents one of the three magi who came to worship the Christ child. The three magi, additionally known as the three wisemen visited Jesus, bearing precious gift in celebration of his birth. Caspar, the second oldest magi, gifted the golden vessel filled with incense as to represent Jesus' deity. In the bible the magi were referred to as the 'men who study the stars', and believed to be astrologers who predicted the birth of Jesus by their ability to read the messages that were hidden in the sky.

More about Hendrick Heerschop: The Dutch illustrator and painter Hendrick Heerschop was born in 1626 and passed away in 1690. He was the Son of the Haarlem Harmen Jasz and the apprentice of Willem Claesz, another Dutch golden age painter popular due to his still life compositions. Hendrick on the other hand was mostly known for his portraits and genre scenes, a form of art that depicted aspects of everyday life by the portrayal of ordinary people engaging in common activities.

More about the material and techniques: The painting of King Caspar was made using oil paints applied on oak wood panel, known for its durability and little warping when exposed to sunlight. The painting can be seen as a prime example of Haarlem classism, often characterised by a rather naturalistic painting style and depictions of a prosaic or ordinary subject matter.

In this painting Hendrick plays with the images lighting, putting the focus on King Caspar's face and his expression, showing dignity and grandeur.

Blender models

The models used in the final installation were made in the Blender program. All accessories were modelled to closely resemble their 2D counterparts in the portrait. All objects found in the museum were modelled especially for this installation except the turban found in the portrait of The Head of a Boy in a Turban. This model was imported from an open sourced website [link].

In addition to the modelled objects, a table was created which could house the mechanisms of the matching puzzle and its prompt cards. This table was based on the Cabinets of Curiosities which were popular in the 17th century. Such cabinets, or wonder rooms on larger scale, housed collections of notable objects or artifacts of the owner. In the case of the installation it would house the matched objects with its description. The design of the table was kept quite simple as to not distract the user from the actual installation, including some bevelled edges and notches. It was thought that a modern table would look a bit out of place, whereas a 17th century inspired table would reinforce the overall theme of the exhibition.

Figure 8. Blender models of the objects in the installation. From left to right: The diplomatic gift, the golden accessories, the feather, the incense pot, the ivory tusk, the Cavalier hat and the prompt table.

Coding

Before all the models and informative text could be implemented in the installation all the separate interactions of the exhibition were coded in a separate world. Here the focus was solely on the programming with logiX and making the interaction function without the incorporations of the objects. This would serve

as a more organised approach to solving the complexity of the separate coding combined, after which they could directly be implemented into the final exhibition.

The grabbing of objects

The first interaction that will be discussed is the ability to grab 3D objects from inside a painting. This interaction was created using the UX options of an object in the programme. In the inspector specifications of all objects in the digital world can be found and added, such as the ability to grab something or change its colour. For this interaction two simple 3D models of a pyramid and a cube were used for demonstration. The cube would represent the painting with the pyramid being the 3D counterpart of an object shown in the portrait. In the inspector a grab instance is added to the cube. Within this element you can add which object should appear when 'grabbing' inside of the cube. When adding the pyramid object in this setting, said object will appear when the user grabs its 2D version in the portrait. To display the information on the symbolism of the object a canvas child was added which would then spawn together with the artifact when grabbed.

Figure 9. The programming of the grab instancer.

The triggered animation

The second interaction that was worked on was the triggering of the animation with the paintbrush for the node tree. This animation would show a paint swoop triggered by a paintbrush, leading to a sub category of additional information chosen by the user on a selected painting. A simplified version of the brush was created using a cylinder and sphere child. Here, the type of the sphere collider of the object was changed to a haptic sampler, where separate box would be given the haptic trigger setting. When the brush would make contact with the box a trigger would be activated. Using the logiX coding the programme would check whether the trigger was activated by the user holding the brush, in which case an animation would start. In the first version of the triggered animation (figure 9) the video would be activated by a simple button. This

simplified version of the mechanics was made in order to measure the correct delay that should be added until the animation, or node tree, would be removed. It was thought that this setting should be added since the accumulation of multiple tree branches could eventually lead to a messy and overwhelming environment for the user. Additionally, this would make the overall installation look unorganized and unprofessional, taking away from the story it is meant to convey.
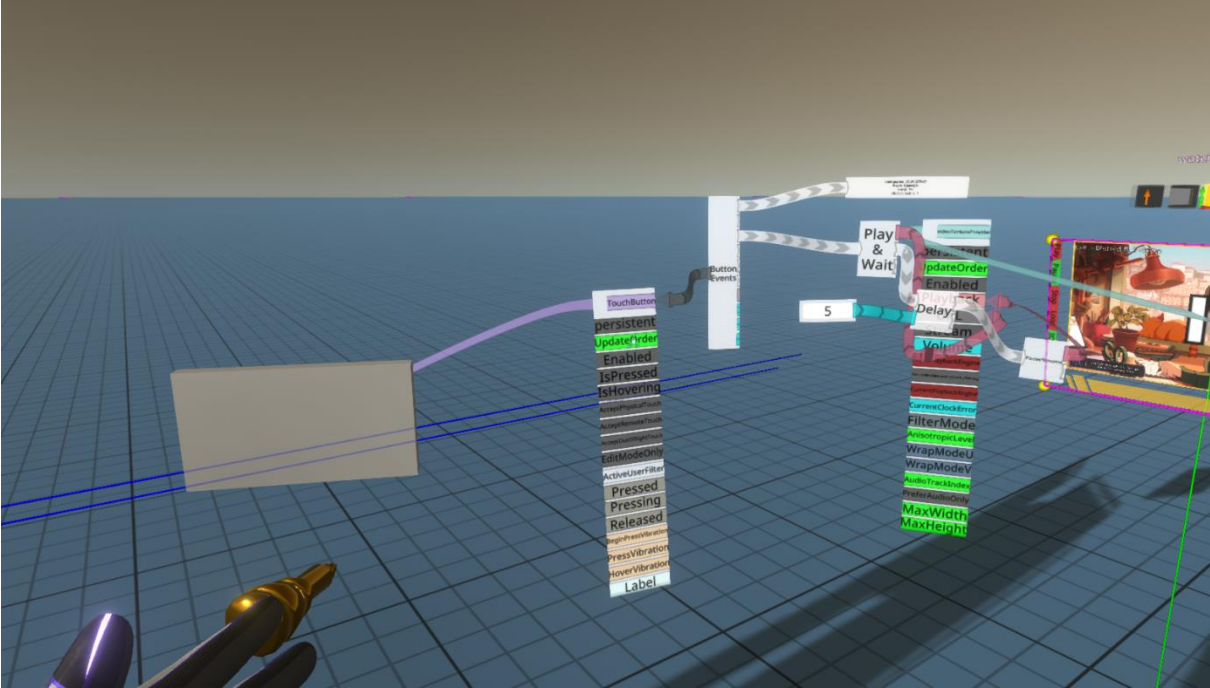

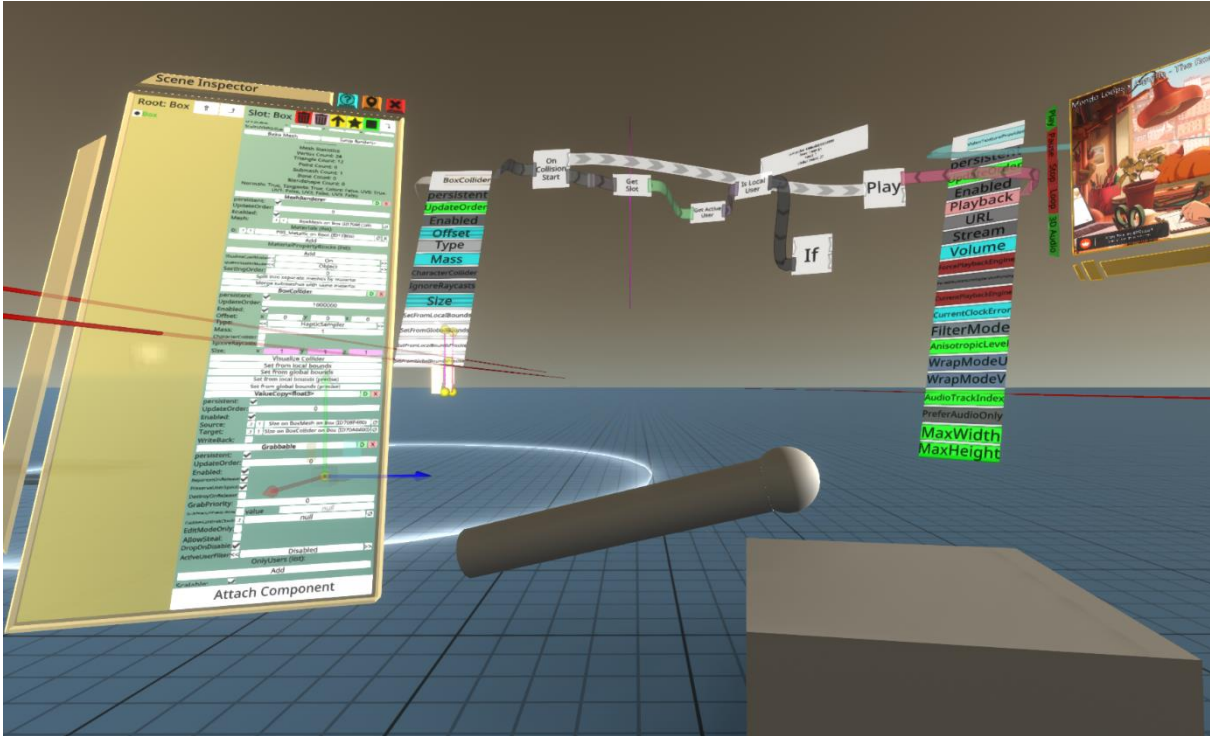*Figure 10. First version of the triggered animation.*

Figure 11. The addition of the paint brush with the animation trigger.

Checking snappable objects

The last interaction of the museum exhibition would be the placing of objects on the presented prompt table. In the installation each portrait will have a set of objects that can be matched with the correct prompt on the table. For clarity, each of these objects should have their own fixed space on the table. Luckily, Neos UX includes an component called snappable, allowing for the snapping of objects onto another object into a fixed position. As seen in figure 11, a torus was used as the snap target, with the sphere as the snappable item. These components are linked between objects by the use of a *SnapperKeyWord.* When an object is placed within the vicinity of the box collider of the snap target, both objects are checked based on their *SnapperKeyWord*, and in the case of a match, snapped.

Additionally, after the snapping of objects the program should check whether the object placed in the snapper slot matches with the fitting prompt. In case of a correct matching, an indication should be made to the user to show a correct answer was given. Using logiX activated by the pressing of a button, the program will look for the slot name of the torus and its child, the snapped sphere. Name of the sphere object is then compared to a label added in a logiX equal statement. When the label and name matches, the program set the statement to true, triggering an if statement. This if statement will then trigger a visual indication of success in the form of sound or light to the user.
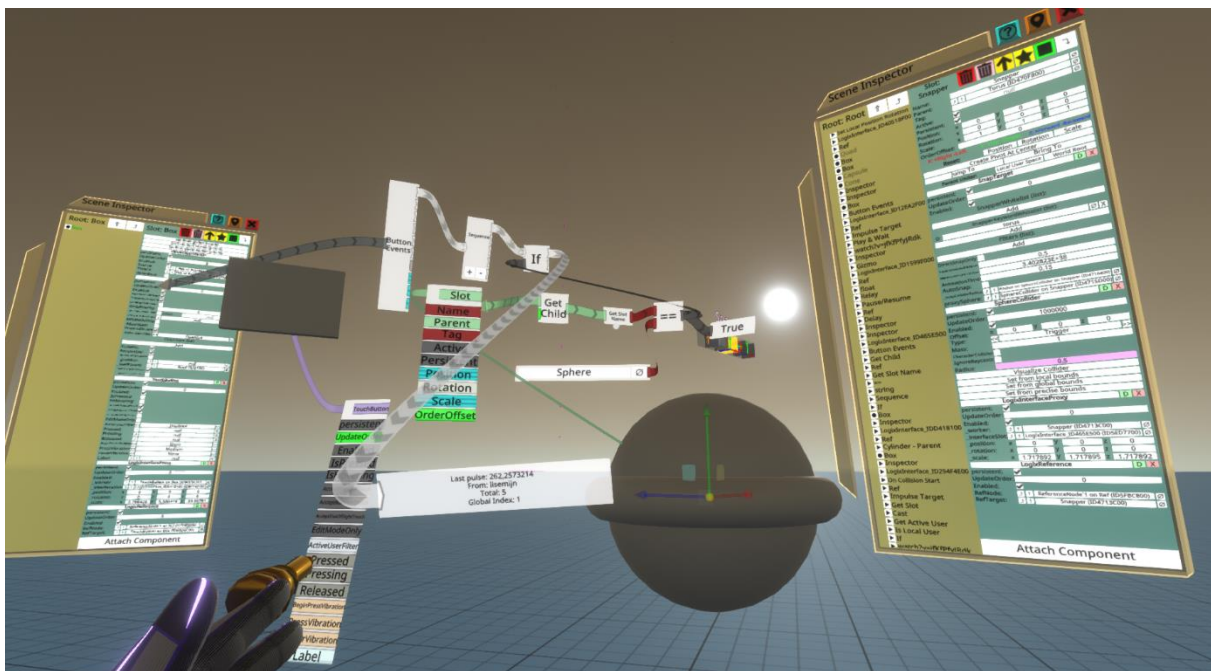
Figure 12.. The checking of snappable objects.

6.3 Component integration

After the development of all the separate components of the museum visit, everything was combined into the base replica of the Rembrandts Huis exhibition HERE, Black in Rembrandts time. This includes the coding for the snappable objects, added to all eight prompt slots on the table and the grabbable 3D objects from the presented objects. Sadly, the coding for the animated node tree was not incorporated into the final design due to time restrains and repeated difficulty with its functionality. As an accommodation, the

additional information on the portraits painter, story and techniques were presented in three separate categories on the wall, as seen in figure 18.

This specific installation will mainly focus on the second room, as this is the location of all the paintings included in the interactions. The table with the slots for the prompt cards was placed in the middle of the installation as a centre piece, catching the eye of the user. However, the ensure that the focus would still be on the portraits and their origin story, the table was given the same dark grey colour as the wall accents, blending in with the overall environment. Furthermore, the additional information originally presented under each painting was removed from the portraits included in the interactions. This ensures that no knowledge can be obtain without the use of the available interactions and that the puzzle can only be solved using the information included with the 3D objects.

On the table eight torus's were placed together with a matching prompt. These slots would serve as the snapping target for the objects the user can explore from the presented paintings. It was decided that separate orbs would serve as the snapping objects. This decision was made as it was thought that eight identical orbs would give an overall cleaner and more professional look to the installation. These orbs are located under its corresponding portrait, giving an indication of which objects are available for exploration, as seen in figure 13. The orbs and their corresponding slots were textured with a washed up gold, accentuating the yellow and brown tints of the overall installation, and emphasizing the classical feel of the Dutch Golden Age.

Thus to ensure that the installation won't get too crowded the grabbable objects from the painting are set on

DestroyOnRelease. This entails that while holding the object, the user can inspect the artifact and its information to the fullest extent. However, once released, the object will be removed from the installation as a way of keeping everything as organized as possible. All the objects were given their own text and fitting texture, as seen in figure 16 and 17, aiming for optimal realism to increase the immersion of the user.

Lastly, an instruction panel, shown in figure 12, was included in the installation. This panel would serve as the explanation for the interaction that are available in the virtual environment, in addition to the basic controls. The instructions would be presented upon entering the second room of the virtual museum, instead of the spawning point, allowing the users to quickly refresh their memories if needed without the need of leaving the room.
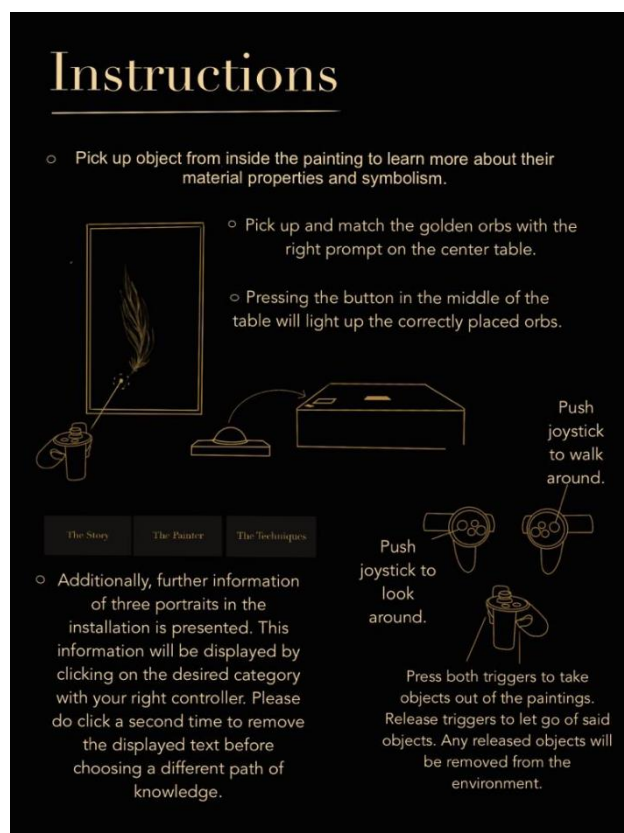
Figure 13. The instruction panel presented in the exhibition.
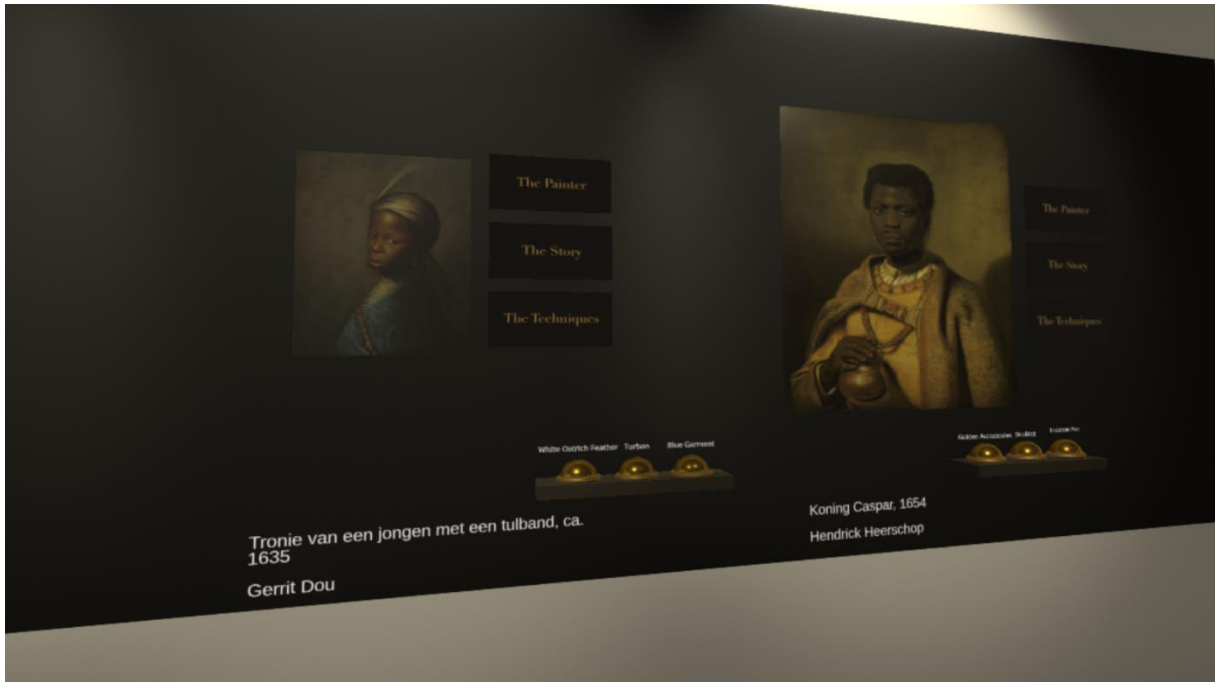
Figure 14. Presented orbs and additional information categories available for selected portraits.
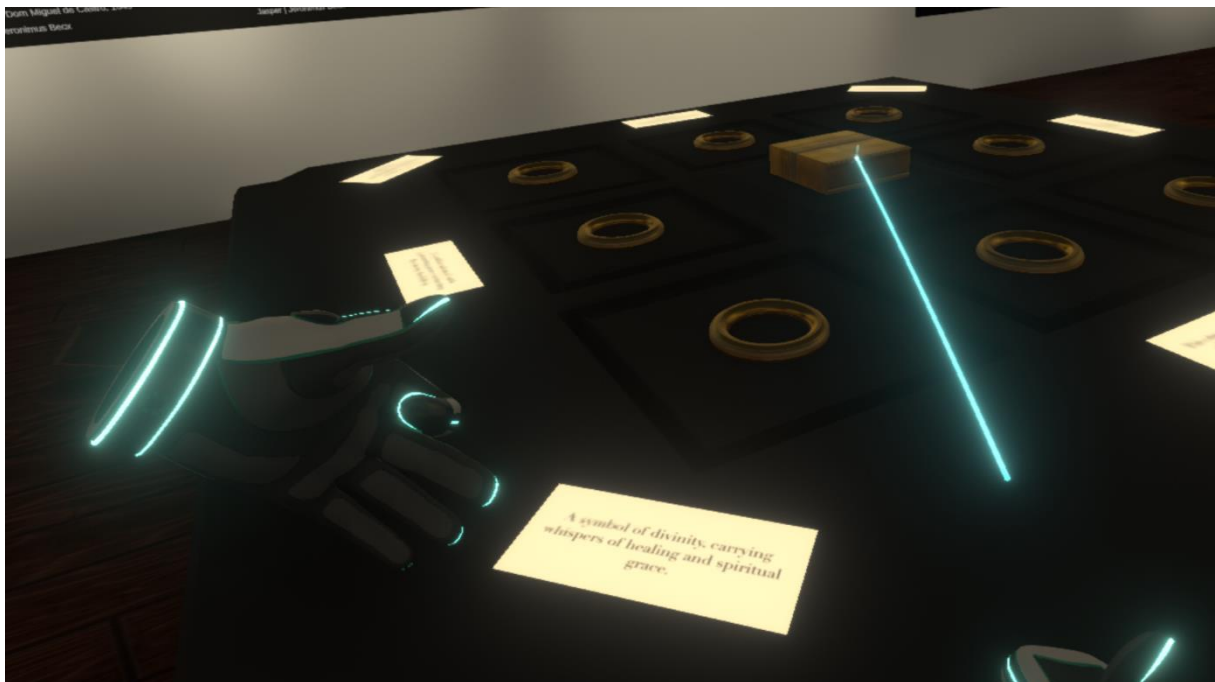
Figure 15. Examining the prompts on the centre table.
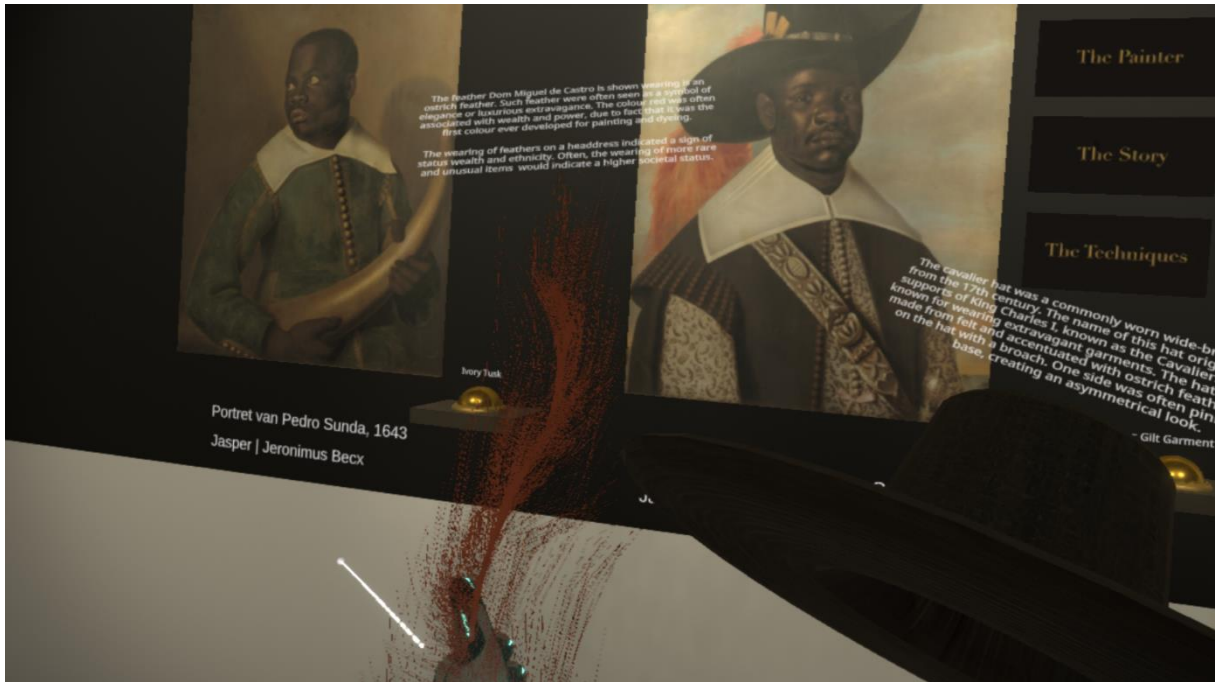
Figure 16. Exploring the 3D objects from the portrait of Dom Miguel De Castro.
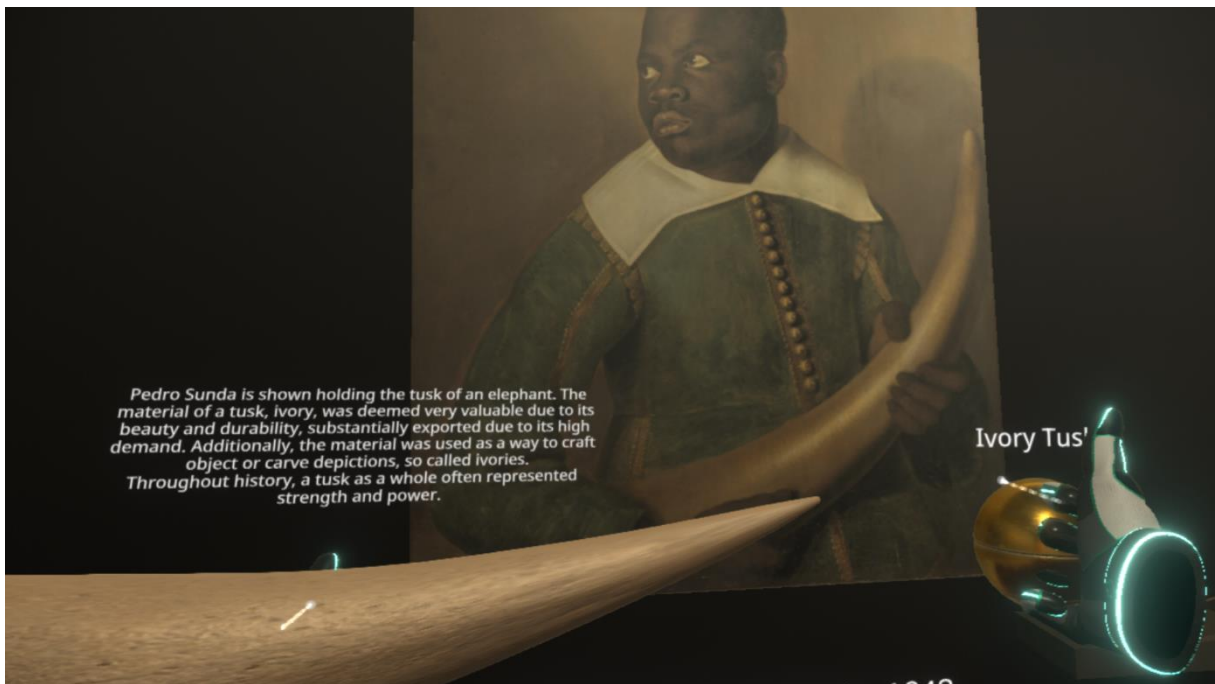
Figure 17. Exploring the 3D objects of the portrait of Pedro Sunda.
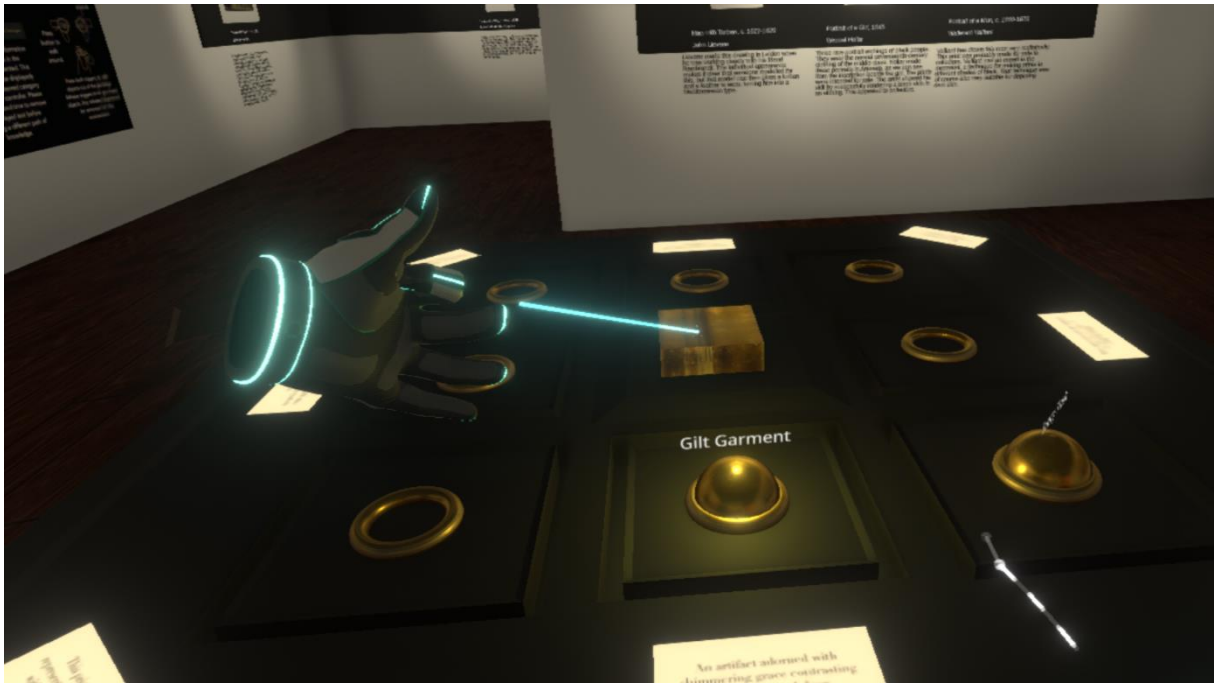
Figure 18. Checking if the correct orb was placed on the table.
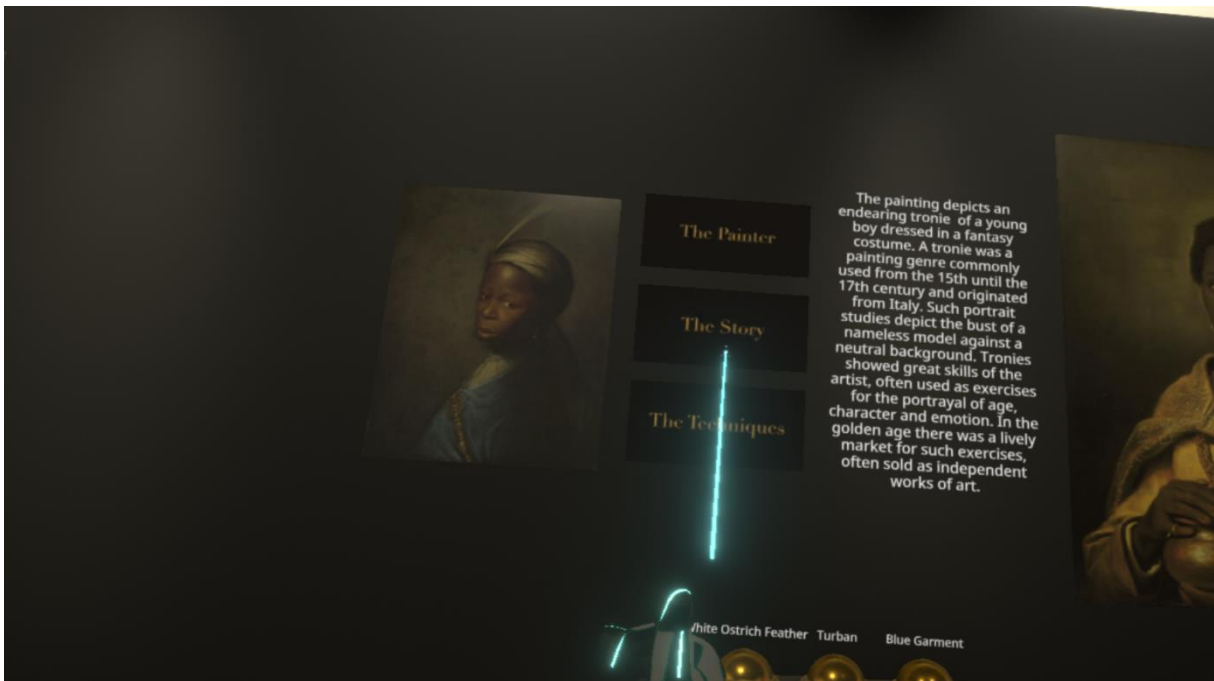
Figure 19. Interacting with the additional information available on the portrait of The Head of a Boy in a Turban.

Chapter 7 – Evaluation

The following chapter will discuss the evaluation of the prototype, finalized in chapter 6 . As stated in the Design Process for Creative Technology, in this phase a number of aspects are addressed, with the main element being the user testing of the virtual museum visit. The installation will be tested by a user pool and evaluated based on whether the initial requirements and specification, identified in the ideation and realization phase, are met. Additionally, the user testing will show whether the decisions made during the product development will indeed facilitate the experience the installation is meant to convey.

The chapter will be divided into two main sections. The first will discuss the set-up of the user testing and its execution. The second will focus on the results and findings from the collected user data in the form an interview and questionnaire analysis.

7.1 User testing

In the case of the specific situation of this graduation project, it was decided that a user study would be best fit, as this would allow for the assessment on whether initial requirements of the product were met in the final prototype. To ensure for an ethically responsible procedure, prior to the testing an ethical request was done. Such requests are done with the aims of establishing risks that could occur, prior to the actual testing. Due to the nature of the virtual museum visit, the main risk of the study could be possible motion sickness or disorientation in the user due to unfamiliarity in the user. Thus, as no notable risks were identified, the ethical committee accepted the request, deeming the prototype safe for user studies. Said request will not be linked in this document, however, the complete dossier can be found on the ethical review website of the university of Twente under the case number *230347.*

The set up

As seen in the research questions stated in chapter 1, the evaluation of the installation focusses on two different aspects. The first aspect would be the engagement of the user and overall immersion in the installation, with the second focussing on the addition of a multiplayer element. To test the multiplayer aspect of the installation, the participants will be divided into two separate user groups. Here the between-subjects design is used, where each group is only exposed to one of the conditions. In the first group, users will get to experience the installation individually, where the focus will be on measuring engagement only. However, in the second, two participants will jointly experience the virtual museum visit, thus the focus being both the users engagement and the multiplayer element. The first group of individual participants will act as a control group, allowing for insight on whether engagement in the user is caused solely by the used design tactics or additionally the inclusion of a second user into the environment. The users in the multiplayer set will be split into two separate room and meet digitally in de Neos program. Via the built in spatial sound software of Neos the users can digitally communicate and discuss their experience during the installation. The spatial audio here additionally adds to the immersion of the users as the volume and orientation changes based on the users location. Both of the groups will be testing the exact same installation with the same design tactics implemented into the virtual environment.

Commonly in between-subjects groups subjects are divided into groups using randomisation. Although this method could result to an unequal number of participants in each user group, randomisation removes any possible bias or outside factors that could infect the data collection. However, in the situation of the museum visit it is preferred to use two participants for the multiplayer group that have prior relations. This

is done as to as closely resemble the real museum environment as possible as visiting an installation with friends or family instead of strangers is customary.

Even though a different method of participant division is used that usual it should be made sure that the final ratio of participants will approximately by 50/50, ensuring an equal amount of data collection for both user groups. Additionally, it is aimed to reach a participant pool between 20 to 50 people. This would serve as a sufficient sample size for the eventual data collection and analysation, for the scope of this graduation project.

The procedure

The user testing procedure of the virtual museum visit will be categorized into two user groups. The first group would be the individual testing of participants as a form of a control group, with the second being the testing of two participants in the same virtual environment. This set up will open up the possibility of measuring the influence of a multiplayer aspect into the installation on the engagement of the users. To clearly explain the final procedure of the testing all steps are shortly explained.

Briefing

Prior to the actual testing the participants that volunteered for the user testing are presented with an information letter and short explanation on the origin of the research. Said information is given during the recruitment of the participants, either in person or via email depending on the method of which the participant was contacted. The briefing includes a general overview on the story of the virtual museum visit and what can be expected when it comes to the user experience. Additionally the participants rights and risks are discussed as to optimally inform the user on all aspects concerning the research. It should be noted however, that details on measuring the engagement of the user during the testing are withheld, as this could possible impact the behaviour of the user and the results of the testing. The information letter can be found in appendix E.

Informed consent

When involving human participants in the testing of a product, it should be insured that the involved participants are aware of all ins and outs of the procedure. Thus to ensure all parties clearly understand the situation informed consent should be attained from all participants. The usage of an informed consent form is seen as an important part of human centred research and its reliability according to the GDPR regulations. The consent form states the risks and rights of the participants similarly to the briefing, additionally asking for the permission of data collection for the purpose of this thesis. The empty consent form can be found in appendix E, whereas the filled in consent forms will be separately included with this paper.

First questionnaire

Right before the instructions and actual testing of the installation the participants are asked to fill in a short questionnaire. This questionnaire, found with the included documents of this thesis, focuses on the museum behaviour of the participants and their prior experience with virtual reality and possible side effects. It is hoped that this data will give insight into the experience of the user in normal museums, whether passive or active, and their interests or focus points when it comes to learning about cultural heritage. Additionally the participants are asked whether they would prefer to experience a museum individually or together with friends or family. In the interview this question will be referenced, measuring possible changes in this preference as a result of the museum experience. Lastly, the participants are asked to provide their age and

biological sex, which will give insight on the origin of possible side effects that could arise during the usage of virtual reality.

The installation

The actual user testing of the museum visit starts with the set up of the virtual environment and the prior head set. For the testing two adjacent glass rooms were used as convience for the researcher to make sure all participants are optimally supervised to ensure safety and comfort, as seen in figure . Depending on wether the selected participants are part of the individual or multiplayer set, one or two rooms are used. The participants are then asked to follow one of the two researcher into either room to start with the introduction to the software and headsets used for the testing. During said introduction, the participants are given a general description of the program together with instructions on the controls needed during the testing of the museum visit. After this, the users are connected to Neos, spawned at the start of the museum installation, and depending on the set additionally the digital communication software. The participants are then informed that the researcher will stay in the room and will take notes during the interaction on their behavior, and ensured that incase of any side effects or questions they are free to halt the testing process. After this, the users are allowed to start the user testing, and enjoy their virtual experience of the museum exhibition.

Figure 20. The setup of the user testing.

Second questionnaire

After the user testing the participants will be asked to fill in a second questionnaire. This would be a combination of the standardized presence and immersion tendency questionaries by Witmer and Singer [38]. These questionnaires measure the presence or immersion of the user together with their tendency to immerse themselves in everyday experiences. This combination of data allows for the evaluation of

relationships between reported presence and other research variables [38]. The presented questionnaire is included in is included within the relevant documents folder of this thesis.

Interview

Following the questionnaire a short interview is conducted. Depending on the user group the participants are asked on the design tactics included in the installation and their overall experience. The multiplayer user set will additionally be asked about their immersion with the inclusion of a second player into the environment and the possible impact on their learning and understanding of the installations story. Additionally, the communication and cooperation between users via the Neos software will be discussed. The interview is aimed to give insight into the users feelings and opinions on the decisions made in the product design and their experience compared to a normal museum visit. Additionally, the combination of an interview and questionnaire serves as both an objective and subjective of measuring results, allowing for rich data collection. The answers of the interviews were recorded and transcribed with permission of the user given in the informed consent form. The answers given by the participants are included in appendix K, sorted by participant number per the participation listing included in subchapter 7.2

Debriefing

At last, after the user testing the participant will be given a short debriefing on the conducted experiment. The terms and conditions of the testing, including the withheld information on user engagement will be brought forward and the possibility is given for additional questions. The participants will be rewarded with a small compensation for their cooperation in this research in the form of a variety of snacks or drinks.

7.2 Results

Upon the finalization of the user tests, all the collected data for each participant was safely stored and sorted. Said data included the pre- and post- testing questionnaire results, the observations made during the testing and the answers given during the interviews. The combination of both objective and subjective data aims to provide a rich data collection and detailed analysis on the impact of the museum visit on the users engagement.

However, before the data analysation could take place, a few administrative tasks were conducted. First, the collected results were chronologically ordered for clarity and convenience, of which the list can be found in appendix F. The complete participant pool was determined to consist of an equal amount of men and women, with 83% percent of the users ranging from the ages of 18 to 24. Second, all participant results of the post-testing questionnaire were combined and sorted on their corresponding subsection. Additionally, the questions 19 and 35 were removed from the dataset, as these turned out to be accidental duplicates. Lastly, the selection of inverse questions, as indicated in orange in Appendix K, where reverse scored. Here the answers, ranging from 1 to 7 were subtracted from 6, thus resulting in its inverse.

Questionnaire analysis

The first section of this chapter is aimed to analyse the results the conducted questionnaires. Here the collected data will be discussed and visualized, starting with the pre-testing questionnaire. This questionnaire consisted of two sections, the first discussing the users museum behaviour and the second which is focused on any prior experience of the user with virtual reality. The following table will present statements that

resulted from the presented questions and the percentage of agreeance of the participants sorted on their user group.

It should be noted however that due to an error in the Microsoft form that was used, the answers of the first 4 participants surrounding museum behaviour were not saved. Thus the percentages of the first four statements are made up from the answers of 20 out of 24 participants. The percentage presented for each statement solely includes the users agreeing with the prompt, thus excluding user who did not agree or had no preference on the statement.

STATEMENT	FREQUENCY - INDVIDUAL SET	FREQUENCY - MULTIPLAYER SET
I have visited a museum before.	100%	100%
I would like to experience a museum with the company of friends or family.	87.5%	93.8%
When I am in an exhibition I scan most of the objects, only looking into its details if it catches my interest.	87.5%	87.5%
I would prefer a different method of presenting information in comparison with the usual display of text on the wall.	62.5%	50%
I have prior experience with virtual reality.	100%	79.2%
I have experienced motion sickness while using VR.	25%	37.5%
I have experienced blurry vision using VR.	37.5%	37.5%

Table 1. Pre-questionnaire results

Reliability

Before the collected data of the second questionnaire can be plotted and visualized, a reliability test was conducted. This test aims for insight on how dependably a test measures a certain characteristic and probability on whether a user will provide similar answers when asked to repeat the questionnaire. This test is done to estimate possible errors in the measurements and give suggestions on possible improvements that can be made to increase the validity of the questionnaire in the future. The reliability test was conducted for each subsection of the questionnaire, resulting in a Cronbach's alpha score, which can range from -1 to 1. Here the latter, or a high reliability score of the questionnaire is deemed to be optimal.

SUBSECTION	CRONBACH'S ALPHA
Knowledge and understanding	0.734
Engagement and presence	0.894
Immersive tendency	0.002

Table 2. The reliability test of the post-testing questionnaire.

After the reliability test was completed, the participants overall score of each subsection was then visualized in a bar graph, as can be seen in table two. Here, the individual and multiplayer user set were plotted parallel to each other, comparing the differences in performance between both participant pools. Furthermore, an area chart was created, plotting the average of all participants for each separate question. Similar to the bar graph, this visualization was conducted for each subsection separately, where the performance of each user pool was shown parallel to each other.
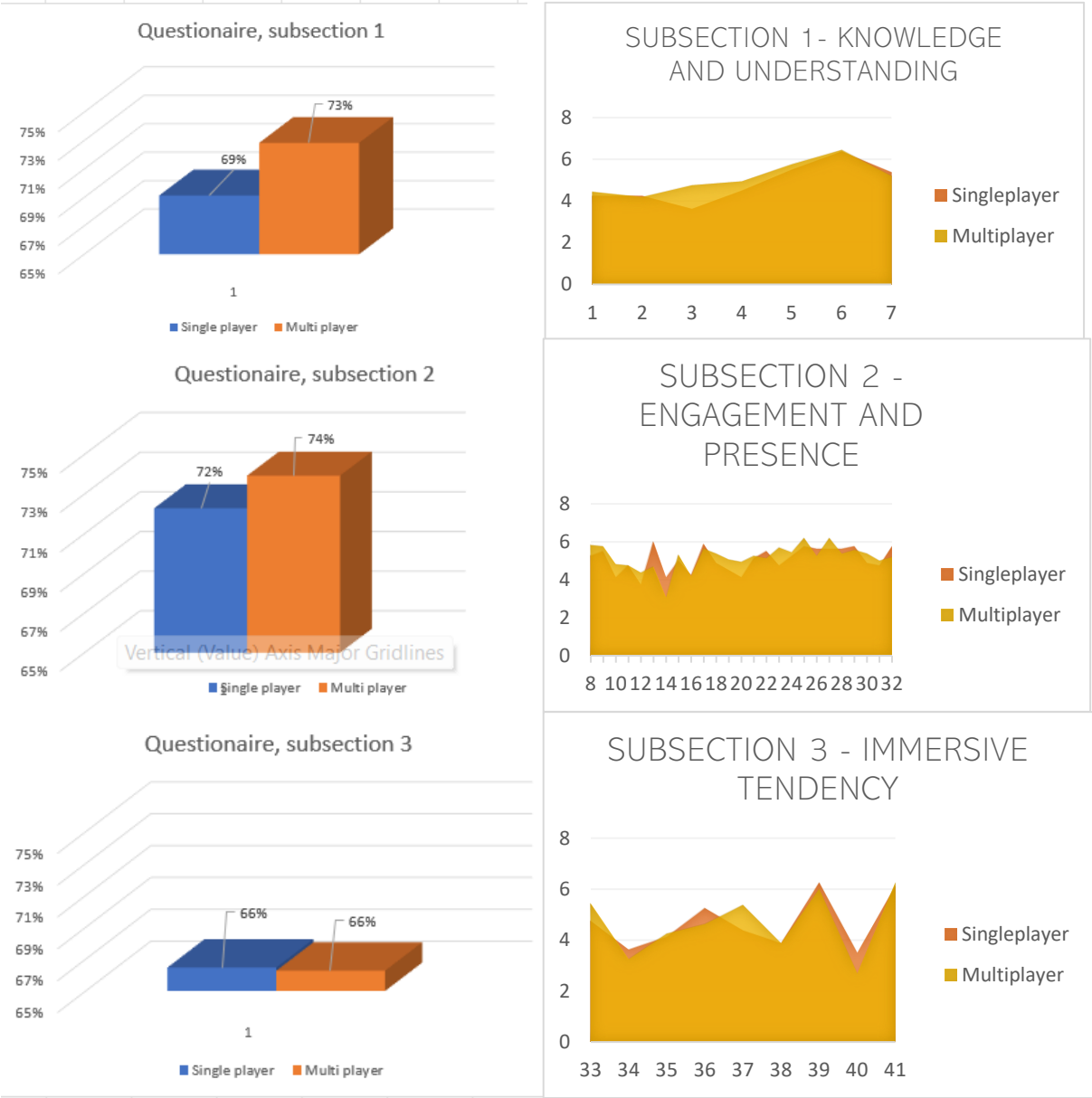
Figure 21. The visualizations of the post-testing questionnaire.

In addition to the overall performance of each user group, a second analysis was conducted. Here the participants averaged score per subsection, converted to percentage is sorted based on their immersive tendencies. Seperately shown in table 3 and 4, both user groups are ordered in an descending order, starting with the person that scored the highest in the immersive tendency section of the questionnaire.

PARTICIPANT	IMMERSIVE TENDENCY	ENGAGEMENT AND PRESENCE	KNOWLEDGE AND UNDERSTANDING	AVERAGE
7	76%	75%	73%	74%
21	75%	83%	90%	86.5%
23	70%	78%	71%	74.5%
24	68%	66%	65%	65.5%
13	65%	63%	65%	64%
4	63%	80%	69%	74.5%
3	60%	78%	53%	65.5%
10	54%	54%	65%	59.5%

Table 3. The average score of each participant per subsection, sorted on immersive tendency, for the individual user set.

PARTICIPANT	IMMERSIVE TENDENCY	ENGAGEMENT AND PRESENCE	KNOWLEDGE AND UNDERSTANDING	AVERAGE
5	76%	66%	76%	71%
9	75%	77%	70%	73.5%
18	73%	73%	69%	71%
6	71%	79%	84%	81.5%
20	70%	82%	88%	85%
2	70%	74%	80%	77%
15	70%	72%	43%	57.5%
14	70%	45%	49%	47%
1	68%	81%	82%	81.5%
19	65%	82%	96%	89%
12	63%	81%	86%	83.5%
16	62%	63%	55%	59%
22	59%	87%	80%	83.5
17	57%	78%	49%	63.5%
8	56%	67%	82%	74.5%
11	56%	77%	67%	72%

Table 4. The average score of each participant per subsection, sorted on immersive tendency, for the multiplayer user set.

Observation and Interview analysis

Lastly, the observation and interview results of all participants combined were sorted, where any common remarks made by the participants were noted down. In table 5 the statements made by the users are provided, together with the percentage of users that agrees with the statement. In this analysis, the same division is made between the participants as in the questionnaire analysis, separating both of the user group to give inside on particular differences in their experience.

STATEMENT	FREQUENCY INDIVIDUAL SET	FREQUENCY MULTIPLAYER SET
I felt like the interactions added to my experience.	75%	87,5%
I was motivated by the prompts to look deeper into the story.	100%	100%
The presented information impacted my understanding of the museum	100%	100%
The multiplayer element added to my experience and engagement.	0%	100%
I felt like the addition of a friend or colleague stimulated communication.	0%	100%
The spatial sound positively impacted my experience.	0%	87.5%
I experienced difficulties with the controls	25%	25%
I had experienced blurry vision and had difficulties reading.	12.5%	185%

Table 5. Common statements made during the interview, sorted on user groups.

Findings

In this last section of the evaluation all findings as a collective will be discussed and summarised. Said findings will result in general interpretation of the obtained measurements and their relevance to the conducted research. For clarity, a division into two categories of results is made. Here, the first discusses all aspects and elements that were found to visualization of the post-testing questionnaire of both user groups, looking into their impact on the engagement of the user. The second consists of a comparison between the users preferences prior to the installation provided in the pre-testing questionnaire and the observations or statements made during the user tests. Additionally the observation and interview results surrounding the user engagement and implementation of a multiplayer aspect into the product design will be discussed, delving into its effects on the learning and understanding of the exhibition and its story.

When looking at the variety of visualisation that resulted from the post-questionnaires a few points of interest can be appointed. When first looking at the general questionnaire results per user group, a slight increase in engagement can be seen in the results of the multiplayer user set. Due to its diminutive size however, it cannot definitively be concluded that this increase was caused by the multiplayer addition to the installation. Due to the addition of a second person in the environment, both user experiences are effected by multiple stimuli. This could be the usage of a fairly new technology, the interest of the user, their communication or the type relation between the users. Thus, although it might be true that the multiplayer element did increase engagement in the user, it cannot clearly be confirmed from the collected data.

Additionally, the averages of each individual question can be explored, as seen on the right in figure 20. It can be seen here that the percentages of the participants average scores are generally quite similar between both user group. The two biggest deviation between the groups can be seen in the results of question 13 and 14 respectively. The first, question 13 focusses on the awareness of the users surroundings in the real world during the virtual experience. As seen in the visualization, the single player user set, scores significantly higher on this specific question. As question 13 was part of the inverse questions, a high scores indicates a low level of awareness, and thus a high level of immersion or engagement in the user. It could be argued that the reason for this higher score is the exclusion of a second user into the environment. Although the multiplayer element adds additional stimuli and communication between users, it additionally adds one significant aspect: a connection between the virtual and the real world. In the single player set the user is completely closed off from reality with the exclusion of all outside stimuli. It could be said that the multiplayer set still allows for a connection with the real world, making the user more aware of its surroundings. The second question, focussing on the awareness of the user when it comes to the controls, coincides with this argument. Again, as the question was inversed, a lower score corresponds with a higher awareness and thus lower immersion. An assumption can thus be made that perhaps a lower immersion due to the inclusion of a second person in the environment additionally causes a high awareness of the real world.

Another remarkable element in the questionnaire results could be seen in table 3 and 4, show the participants averaged score per subsection, sorted in descending order based on their immersive tendencies. In the individual set results the average of both the knowledge and presence subsection combined, descends in a similar matter as the immersive tendency scores. Although not perfect, a clear decline can be seen, where participants with a lower immersive tendency score lower in engagement and knowledge combined, and vice versa. The resulted scores of these questions could be seen as quite logical, as a person with a lower immersive tendency might be expected to have a harder time immersing themselves in the virtual museum visit. However, if said results are then compared to the multiplayer set results, it can be seen that such a correlation is not quite found in the other user group. Here, the average scores seem to be all over the place, with the lowest scores of engagement and obtained knowledge correlate with users 14 and 15, both located in the top half scores of the immersive tendency section. It could be said that this disorganization could be the result of the multiplayer element in the environment. This implementation results in the addition of outside stimuli such as communication and cooperation. Although additionally seen as a positive aspect, as noted by some of the participants during the interview this element could lead to possible distractions and overwhelming of the user. As now both users are effecting each other's experience, based on the way each separate user processes information, this could have both positive influences on separate elements that make up the total engagement and result in the disorganized percentage scores in table 4.

Continuing on this phenomenon, it is notable that the two lowest averaged scores of their experience are all of multiple set users, namely user 14 and 15. This is very interesting considering both participants were part of multiplayer set 5, thus testing the installation together. These results coincide with the results of their interviews, as it was indicated that both found the inclusion of a second person slightly distracting, taking away from their immersion. Even though both participants indicated that their preferred way of visiting a museum would be in the company of friends and family, it could be that this specific match did not exactly line up. This could be because of the relation between the users or other additional outside variables, affecting the total engagement of both users combined. In this specific situation it is however known that this could not have been cause by software or hardware limitations, as both participants did not report any glitching or difficulties with the controls. As no clear evidence on the reason for these scores was found, its origin remains unknown.

Pre-testing questionnaire comparison with interview and observation results
In the questionnaire results shown in table 1 a couple of interesting elements can be discussed in comparison with the attained interview and observation results. First however, it should be noted that all participants had prior experience with museum exhibitions. For this specific research this is could be deemed as useful as this would entail the existence of a preference on certain aspects of common exhibitions design elements. It can be seen that the most of the users in both user groups scan the presented museum objects for elements of interest, as opposed to a more detailed and extensive exploration of all artifacts. It is thus interesting to see that in the interview results the opposite is stated. Here, the all users state that the inclusion of the prompt cards motivated them to actually explore the presented information and look deeper into the story of the artifacts.

Furthermore, the participants express that without the addition of the interactions they would not have read the text or delved deeper into the installations story, affirming the results attained in the pre-testing questionnaire. Additionally, 3 participants stated in their interview that due to their indifference on art history, they would normally not delve into any additional text or information that would be provided in the installation. However, to their surprise they found the extra information presented with the available 3D objects to be quite fascinating and informative, expressing interest in the topic. Continuing on this, other users noted that the vague phrasing of the cards positively forced them to actually read the informative text, aiding them with the matching of the objects.

Additionally, the majority of the participants indicated a preference for the company of friends and family during a museum visit, as an enrichment of their experience. The results from the interview additionally indicated this preference, which was expected. It could however have been the case that the experience changed the users preference, now favouring a solo experience. Nonetheless, the participants indicated that the installation did not change their views on this matter, perhaps reaffirmed it, as it showed the exact reasoning for their decision through the added layer of experience of a multiplayer based environment.

When looking at the preferred method of displaying the general information of the presented cultural heritage however the preferences are more divided. Even though approximately half of the participant sets indicated indifference on how the general information in a museum should be presented, the interviews resulted in a different viewpoint. Almost all participants stated that the method of presenting information in the virtual installation was very original and increased their understanding. This leads back to a prior section

where it was discussed that participants preferred this method instead of the usual display of information in text format on the wall, stating an overall increase in their motivation to delve into the story of the artifacts.

When looking at the general results of the installation it can be said that the percentages indicate quite a high level of engagement and understanding, with their first three statements resulting in scores close to 100%. It should be added here that for the first statement on whether the installation added to the user engagement, the users that did not agree with the statement were not necessarily a negative indication of possible flaws in the installation. Here, the participants stated a general indifference on the subject, adding that a different group of users that showed interest in the topic would definitely enjoy the experience. Additionally the results indicate quite a high percentage of participants that experienced a form of blurriness or difficulties with the controls. During the interviews participants stated that this affected their experience of the overall installation, which withheld them from fully immersing in the exhibition. This limitation could thus possibly be an explanation for lower results in some categories of the questionnaire that were indirectly impacted. This same consequence of decreased engagement was additionally the case for the participants in multiplayer set 3. Due to problems with the Neos program the audio had to be connected via a normal phone call, allowing them to continue with the testing. Although no negatives were mentioned this did effect of the impact of spatial sound, as seen in table 5.

Furthermore, with regards to the question on whether the multiplayer element added to their experience, all multiplayer sets agreed. As stated in the prior section, worth bearing in mind is the fact that 18.5% of the participants stated that despite increased engagement the multiplayer element can be experienced as distracting as another person is included in the interaction. Additionally, it was noted that this implementation could result in missing certain elements or available information from the installation as a second person is consecutively using the same interactions. However, other participants stated this as a positive, mentioning how an additional user allowed for the discussion and sharing of knowledge. The possibility for cooperation allowed them to complement each other's experience.

Some last interesting notes that were made during the interview included possible feedback on future implementations in the environment. One of the main comments here was the inclusion of some form of voiceover or animation as a different form of presenting the instructions or available information on the objects to the user. It was said that this possible addition could give a clearer understanding or visual to the user and would better retain the focus of the user on the installation itself, increasing their immersion and learning of the installations story. Additionally, elements such as the incorporation of competitive element or the ability to check which prompts were matched by which user could add another layer to the installation and the ways it can be experienced, overall increasing the exhibitions inclusivity.

Chapter 8 – Discussion

The following chapter will discuss the quality of the conducted research by analysing and interpreting the research findings, exploring the significance of the results and their implications. Additionally recommendations surrounding possible future work will be presented, aiming to offer insights and identify areas that are open for further exploration. For clarity this chapter will be divided in two sections, the first revisiting the finalized design and the second focussing on the evaluation and the conducted procedure.

The design

As discussed in the findings section of chapter 7, the design of the virtual museum visit includes some issues that became apparent in the results of the user testing. One of these issues pertains the decision to only include a few paintings in the possible interactions, focussing only on one of the three rooms presenting cultural heritage. This decision was made due to the time restraints for this project and the fact that most of the did not include a lot of objects that could be explored based on their symbolism and material techniques. Additionally, often little to no information could be found on the excluded paintings, preventing the possibility of presenting enough viable information on the objects to the user. It can be said that by limiting the number of paintings available for exploration the user can devote their attention more on each painting separately, without getting overwhelmed on all the available details. However, it could additionally take away the attention of the paintings that are excluded from the interactions, as these would not provide any additional interactions, thus not attracting the attention of the user, leading them to disappear into the background. Thus, a clear balance should be made on the amount of paintings available and their placement within the installation, ensuring that all artifacts are equally highlighted and the users are provided with enough variety for an optimal experience.

Continuing on the priorly discussed issue, due to time constraints it was not possible to fully implement the design of the node tree, providing the user with three additional categories of information on the portraits. Due to difficulties obtaining such information, it was decided to go for a simplified version, as seen in chapter 6. However, this meant that the design tactic included in this design, the users ability to choose their own path of exploration, was removed from the installation. This decision thus resulted of the elimination of an important design tactics which would give the user a feeling of autonomy, increasing their engagement. Thus to optimize the installation the inclusion of design should reconsidered, opting for a possible conclusion which could add a new layer to the story of the cultural heritage.

A last noteworthy issue at hand considers the readability of the prompts presented on the table in the virtual museum visit. As was observed during the user testing, small texts such as the prompts and information displayed with the 3D models were often difficult to read due to the experience of blurry vision or the limitations of the Neos software. However, it is essential to ensure that all participants can easily read an comprehend the presented text, including visitors with a visual impairment. Thus, to ensure optimal readability and inclusivity options such as a voiceover narration or animation highlighting elements of the artifact can by implemented to improve accessibility and engagement. Additionally, providing the ability to zoom in on the text can allow the users to examine the presented up close, enhancing their understanding of the artifacts context.

The evaluation

Although the results obtained during the evaluation gave valuable insight on the users behaviour and engagement during the virtual museum visit, it is important to discuss the limitation that were encountered during the user testing, as they could potentially have had an impact on the validity of the results. The first and most important issue here would be the small sample size of the evaluation, namely 24. This limited sample size could have limited the ability to draw conclusive results about the general user population. It can thus be said that for future testing a sample size of 50 is advised, as this could enable a more extensive analysis of the product and the user experience.

Another interesting point of discussion would be the outcomes of the post-testing questionnaire. As was seen in chapter 7, only a slight increase was found between the single player and multiplayer set of the participants. Although not expected, this result should not necessarily be seen as a negative. Both of the versions carry different pros and cons influencing the experienced engagement of the user, depending on the preferred method of learning in the participants. It could thus be said that the including both types of experience in the final installation could allow for an optimally inclusive installation that does not force a certain learning technique on the visitors. Here it could additionally be said that the usage of a larger sample size could lead to different results, which should be kept into mind for future research. However, as of right now a definitive cause can not be appointed, thus additional testing should be done to allow for possible distinctive results in the participant results.

Additionally it should be noted is the low reliability score of the third subsection of the questionnaire considering the immersive tendencies of the user, which with a score of 0,002 could be considered as questionable. One of the possible reasons for this score could be the clarity of the wording or in consistent formulation of the presented questions, resulting in inconsistent responses of the participants. It should be recognized that the design of a questionnaire plays a significant role in obtaining reliable data, and that thus some improvements on the structure of the questionnaire should be made in future iterations.

A last limitation would be the overall unstableness of the virtual reality software and hardware that was utilized during the testing. Commonly mentioned issues by participants included blurred vision, difficulties with controls and small-scale glitches of the environment. These inabilities could have hindered the participants ability to fully engage with the installation and might have negatively influenced their overall immersion. It is crucial that such difficulties are not ignored and resolved in future testing as such limitations could impact the user experience and overall understanding of the virtual museum visit.

Recommendation

Apart from the elements noted in the first section of the discussion some additional recommendations can be made, opening up a guiding path for future work and additional research that will be done regarding the topic of this thesis. The following recommendations aims to enhance the users engagement and understanding of the virtual museum visit, exploring additional implementations that could optimize the exhibition.

First and foremost, one recommendation would be to further investigate the learning techniques used by participants during the variety of interactions. As was seen in chapter 7, multiple approaches for the prompt matching were found, some more competitive or cooperative in nature. Thus, future research should focus on understanding the cognitive process and decision- making strategies used by the participants. The

identification of such techniques could further optimize the museum visit regarding the users comprehension and immersion of the story of the presented artifacts.

In addition to this, the possible implementation of displaying additional information on the presented portraits in the form of a node tree could be reconsidered. The inclusion of this design element would allow the user to choose their own path of knowledge, giving them a feeling of autonomy in the environment and allowing them to navigate through the installation based on their individual interests. A way of collecting this data on the most commonly chosen paths could provide insight on the users preferences, which could be of interest for future research on museum based learning environments. Additionally, said data could be used to identity patterns within the users exploration paths, which then can be analysed and visualised in an effort to optimize the users engagement and give insight on ways of personalizing museum experiences based on the users preferences and behaviour.

Lastly, research could be done on the optimization of the installation when it comes to multiplayer virtual reality visits. As was found during the background research, due to the recent development of this implementation, it has not yet been fully explored in the existing research literature. However, as the interest on social virtual reality visits is increasing, it can be deemed important that this existing gap on knowledge of its optimized design is narrowed or closed. Further exploration should be done to optimize the design of multiplayer environments, considering both single player and multiplayer implementations. Both options should be included into future museum environments as this would optimally include all visitors, both passive or active, and their preferred method of processing information. Thus, such research could provide the benefits and challenges of both versions, allowing for the optimisation of the environment when it comes the users engagement and understanding.

Chapter 10 – Conclusion

In this thesis it was aimed to explore how users can be engaged in a virtual version of the exhibition *HERE, Black in Rembrandts Time by the Rembrandts Huis*, using the incorporation of different design tactics and the addition of a multiplayer setting. The findings of the conducted research provided insight on possible ways of optimizing the environment on aspects such as the users immersion and understanding of the story the installation was meant to convey.

As stated in chapter 1, this thesis aimed to answer the main research question: "How can virtual reality enhance engagement of the users during a social museum visit, presenting cultural heritage?". To aid in answering this question two sub questions were constructed, which could be answered with the use of the conducted research and implemented product design developed during this project. In this section, first the sub questions will be concluded, which in turn would answer the main research question.

When it comes to the overall design of the installations, the conducted interviews and observations showed that the inclusion of the available interactions in the exhibition did in fact impact the overall experience of the users. This then raises the first sub question: "What design tactics can be implemented to help convey the story of the artist in a way that will leave an impression on the users?". From the results of the conducted user tests it was found that the inclusion of the ability to interact with objects, and thus the installations story, added the most to levels of engagement of the installation, according to the participants. Additionally, the inclusion of a storytelling element in the form of the presented prompts added a layer of context to the story of the installation, increasing the understanding of the user by allowing them to be indirectly involved in the history of the presented artifacts. It can be said here that the results found during the user tests

perfectly coincide with the conducted background research, indicating a positive impact on the users engagement due to the inclusion of several design tactics. Here, a combination of the tactics is deemed optimal as this allows for the inclusion both active and passive users, giving visitors the optimal freedom on deciding their preferred method of exploration.

When it comes second sub question: " How can a multiplayer environment encourage the users and thus each other to look deeper into the meaning behind the object at face value, as an alternative to a single player VR visit? ". However, a less clear conclusion was found. In the interviews, participants stated that the inclusion of this setting allowed for cooperation and communication between two users, enabling the ability to share knowledge and discuss their experience, increasing their experience. However, when looking at the objective results obtained in the questionnaires, only a slight increase was found when comparing the single player user set with the multiplayer set. It was then concluded that the incorporation of a multiplayer element added multiple outside stimuli, which affected the users engagement, of which some were found distracting by the users. Therefore both pros and cons can be noted on the inclusion of a multiplayer as well as the usage of a single player setting for the installation. Here there is no alternative version to the other, as both were found to add to the users experience, depending on their cognitive processing. Thus, for the purpose of a virtual museum visit, both should be included into the installation, allowing the user to decide their experience based on personal behaviour and preferences.

Thus, using the sub conclusion it can be said that the engagement of the user in a social museum visit can be impacted using a variety of implementations. Here, it ultimately depends on the focus and objective of the museum visit. The usage of design tactics adds a new layer to the experience of each user, focussing on positive stimulation of the individual users. However, the incorporation of a multiplayer aspect allows for a new layer of experience into the installation. Here both could be used hand in hand, adding to each other and increasing the impact of each implementation. The only thing that should be noted here is that such recombination's should be done while focussing on optimizing the users experience, and should thus not be perceived as overwhelming or distracting from the story the installation is meant to convey. Ultimately the exhibition should lead to an optimal museum learning environment, exploring the world of cultural heritage beyond the borders of reality.

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[39] E. Kolfin and E. Runia, *Black in Rembrandt's Time*. Zwolle: WBOOKS, 2020.

Appendix A: The literature matrix

	[1]/[11] (same book)	[3]	[6]	[9]	[5]
RQ1	Let the user experience the context of the object themselfs/use vr not as an add on but an integral part of the installation	Presenting vr content and enriching it with other senses.	Letting the user be part of a photorealistic 3d environment, handling objects (not possible in real life due to safety reasons. Let the visitors make their own interpretation of the object/ visual stimuli increases understanding of the object	Giving the user the option to choose their exploration path using iteration.	People need to be encouraged to get involved, be able to make a connection with the context, be triggered to perform behavior -> enhancing the quality of spatial experience/ giving the user a amount of control and autonomy increases interaction with the spatial environment. Digital storytelling makes the audience choose their path/ interaction with people and objects.(the main three stages!)
RQ2		Telepresence serves as the core for creating an	Vr visits that are rich in stimuli		

		optimal vr environment(user has feeling of being there, uses and gratification theory/ confirmation and disconfirmation theory but has some criticism			
RQ3	Example: user is able to step into the photograph and see how this is an subjective form of storytelling (not objective as first thought)		Create installations that are rich in stimuli experiences (a list of examples with the amount of engagement/effectiveness)	adding human actors into the storytelling adds human interaction/empathy + make it interactive	Give the user choices and versions they can make themself
RQ4	*When objects are no longer material how can you create meaning? (tangible and intangible)*	Most research is focussed on making sure users revisit museums, info on effectively explaining phenomena in vr remains scarce/ a lot of research on experiential factors of vr not a lot on vr specific gratification (what drives for pleasant experiences and how?)	Design challenges when it comes to the shell of the museum, more comes into play when designing a digital experience compared to a real museum installation	Motion sickness (can be overcome by introducing static objects) + can be avoided further by using the teleport option instead of walking when possible (some people are not comfortable with walking due to safety) /confusion when people are not familiar with the VR (need available staff)	Safety and security-> user cant sense anything from the real world when wearing a headset, make sure no accidents occur/ losing awareness of the actual space might increase chance of accidents

	[8]	[7]	[4]	[2]	[10]

RQ 1	Experiential and situational learning (multimedia learning theory)	Gamification to promote learning and increase engagement, create full immersion (make the user feel part of the installation)/ turn passive users into active by making them involved with the object/ social aspect increases learning Full engagement can be seen through positive motivation and full immersion - when a user is fully involved	Digital storytelling	Multisensory interaction and perception	Evoke more emotion in the exhibition that fits with the art, by enhancing the emotion the experience will also be improved
RQ 2			High eeg ratings can conclude positive/good engagement. Positive questionnaires of users on immersion etc. can als conclude the same (eeg, alpha waves) -> subjective and objective research	Multimethod approach (HR monitor/eye tracking/questionnaire) can give inside on engagement -> results: (measured in semiotic/physiological/behavioral dimensions) bodily sensation maps can give inside on engagement/experience. Geneva emotion wheel gives indication of the emotions that were felt	

RQ 3	Incorporating emotional designs to stimulate the user to exert more mental effort to make sense of the material. Manipulate or interact with objects. Simulate a phenomena or specific situation	Transporting the user through history and time lets them be involved with the objects context/ photorealism helps with the feeling of immersion	Adding actors/characters to the digital environment- (360 degree storytelling)		Make the environment fit with the art piece/ the surroundings should convey the same emotions/enhance the emotions create environments that would be unexpected for a museum(create the unexpected)
RQ 4	Dizziness and device burden might influence the learning effect	Many people are not familiar with vr (training), motion sickness(different genre of games my cause less motion sickness)/ vr should serve multiple people at the same time, this might cause administrative errors	When users are free to look around, they might look away from the story(you can not really use a base location		Since art is all subjective it is hard to regulate all the visitors emotions the same way with the design choices made (not vr specific but specific to design choices

Virtual Museum Installation: HERE in Rembrandts time

This form is about the development of a virtual museum visit in cooperation with the Rembrandts huis, with the aims of digitalizing the past exhibition 'HERE in Rembrandts Time'. This installation displays paintings of people of color in Rembrandts time, often as the leading character, with the aims of breaking the stereotypes.

The virtual visit will aim to recreate this installation VR however adding immersion and the possibility of two people experiencing the installation at the same time.

In this form questions will be asked about the participants museum behavior, knowledge on virtual reality and thoughts on the two initial designs for the virtual exhibition. All answers are anonymous.

Museum Behavior

1.   Current museum behavior - Question 1

Mark only one oval.

⬭   I   have never visited a museum before.

⬭   I have visited a museum once.

⬭   I have visited a museum on multiple occasions.

2.   Current museum behavior - Question 2

Mark only one oval.

⬭   When I go to a museum I like to roam free around the museum and explore it myself.

⬭   When I go to a museum I'd like to join a guided tour, giving me more insight on the details.

3.   Current museum behavior - Question 3

Mark only one oval.

○   I   would like to experience a museum on my own

○   I would like the company of friends/family to talk about the presented objects

4.   Current museum Bevavior - Question 4

If you would join a guided tour, would you be comfortable to ask questions when information is not clear *Mark only one oval.*

○   Yes, I would like to fully understand the presented information

○   Only in a private guided tour (no group tours with 30+ people)

○   No, I would rather not ask questions

5.   Current museum behavior - Question 5

Mark only one oval.

○   When walking through an exhibition I scan the presented object, I dont feel the need to look more into the given information.

○   I scan most of the objects only looking into the details of an object if it catchesmy interest.

○   When I am in an exhibition I examine each object individually, taking up all the given information

6.   Current museum behavior - Question 6

What is your opinion on the current presentation of information on artifacts (mostly in the form of text presented on a wall) *Mark*

only one oval.

○   I   like this method of presenting information

○   Another method would help me better understand the information, video, audio, etc.

Virtual Reality

7.   Virtual Reality - Question 1

Mark only one oval.

    ◯   I have experienced virtual reality before

    ◯   I have not experienced virtual reality before

8.   Virtual Reality - Question 2

Mark only one oval.

    ◯   I enjoyed the experience of VR

    ◯   I did not enjoy the experience of VR

    ◯   I have not experienced VR, but would be interested

    ◯   I have not experienced VR nor would be interested in doing so

9.   Virtual reality - Question 3
     Did you have any problems with your experience of VR? (multiple options possible)

Check all that apply.

    ☐   Motion sickness

    ☐   Confusion in orientation, feeling unstable

    ☐   Blurred vision during the usage of VR

    ☐   I have not experienced problems with VR

    ☐   Not applicable (when not having prior experience with VR) Other:

    ☐

                       _____

Initial Ideation Concept

10.   Initial ideation concept 1 - Question 1
     The first concept of the virtual installation will be presented, after which we would like you to answer some questions on its design.

In the first design the user is able to step into a presented painting, entering a new world.

Version 1 would have a recreation of the original surroundings of the presented paintings, essentially going back to the 1600s
Version 2 would put you in the position of the painter, being able to see beyond the borders of the painting and taking you to the rembrandts huis in the 1600s **Version 3** would display the whole process of the creation of the painting, from the creation of the canvas to the painting process of Rembrandt. *All versions would have the inclusion of sounds and side characters*

Mark only one oval.

◯ If I could choose I would prefer version 1

◯ If I could choose I would prefer version 2

◯ If I could choose I would prefer version 3

11. Initial Ideation Concept 1 - Question 2

Mark only one oval.

◯ Making this concept as realisitic as possible would help me immerse into the environment

◯ Stylizing the enviroment to the painting style of Rembrandt would help me immerse into the environment

12. Initial Ideation Concept 1 - Question 3

Mark only one oval.

◯ I think this concept would help me better understand the context of the painting

◯ I dont think this concept would add anything to my experience

13. Initial Ideation Concept 1 - Question 4

A list of elements that can be added into the experience will be presented, please select the ones you would feel will add to your experience. (multiple options possible)

Check all that apply.

- ☐ Being able to pick up/ inspect objects in the created world
- ☐ Being able to walk around
- ☐ Being able to interact with characters/ask questions
- ☐ The inclusion of a real life tour guide, letting you ask questions about all the presented details
- ☐ The addition of a story being told in the virtual world
- ☐ Being able to make choices around a presented story (like in games) creating your own path
- ☐ Other: _____

14. Initial Ideation Concept 1 - Question 5

Here you can give feedback on the first concept, any elements you think should be added or should specifically not be included.

_____

15. Inital Ideation Concept 2 - Question 1

The second concept of the virtual installation will be presented, after which we would like you to answers some questions on its design.

In this concept the user is able to take specific elements or objects out of the presented painting being able to handle and interact with a 3D version of said object (like earrings, fabric from clothing etc.).
Information on the object wil be given to the user via audio and animation, ranging from material information, cultural meaning (signs of power or wealth).

With the implementation of a tourguide, when picking up a presented object, the tour guides avatar will change to a person from that level of power or a craftman that would create such an object.

◯ I would be interested in this concept, and think it would help me understand the meaning behind the painting

◯ I dont feel like this concept would add to my museum experience

16. Initial Ideation Concept - Question 2

How would you like to get information from the presented object, what do you think would be the most effective? (multiple options possible)

Check all that apply.

☐ Through text

☐ Through audio

☐ Getting information on the material by displaying what it is made of visually A small situational video explaining its signi cance

☐ Other: _____

17. Initial Ideation Concept - Question 3

Here you can give feedback on the second concept, any elements you think should be added or should specifically not be included.

_____

_____

_____

_____

_____

18. Second To Last Question

Mark only one oval.

○ Ifeel like one concept on its own would give enough immersion and experience

○ I think the combination of both would be optimal

19.   Final question

Mark only one oval.

○ Iwould personally prefer the rst concept

○ I would personally prefer the second concept

○ I dont have a preference and think both would equally add to my museum experience

Appendix C: Research on the objects and their symbolism

Included objects:

- *A02 – King Caspar*
- *A03 – Head of a Boy in a Turban*
- *A05 – Portrait of Dom Miquel de Castro*
- *A06 – Portrait of Diego Bamba*
- *A07 - Portrait of Pedro Sunda*

Incense pot A02 – Presented as golden vessel

The golden pot in the painting represents a gift for Jesus and held incense. Presented in ornately golden container thus expressing its worth, as explained in the bible gold represented the kingship of Jesus. In the bible the incense was given as one of the three gifts after the birth of Jesus. The objects represented here

specifically in the painting is frankincense. This meant to represent Jesus' deity. In the old testament frankincense was typically burnt in temples as an offering for god. King Caspar gifting this to Jesus, he affirms that Jesus is both man and god. Additionally frankincense was thought to have healing powers, used in the east as a traditional healing method.

Golden accessories A02 – presented in the golden necklace

In the painting Caspar is seen wearing different types of golden accessories. Due to its rarity and unique colour gold was often used in paintings as a form of symbolism. Gold would represent the high power and status of the wearer.

The 17th century was often thought as the age of elegance when it comes to accessories. The sprinkling of jewels to show power was replaced by the wearing of a few carefully selected statement pieces to show taste. Finely carved rings, such as the one worn by King Caspar, were the preferred type of jewel worn by nobles.

Additionally gold often represented the light of god in Christian art.

The doublet A02

The man in the painting is seen worn a yellow doublet paired with an intricately detailed and jewelled cloak. A doublet is a type of form fitted waist length jacket worn with the aims of adding shape and padding to the body, often made from linen or wool which would help keep the wearer warm.

Additionally, the colour yellow was often associated with the sun and was seen as a connection to god in many religions.

The turban A03

A turban is a type of headwear constructed by the winding of cloth. It was often made from strong fabrics such as cotton and worn as customary headwear by people of various cultures.

The feather A03

The feather seen in the painting forms a type of decoration on the turban worn by the boy. The addition of elements of nature was deemed as a way of honouring culture and land. In many cultures a white feather is seen as a sign of hope or peace.

The blue garment A03

The garment worn by the boy represents a fantasy costume, with elements from a variety of styles from 17th century clothing. During this time, the pigment blue was the most lavish and difficult to obtain. It was the colour of power and royalty and represented self-worth.

The feather A05

The feather Dom Miguel de Castro is shown wearing is an ostrich feather. Such feather were often seen as a symbol of elegance or luxurious extravagance. The colour red was often associated with wealth and power, due to fact that it was the first colour ever developed for painting and dyeing.

The wearing of feathers on a headdress indicated a sign of status wealth and ethnicity. Often, the wearing of more rare and unusual items would indicate a higher societal status.

The hat A05

The cavalier hat was a commonly worn wide-brimmed hat from the 17th century. The name of this hat originates from supports of King Charles I, known as the Cavaliers, who were known for wearing extravagant garments. The hats were often made from felt and accentuated with ostrich feather, secured on the hat with a broach. One side was often pinned to its base, creating an asymmetrical look.

The garment A05

The garment worn by Dom Miguel de Castro is ornately decorated with silver gilt embroidery, using metal threads. Silver often symbolized wealth, grace and elegance.

Additionally, the garment includes a plain falling band, a commonly worn collar during the 17th century. Such bands were often made from sheer, white fabric such as linen without additional lace on the edges.

Box A06

The small casket held by Diego Bemba is assumed to be a diplomatic gift. Such gifts were given by a diplomat or leader as a courtesy when entering a foreign country. A decorative box such as the one presented in the painting, was more than a functional packaging, complemented with artistic elements.

Tusk in A07

Pedro Sunda is shown holding the tusk of an elephant. The material of a tusk, ivory, was deemed very valuable due to its beauty and durability, substantially exported due to its high demand. Additionally, the material was used as a way to craft object or carve depictions, so called ivories.

Throughout history, a tusk as a whole often represented strength and power.

Interactive general information

A02

Painting description: The portrait of King Caspar was created by Hendrick Heerschop, a golden age artist, in 1654, depicting King Casper in full glory.

More about the story: The painting represents one of the three magi who came to worship the Christ child. The three magi, additionally known as the three wisemen visited Jesus, bearing precious gift in celebration of his birth. Caspar, the second oldest magi, gifted the golden vessel filled with incense as to represent Jesus' deity. In the bible the magi were referred to as the 'men who study the stars', and believed to be astrologers who predicted the birth of Jesus by their ability to read the messages that were hidden in the sky.

More about Hendrick Heerschop: The Dutch illustrator and painter Hendrick Heerschop was born in 1626 and passed away in 1690. He was the Son of the Haarlem Harmen Jasz and the apprentice of Willem Claesz, another Dutch golden age painter popular due to his still life compositions. Hendrick on the other hand was mostly known for his portraits and genre scenes, a form of art that depicted aspects of everyday life by the portrayal of ordinary people engaging in common activities.

More about the material and techniques: The painting of King Caspar was made using oil paints applied on oak wood panel, known for its durability and little warping when exposed to sunlight. The painting can be seen as a prime example of Haarlem classism, often characterised by a rather naturalistic painting style and depictions of a prosaic or ordinary subject matter.

In this painting Hendrick plays with the images lighting, putting the focus on King Caspar's face and his expression, showing dignity and grandeur.

A03

Painting description: The portrait of a Head of a Boy in a Turban was created by the Dutch artist Gerrit Dou in 1635.

More about the story: The painting depicts an endearing tronie of a young boy dressed in a fantasy costume. A tronie was a painting genre commonly used from the 15th until the 17th century and originated from Italy. Such portrait studies depict the bust of a nameless model against a neutral background. Tronies showed great skills of the artist, often used as exercises for the portrayal of age, character and emotion. In the golden age there was a lively market for such exercises, often sold as independent works of art.

More about Gerrit Dou: Gerrit Dou, additionally known as Gerard Dou was born in Leiden in 1613 and died in 1675. Although originally apprenticed by his father Douwe Jansz, a glass painter, Gerrit became the first pupil of Rembrandt. He took up his masters idea of studying black people, resulting in tronies such as the one presented here.

More about the material and techniques: The painting of the Boy in a Turban was made using oil paints applied on panel. The paintings of Gerrit Dou were known for their immense perfection and attention to detail. Additionally, he perfected the light and dark effects also known as Chairoscuro, an Italian painting style where light and shadows are often depicted stronger and more dramatic than they often are in real life. However, his technique eventually lead to a decline in his status as an artist, as his clients did not have the time pose for an extensive amount of time.

A05

Painting description: The portrait of Dom Miguel de Castro was created by Jasper or Jeronimus Beckx

More about the story: The man portrayed in the painting is Dom Miguel de Castro, the emissionary of Congo and cousin of the Count of Sonho. De Castro was sent as an envoy to the Dutch Republic, asking for a mediation the Count had with king Garcia II of Congo. The portrait was created during his two week stay in Middelburg as part of six commissioned paints. Two of these additional paintings portraying both of his servants Diego Bemba and Pedro Sunda.

More about the painter: Originally, the portrait of Dom Miguel de Castro was though to b created by Albert Eckhout, a dutch portrait and still life painter. This painting, together with 20 brazilian paintings by Albert Eckhout were donated to king Frederick III of Denmark, which eventually led to them ending up at the National Gallery of Denmark. Due to these circumstances, the painting was wrongly attributed to Albert Eckhout. It is however currently thought that the portrait was created during Dom Miguel de Castros stray in Middelburg, assumed to be painted by one of the brothers Jasper or Jeronimus Beckx.

More about the material and techniques: The portrait of Dom Miguel de Castro was made using oil paints on oak wood panel. The identification of the base material of the panel lead to the correct attribution of the original painter of the portrait. At the time of its creation oak wood was not readily available in Brazil, indicating that the portrait must have been created somewhere in Europe.

Appendix D: Additional pictures of the installation

Appendix E: Information letter and informed consent form

Consent Form for Developing a virtual exhibition for remote guided tours
YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	O	O
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	O	O
I understand that taking part in the study involves filling in a short survey on general museum behaviour and expectation prior to the research activity. Additionally, interaction with a prototype version of a virtual museum visit for the installation 'HERE, black in Rembrandts time' by the Rembrandts Huis museum will take place. After this, a final interview on the overall experience of the virtual museum visit will be conducted.	O	O
The interaction and following interview will be captured in the form of audio recording. The data on museum behaviour and engagement collected during the research activity will be anonymously transcribed to text, after which, the audio recordings will be destroyed. Additionally the interaction with the prototype will be screen and audio recorded. This data will be anonymously transcribed to text, after which the audio recordings will be destroyed.		
Risks associated with participating in the study		
I understand that taking part in the study involves the following risks: motion sickness and/or possible dizziness due to the usage of virtual reality.	O	O
Use of the information in the study		
I understand that information I provide will be used for a written bachelor report, in which the data collected during the research activity will aid in concluding how the design of a museum visit can influence the engagement of the visitor.	O	O
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	O	O
I agree that my information can be quoted anonymously in research outputs.	O	O

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Signatures

_____   _____ _____

Name of participant [printed]   **Signature**   **Date**

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____   _____ _____

Researcher name [printed]   **Signature**   **Date**

Study contact details for further information: **[*Name, email address*]**

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Ethics Committee/domain Computer and Informational Sciences (CIS) of the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) at the University of Twente by ethicscommittee-cis@utwente.nl

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Information letter

Dear Mr/Mrs,

In this letter we would like to inform you on the research you have agreed to participate in. The testing will take place on 15 June at the Citadel at the University of Twente in room T202a and T202b. As a participant you will be asked to interact with a prototype and give feedback on the current design in the form of a short interview. Additionally, before and after the interaction you will be asked to fill in a survey.

The prototype in question is a virtual museum visit of a past physical exhibition by the Rembrandts Huis called 'HERE, black in Rembrandts time'. The virtual installation is aimed to create a multiplayer experience allowing for remote interactions between users. In this installation cultural heritage will be presented with the aims of changing stereotypes often assumed about People of Colour in Rembrandts time. During the testing you can freely interact with the prototype, there are no mandatory tasks. The questions asked in the forms of a survey and an interview will be focused on museum behaviour and knowledge on virtual reality. The whole session will take approximately 45 minutes.

This is a low-risk research, reviewed by the Ethics Committee Information and Computer Science. However, due to the nature of virtual reality there is a possibility that you will experience a form of motion sickness or slight disorientation. For this reason a researcher will always be present during the interaction with the prototype to ensure your safety and help guide you through the process. If you don't have prior experience with the virtual reality and the program used during the testing you will be given the opportunity to follow a tutorial explaining the mechanics and basics of the virtual world.

Participation in this research is voluntary and does not include a form of reward. At any time during the research you can withdraw your decision to participate without any consequences or reasons for doing so. Additionally you can reconsider your decision to participate in a timeframe of 24 hours after the testing took place, after which any collected data will be deleted.

The data collected during the interview and surveys will be stored in the form of anonymous text. Additionally screen and audio recordings will be made of the interaction with the prototype. The audio recordings will be anonymously transcribed, after which they will be deleted. The collected data will be used for a bachelor report only and will thus not be made publicly available. The retention period of the research data will be exactly 1 year, with the start date being the date on which the research was conducted. After this period, all data will be deleted.

All data is confidential and anonymous and will not be shared with third parties without your permission.

If you have any additional questions or concerns you can contact the researcher of this study at the following email address: l.presser@student.utwente.nl

Yours Sincerely,

Lisemijn Presser

Appendix F: Interview questions

Engagement questions

- How did the interaction in the exhibition impact your learning and understanding of the presented cultural heritage?
  - o Did the presented prompts on the table affect your willingness to explore the story of the presented artifacts?
- Which interaction stood out the most to you?
  - o What design elements of this interaction peaked your interest and why?
- To what extend did the presented information impact your experience of the museum?
- To what extend did the instructions affect your understanding of the installation. Do you have any remarks on the way the instructions were worded and displayed?

Multiplayer questions

- How do the multiplayer aspect impact your experience and understanding of the museum visit?
- What was your favourite aspect when it comes to being able to experience virtual reality with multiple people?
- Did the digital communication impact your museum experience?
- Did you experience any limitations of the used software during the testing?
- this virtual experience affect your preference on experiencing a museum visit alone/with multiple people.
- How did the ability to exchange thoughts and communicate your experience during the testing impact your learning, motivation and understanding of the story of the cultural heritage.

Chronologically ordered Participation list

16 June 2023

- Multiplayer set 1 – Participant 1
- Multiplayer set 1 – Participant 2
- Individual set 1 – Participant 3

21 June 2023

- Individual set 3 – Participant 7
- Multiplayer set 3 – Participant 8
- Multiplayer set 3 – Participant 9
- Individual set 4 – Participant 10
- Multiplayer set 4 – Participant 11
- Multiplayer set 4 – Participant 12

24 June 2023

- Multiplayer set 6 – Participant 16
- Multiplayer set 6 – Participant 17
- Multiplayer set 7 – Participant 18
- Multiplayer set 7 – Participant 19
- Multiplayer set 8 – Participant 20
- Multiplayer set 9 – Participant 21

28 June 2023

- Individual set 7 – Participant 23
- Individual set 8 – Participant 24

20 June 2023

- Individual set 2 – Participant 4
- Multiplayer set 2 – Participant 5
- Multiplayer set 2 – Participant 6

22 June 2023

- Individual set 5 – Participant 13
- Multiplayer set 5 – Participant 14
- Multiplayer set 5 – Participant 15

25 June 2023

- Individual set 6 – Participant 22

Appendix K: Participant interview results

	1	2	3	4	5	6	7	total subsection 1	Percenta
1	5	6	6	5	6	6	6	40		82%
2	5	5	5	6	7	7	4	39		80%
3	2	2	1	2	6	6	7	26		53%
4	5	3	2	4	6	7	7	34		69%
5	5	5	5	4	5	6	7	37		76%
6	5	5	4	6	7	7	7	41		84%
7	3	5	4	4	7	7	6	36		73%
8	5	4	5	6	7	7	6	40		82%
9	7	5	6	6	6	7	3	40		82%
10	3	5	5	4	3	6	6	32		65%
11	3	2	5	4	6	6	7	33		67%
12	4	7	7	5	5	7	7	42		86%
13	5	6	4	3	2	6	6	32		65%
14	2	1	5	2	5	6	3	24		49%
15	2	2	2	2	4	6	3	21		43%
16	3	2	2	4	6	5	5	27		55%
17	1	1	3	4	6	6	3	24		49%
18	6	4	3	6	2	6	7	34		69%
19	6	6	7	7	7	7	7	47		96%
20	6	6	5	5	7	7	7	43		88%
21	7	5	4	7	7	7	7	44		90%
22	6	6	6	7	6	7	1	39		80%
23	5	3	4	6	7	7	3	35		71%
24	4	5	5	6	6	5	1	32		65%
Average	4,375	4,20833	4,375	4,79167	5,66667	6,41667	5,25		Average:	72%

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	total subsection 2	Percenta
4	5	6	3	5	5	3	6	5	7	6	6	6	5	6	6	7	7	7	4	6	6	6	7	7	141	81%
7	5	5	5	4	6	3	5	4	5	5	5	5	6	3	6	5	7	5	6	6	6	4	5	6	129	74%
7	5	6	5	2	6	5	3	4	6	5	3	4	7	7	7	6	5	7	6	6	7	6	5	6	136	78%
7	6	5	6	4	7	6	5	3	7	6	6	4	6	5	5	6	6	5	6	6	5	6	5	7	140	80%
6	5	4	4	3	4	5	4	3	6	5	4	3	5	5	5	6	5	5	6	4	5	5	5	3	115	66%
6	6	5	6	5	6	5	6	4	5	6	5	5	7	6	7	4	7	5	6	6	5	4	5	7	139	79%
6	6	6	5	4	5	2	6	4	6	5	4	4	5	5	6	6	7	6	5	6	5	5	5	7	131	75%
4	5	5	5	5	4	2	6	3	4	5	5	6	3	5	5	4	5	5	7	5	5	6	5	4	118	67%
5	6	5	4	5	6	4	4	5	6	6	6	6	6	5	5	6	6	6	6	5	5	6	6	4	134	77%
3	5	1	3	1	7	5	4	3	6	1	3	2	3	4	3	6	5	4	6	5	4	2	4	5	95	54%
7	6	6	4	6	3	4	5	4	6	2	5	6	5	5	6	6	6	7	6	6	6	6	6	6	135	77%
6	7	5	6	3	6	3	4	5	7	7	7	6	7	6	6	7	6	5	7	5	5	5	4	7	142	81%
4	5	1	3	4	6	3	5	5	5	6	4	5	3	6	3	6	5	5	6	6	5	3	3	4	111	63%
4	6	2	5	2	3	3	4	4	4	1	1	2	2	1	3	3	5	3	4	5	4	3	2	2	78	45%
7	6	5	5	5	5	1	7	5	6	5	4	5	2	3	6	5	6	6	7	5	6	7	2	5	126	72%
5	5	2	4	2	4	2	4	3	6	5	6	5	6	5	5	5	6	4	6	5	5	4	4	2	110	63%
7	3	5	2	6	6	1	6	7	6	6	4	4	7	5	6	6	7	7	7	6	6	5	5	6	136	78%
6	6	5	5	2	3	6	6	3	3	6	5	4	6	7	6	6	5	3	7	7	6	5	4	6	128	73%
6	7	6	6	6	5	2	7	2	7	7	5	4	5	6	7	7	7	7	7	3	6	7	6	5	143	82%
6	7	6	7	5	6	2	5	4	6	7	6	5	5	7	5	7	7	2	6	6	6	6	7	7	143	82%
5	5	6	7	6	7	6	7	7	6	5	5	6	6	6	5	2	7	7	3	7	7	5	6	7	146	83%
7	7	5	5	6	3	3	6	6	6	7	7	7	7	7	7	3	7	7	7	6	7	7	7	6	153	87%
6	6	5	5	4	6	4	5	3	6	5	6	5	7	6	6	5	6	5	7	5	7	6	6	5	137	78%
4	6	3	4	5	4	2	5	5	5	6	5	3	4	5	3	5	5	6	6	4	6	6	4	5	116	66%
																									Average:	73%

33	34	35	36	37	38	39	40	41	total subsection 3		Percenta
5	3	5	7	4	3	6	3	7	43		68%
5	2	6	5	6	6	6	2	6	44		70%
3	6	1	7	3	2	7	2	7	38		60%
4	2	4	7	5	4	6	3	5	40		63%
7	7	7	4	6	2	7	1	7	48		76%
5	3	5	4	7	4	6	4	7	45		71%
7	3	3	5	6	6	6	5	7	48		76%
6	4	2	5	3	3	4	2	6	35		56%
6	3	4	7	6	5	6	4	6	47		75%
3	3	5	6	2	2	5	2	6	34		54%
5	2	3	5	2	3	6	3	6	35		56%
5	2	5	6	6	3	5	1	7	40		63%
4	5	6	6	5	3	5	4	3	41		65%
7	2	5	1	6	6	6	4	7	44		70%
5	4	5	7	6	3	6	4	4	44		70%
5	2	3	3	6	6	6	2	6	39		62%
3	4	3	4	5	5	5	1	6	36		57%
6	3	1	6	7	6	7	4	6	46		73%
6	2	5	4	5	3	7	2	7	41		65%
6	5	5	5	5	2	7	2	7	44		70%
7	1	5	1	7	6	7	6	7	47		75%
5	4	4	1	6	2	6	4	5	37		59%
4	3	3	5	5	6	7	4	7	44		70%
6	6	6	5	2	2	7	2	7	43		68%
										Average:	66%