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Reaching behind the glass:

Fashion exhibition and social Virtual Reality

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Abstract

New media technologies, like social Virtual Reality, rapidly become applicable to more variety of fields, including cultural heritage. Museums, constantly challenged to increase interest in their collections, search for new ways to entertain and educate the broader public. This study explores the possibilities of using social Virtual Reality in exhibiting historical fashion.

Social Virtual Reality fashion exhibition has the potential to improve user experience and visitors' knowledge retention, by introducing elements difficult to provide in the traditional museum, like interactions and context. Interactions in social VR can be much more complex and context can be introduced more extensively, as the limits of the physical world do not apply to a virtual environment. Social VR can also provide a new method of "conservation". Placing scans of garments in social VR could create a possibility for curators to keep on researching the pieces after they are too fragile to be touched, without the risk of damaging them.

This study includes a literature review on museum challenges and opportunities social VR could bring them, an expert survey confirming social VR's value in fashion heritage sector, and a focus group with curators to establish design requirements. The results identify five main elements that should be taken into account: learning, user experience, emotions, context and vulnerability. Then the experience is created based on those results and an expert evaluation session is organised to investigate how to best use context in a social VR fashion exhibition. The meeting leads to the idea of contextual build-up, in which the environment gradually evolves from being similar to the physical space the participants are in, into an out-of-real-world setting. The whole research process adapts the human-centred approach, using mixed methods for collecting data and engaging experts in the field of cultural and fashion heritage, associated with institutions such as: the Netherlands Institute of Sound and Vision, Centraal Museum Utrecht or European Fashion Heritage Association.

The experience was designed incorporating three rooms of different contexts: modern museum, neutral space and historical house. The exhibition was created as a social experience, where two or more participants can interact with each other and with the exhibits. The object interactions performed by one of the visitors are visible to all of them. The exhibits shown in the exhibition are scans of real garments, and can be manipulated by the visitors via actions of rotation and scaling.

These findings highlight social VR's potential to revolutionize historic fashion exhibitions by enhancing engagement, storytelling and accessibility, while preserving artefacts for future research. The work identifies key design components such as learning, user experience, emotions, context, and vulnerability. It investigates how to integrate context effectively, suggesting a dynamic environment that evolves from familiar to fantastical settings, as well as benefits context brings to the experience. The results also demonstrate ways to incorporate interactive elements, which play a crucial role in enhancing user experience and learning.

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Contents

1 Introduction

As the times we are living in are changing, human habits and lifestyles are evolving. One of the biggest changes that recently took place was the rise of remote communication, consolidated by the COVID-19 pandemic. In 2022, 50% of enterprises with at least 10 employees used remote communication tools [1]. This trend expands to other areas of life, such as cultural heritage - one of the most important factors influencing human well-being and quality of life of communities, contributing to environmental, social, cultural and economic sustainability [2]. As people migrate more than ever in history [3], they look for a way to keep in touch with their home country's culture and familiarize their children with it [4]. The matter of accessibility also affects disabled individuals, who have faced long-standing restrictions in experiencing cultural heritage [5].
In the present global circumstances, museums face numerous challenges, but they also encounter many opportunities. One of the main challenges is to become more attractive for people to be able to compete with other industries on the market, for example, the entertainment industry. In order to achieve that, they need to:

- become more interactive,
- fulfill the need of *co-production*, e.g. by individual consumer's active participation in one or more activities performed in the experience,
- fulfill the need of *engagement*, e.g. by the psychological state of cognitive and emotional immersion,
- fulfill the need of *personalisation* - tailoring the experience to meet user's needs through customisation, interaction with service representatives and technology [6].

Especially for fashion artefacts, more physical contact with the objects seems crucial since clothes are among the items we keep the closest to our bodies. People are drawn to touch the materials the clothes are made of, they imagine how it would be to wear them, to interact with them [7]. Another challenge is to ensure everybody will be able to access the museum resources, regardless of location or physical/mental state.
Some other challenges museums encounter are universal over time. An example is studying and maintenance of the exhibits. Due to the variety of cultural heritage artefacts, suitable research and specific conservation methods are not well-developed for many of them [8]. Studying and conservation of the exhibits may also sometimes develop a conflict of interest - while restoration of the artefact is crucial to extend its lifetime, it changes the original object [9]. Hence it is important to maintain a good balance between keeping the object "alive" and in good aesthetic, but also follow a "minimum intervention" principle [10] to keep the artefact as unchanged as possible, as a result ensuring that future generations will still be able to conduct scientific research on this object.
Beside the challenges lie opportunities: making the museum more exciting, visited by a broader audience and much more (inter)nationally recognizable, creating new possibilities to maintain and research the artefacts.
This thesis explores a way of implementing all of those changes into the fashion museum experience

through the usage of social Virtual Reality (social VR), which has the potential to engage the public in activities, providing benefits for the individual, the community, and the museum itself.

To create a successful experience it is necessary to consider what are the desired goals. In this case, it seems reasonable that the advantages should consider the following aspects: the individual (creating a better experience), the society (ensuring one step ahead interaction) and the museum (providing broader audience and allowing further research on artefacts).

Let's start with an individual - a visitor. The challenge here is to design the experience well. For example, it is necessary to consider how to make the interaction with the clothing attractive, so the need of being with the piece of clothing is fulfilled - how to make it more "real" than watching the exhibit from behind the glass [7], but also provide an exciting experience that would not be possible in the real world. It is also crucial to fulfill other needs of visitors, for example learning. How to communicate the information to the visitor in an effective way [11]? And what information should be presented? Should it be personalized depending on the knowledge and interests of the visitors [12]?

There is also an issue of how to present the clothes and where to put the most attention. The dilemma to consider is if the clothes should be presented the way they looked originally, or rather how they looked like after they ended up in the museum (or maybe both). Should the imperfections resulting from historical events (like bullet holes) be emphasized, or the focus should lay on the material, design and craft? It is also important to remember that environment and freedom impact an individual experience. The *atmosphere* (defined in the literature as "intangible elements and stimuli", such as color schemes, lighting, allocation of space to exhibitions, programs, spatial arrangement of exhibitions, interpretive signage and object labels, availability and perception of staff, interactions with other visitors and crowding [13]) in the virtual museum should be designed in a way that improves the overall experience [14]. Another aspect is how much freedom should the visitor be granted, so that they feel like they can explore on their own, but at the same time not miss the important parts of the virtual exhibition [11] [12].

But social VR is not only visitor-object interaction. It is also visitor-visitor interaction. This interaction needs to be designed in a way that does not disturb the experience but improves it [15] [6]. The aim is to enable users to experience the social event which could influence and shape the relationships within the groups of people. The second aspect is touched on here: the impact on the community. It is important to answer the question of whether the interaction between visitors should be guided (by, for example, some tasks that need to be performed in a team) or rather left to proceed naturally without outside influence.

The last challenge that needs to be addressed is the benefit for the museum. The goal of the social VR museum is also to encourage people to visit the physical museum [16]. The virtual museum would need some direct connection with the real-world exhibition so that after the experience visitors feel the need to continue their journey in the physical museum and feel more satisfied with the visit (for example because of a better understanding of the exposition), which in turn makes it more probable they will come back to the museum in the future. Next to attracting visitors, museums have yet another mission: studying the artefacts and history behind them. The challenge here is that passing time makes the objects more and more fragile, eventually even leading to the loss of

some of them [17]. This poses an obstacle to a free examination of those exhibits. There are several methods of "non-destructive" ways of examining the objects, for example using various X-ray-based methods, Infrared Spectroscopy or Synchrotron Radiation Techniques [18]. This does not eliminate the need to touch the exhibits completely, as they need to be moved in order to perform the test operations - and for some of them, even slight movement can be destructive. It is important then to find ways to ensure a possibility of studying the artefacts even after they reach this level of fragility. The idea of using 3D models started to appear in the literature next to the physical restoration of the objects [19]. The remaining question is how to work with the models most beneficially and seamlessly.

The aim of this work is to explore how social VR platforms can enhance the experience of fashion museum visitors and help researchers continue studying fashion artefacts. To do so, the first step is to analyse the challenges and opportunities for fashion museums, in both physical and virtual worlds, and explore how social Virtual Reality can be used to bring the attendees closer to the piece, improve connection and interaction with the exhibit's themes, and further improve their overall enjoyment, while offering the chance for curators to bring vulnerable objects to the audience and further examine them. The following sections explore the background themes through an extensive literature review, forming the research questions to be answered in this thesis. Firstly, the museum's evolution as an institution is described. The museum went from being mainly focused on exhibits conservation to transforming into a social museum, whose most important goal is to present the artefacts to the public. Finally, they started to use digital technologies for this purpose and became so-called digital social museums. Those redefined museums face many challenges, which are mainly focusing on ensuring a good visitor experience. How to show the exhibits in an attractive way, how to successfully pass information, what to do to make the whole experience enjoyable and how to ensure satisfaction among visitors - those questions are constantly being asked by the curators. They try to address them while designing the exhibitions. Here, based on the literature review, many elements can be marked as important: the way exhibits are presented, interactions with exhibits but also with museum space and other visitors, well-designed context fitting the story of the artefacts, interesting way of giving information, well-designed space layout and addition of social elements in the exhibition. All of these elements required to create the perfect experience are very difficult to implement in the physical space of the museum. The availability of the exhibits is limited, the layout and appearance of the space are usually hardwired by the museum building and the possibility to interact with exhibits is limited to actions that would not destroy the object - so the interactions usually do not consider the artefacts themselves, but are rather designed with elements around them. The fragility of the exhibits is also an obstacle for curators to study them. Hence, the idea appeared to create a virtual version of the fashion exhibition using social VR. Based on the literature review presented in the following section, the possibilities that this technology gives could allow the curators to build the exhibition ensuring all of the important elements described above. In social VR the exhibit could be presented in any desired way, without limitation of its physicality and fragility, the interactions could be incorporating the artefact itself and would not be limited only to action possible in the real world. Social VR could allow for an out-of-the-world experience, where the users can change the shapes or colours of the objects, make them levitate in the air and so on. All of

the evidence coming from the literature suggests that the creation of a social VR fashion exhibition would bring a lot of benefits for all: museums, visitors and curators. However, an exhibition like that has never been created before, so it seems natural that the first research focus should be on verifying if usage of the platform would actually bring those promised benefits. For this purpose the authors decided to follow the user-centred approach and ask the experts about their opinion on the matter. From this idea the first research question for the thesis emerged:

RQ1: What do experts think of the use of social VR for fashion exhibitions?

To address the question an expert survey was conducted. The obtained answers allowed us to verify that social VR is a suitable tool for the purpose of creating coherent, complete fashion exhibitions. It also made it possible for us to explore the possibilities of utilising social VR in studying cultural heritage artefacts, specifically fashion antiquities, and validate the assumption that it would be beneficial for curators to use this technology while conducting artefacts studies.
The Background section of this work describes in detail how to design the (fashion) social exhibition. As already mentioned, all of the important elements, that are often difficult to implement in the physical museum, are possible to be created in the VR version of the exhibition. There are also many studies describing how to create a good Virtual Reality experience. However, there is no research showing which issues should be taken into account while connecting those components. Before actually developing the virtual exhibition it is important to find out the set of design requirements we should follow to create possibly best experience. Hence, the second research question for this thesis is:

RQ2: What issues should be taken into account while designing a social VR fashion exhibition?

Addressing this question, this time by conducting a focus group with curators, allowed us to define a set of requirements specifically for the design of a social VR fashion exhibition and to find out what elements are the most important to reach the best results for visitor experience and their learning outcomes, which are very important parts of a social museum. It also gave us the idea of how to implement those elements using social VR so that it has the best influence on the fashion heritage sector.
In the course of the literature review many elements that strongly influence the exhibition experience were described. One of them, namely context, was introduced as a very important one, but because of its strong limitations in the real world we lack knowledge of how to use it having the unlimited possibilities of Virtual Reality. Context is proven to have a strong effect on many areas of the experience, from enjoyment to knowledge retention. Context can shape the way the visitors perceive the story, the object and the whole exhibition. However, it was not checked before how this powerful tool can be best used in a creation of a virtual exhibition. Taking into account that Virtual Reality creates an opportunity to easily introduce context on a scale that would not be possible in a physical world it is important to know how to best take advantage of this chance. Hence, the last research question that this thesis aims to answer is:

RQ3: How can we design a social VR fashion exhibition taking into account the context?

To answer this question a series of co-design sessions were organized, the experience was implemented and then evaluated during the validation study. The results achieved in the course of researching this part of the thesis allowed us to understand what is the most beneficial way of using the context in the social VR fashion exhibition. We discovered what elements of the experience smart usage of context can influence, how it can make the transition to the virtual world more smooth for visitors without much experience in VR and how it can make the whole experience less challenging: from managing the controllers until a better understanding of the story.

Apart from the contributions pointing directly to specific research questions already described above, the whole work brought to the table more, broader inputs. Firstly, this thesis shows how to use social VR so that it has the most positive influence on the cultural heritage sector, especially taking into account fashion heritage. Secondly, it gives foundations for the creation of a guideline for curators on how to use social VR in the creation of virtual fashion exhibitions. It also proposes ideas of how to enhance user engagement and interactions with fashion exhibitions using social VR and creates a future possibility for people in remote locations to access the garments physically located in the Netherlands. Finally, the work proposes usage of social VR as a tool for the preservation of cultural artefacts and keeping them in unchanged form indefinitely, thereby fulfilling one of the most important goals of the museum.

Taking into account the specificity of the research questions given, each of them requires different study methods. Figure 1 shows the methodologies followed in this thesis. To answer the first question, we decided to conduct expert studies in the form of a survey. Then, the second research question was analysed based on the focus group with museum curators. Finally, the use of context was investigated via co-design sessions with stakeholders, design and implementation, and evaluation procedure.

The results of the above-described studies indicate that, firstly, the experts are positive about the idea of social VR fashion exhibition. They agree that the experience would help create synergy between exhibition elements, positively influence the storytelling, make the exhibition more approachable to the regular visitor and create more possibilities to study the exhibits by curators. Secondly, focus group results point to a list of elements that should be taken into account during the design process of the experience: learning, user experience, emotions, context and vulnerability. On top of that, the study allowed us to discuss the design ideas with the curators and agree upon many important elements, like interactivity or characteristics of used objects and the way of their virtual equivalents creation. Finally, the expert evaluation session resulted in an idea of how to effectively use the context in the social VR fashion exhibition experience. The concept is to create a contextual build-up, in which the environment should change with time: starting from a space similar to the place the visitors are physically located in, through realistic, but different than the current participants' location area, to the section being out-of-real-world, where the rules of reality do not apply.

This thesis will approach the research questions posed by firstly showing the background in the

form of a literature review (Section 2), from which the question emerged, and then conducting three studies shortly mentioned above to address those questions one after another. Firstly, the expert survey and focus group, detailed in Sections 3 and 4, will be described together with their results analysis. Then, in Section 5, the whole design process will be presented, describing the approach to the task, implementation of the most important elements, like context or interactions, and description of chosen for the exhibition artefacts. After that, in Section 6, the implementation and evaluation session will be discussed. The whole development process will be described together with the most important software and hardware components in Section 6.1. Then, in Section 6.2, the procedure and results of the evaluation session will be presented. Finally, in Section 7, all of the results will be summarized and the work will be concluded by presenting the future follow-up efforts within the project, as well as possible future research based on this thesis.

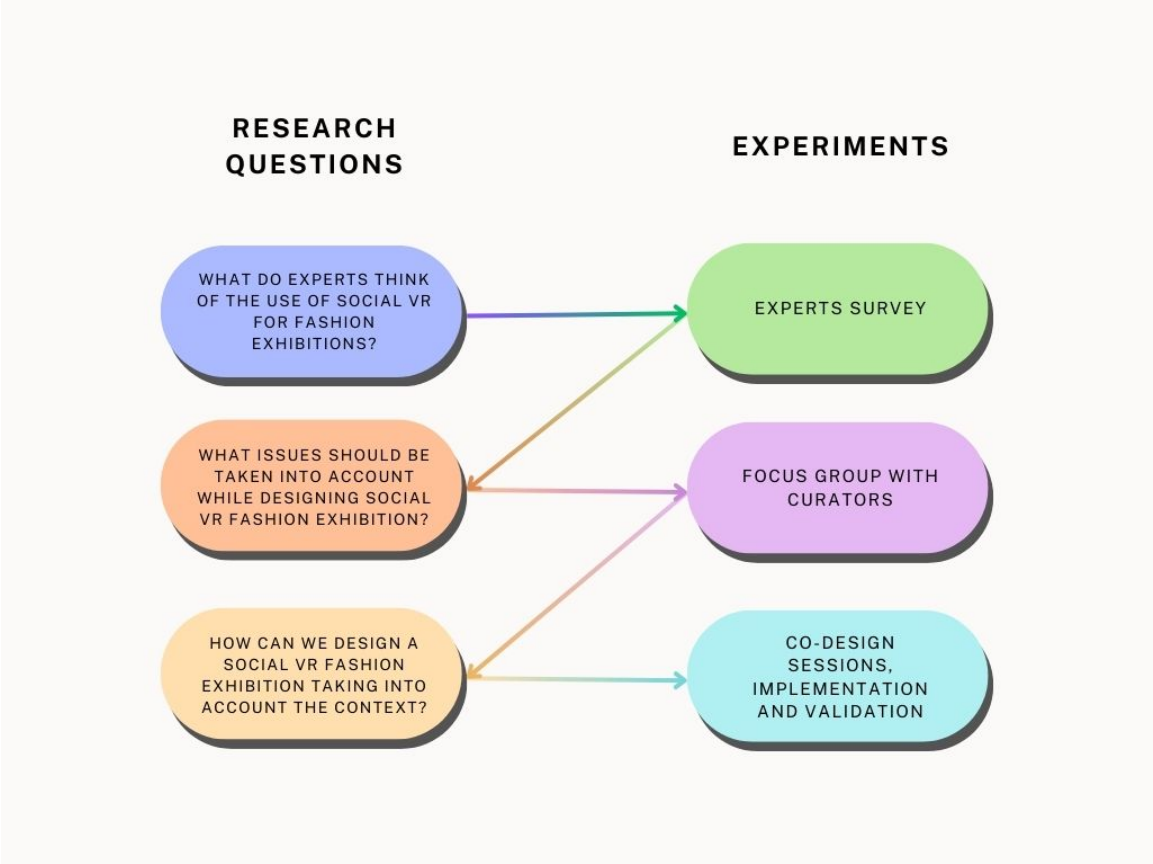


Figure 1: Methodology workflow: research questions and experiments done to answer them.

2 Background

In this section the literature review leading to the formulation of research questions is presented. Firstly, contemporary museums' challenges are described and the potential of social VR in resolving those challenges is shown. This analysis leads to the assumption that social VR could be a useful tool to improve the experience and learning outcomes of museum visitors and results in the formulation of the first research question. Then, the analysis of the important design elements and approaches for social museum and social fashion museum is done. Similarly, the user experience in social Virtual Reality is discussed. These sections introduce the background of the design path for the social VR fashion exhibition. However, they also leave a research gap, showing the important aspects of each of those elements separately, but lacking a description of the design approach for the combination of social fashion exhibition and VR experience. Hence, this analysis leads to the formulation of a second research question, with the aim of creating a set of design requirements for social VR fashion exhibition. Finally, while talking about the important for social (fashion) exhibition elements, one can notice that some topics repeat multiple times. One of those topics is the usage of context in order to create a coherent, interesting story, increase the engagement of the visitors and improve their learning outcomes and experience. Context is particularly interesting in the case of this thesis, because its usage in Virtual Reality can be much broader and less restricted compared to the real world. Hence, the knowledge about context usage from the physical exhibitions cannot be directly transferred to the social VR realm. A separate study on how to use context in a virtual environment is needed and that is what the third research question of this thesis is addressing.

2.1 Museum and its challenges

In the 20th century, museums have undergone a metamorphosis. What changed compared to previous centuries was the primary focus: it shifted from solely conserving and maintaining the exhibits to prioritizing the needs of the visitors. During the 1st International Workshop on Ecomuseums and New Museology, held in Quebec City on October 13, 1984, the basis of the concept of a social museum was established. Since then the museum has become a place of cultural democracy, social dynamism, openness and interactivity [20].

2.1.1 Social museum challenges

Together with new goals, new challenges emerged. The museums wanted to focus on the visitors and adjust the museum space to them. Visitors, however, differ from one to another. One example is the level of knowledge they have in a particular topic. Research shows that people who are more familiar with the topic of the exhibition, rate it higher [12]. It seems important then to fit the specification of the information to the level of the visitor's knowledge, which differs between individuals. But that applies to only one of the museum visitor's psychological needs defined in the literature [21] - confidence. Next to it stand curiosity (expectation of seeing/experiencing things that would not be possible to see/experience elsewhere), challenge, control (feeling of being in charge, having choices and making decisions), play (having fun and engaging in playful/sensory

experiences) and communication (with other visitors and/or exhibits). Fulfilling all of those needs creates a satisfying visit experience, and hence is the ultimate goal of the museums.
There are also various challenges for specific types of museums. Taking into account the fashion exhibition, it is crucial to present the clothes to the visitors in an attractive way. The first criterion is about the realism of the situation. Clothes are objects that we interact with constantly in our everyday life. Seeing them behind the glass is not fully satisfying for people, since the visitors would like to touch them, try them on, be close to them [7]. Museums need to find a way to make the interaction with clothes more interesting, so that the needs of visitors associated with this interaction are fulfilled. Another issue is what part of the clothing to show. Should imperfections, like stains or holes, be highlighted (e.g. because of their historical meaning) or hidden? Should it be split into parts (many costumes from the past consisted of multiple layers) or shown as one whole? Making this decision takes a lot of time of research and directly influences the level of satisfaction of the visitors [7]. What is also problematic is that some of the clothes cannot be constantly on display. Light weakens fabrics and causes dyes to fade, and gravity pulls on the materials and might change their shapes [7]. The clothes need to be then regularly taken for conservation, which might negatively influence the continuity of the exhibition and hence worsen the whole museum experience. Moreover, the lack of some important pieces might cause dissatisfaction among visitors whose goal was to see this particular piece.

2.1.2 Design of social museum exhibition

While trying to address all of those challenges that social museums face, good exhibition design is the first and one of the most important elements. To create the exhibition curators need to take many elements into consideration, starting from the general layout of the exposition and ending at taking care of the smallest details of the objects' presentation. Usually, the starting points are the exhibits themselves - in the end they are the main objects the visitors come to see in the museum. Of course, the selection of the objects strongly depends on the type of museum - a fashion museum will pick mainly clothes, while one focused on automotive will be centred around vehicles. There is, however, a universal need among the visitors for novelties. They are more inclined to visit museums, that change and develop their offer, also by introducing some dynamics in which exhibits are displayed (changing the exhibits, introducing new ones, creating temporary exhibitions) [22].
Together with the exhibit two features arrive: information about it and its physicality. It is important to bring the visitor close to the exhibit, taking into account both of these attributes - reducing the physical and informational distance between the visitor and the visited object [22]. The physical distance can be minimized by allowing interactions between the object and the visitor. During the visit to a museum, the visitors hope to have the possibility to touch and experience things by themselves [22]. Interestingly, the communication between the exhibit and the visitor can also be executed by the object. Using digital tools, it is possible to display content on top of the exhibit, allowing it to "tell its story" to the audience [23]. It is not only the interaction with the exhibit that is important. The whole environment should be responsive and able to engage the visitor, increasing the immersion in the experience. The audience should be entertained but also

sometimes physically engaged and intellectually challenged, allowing for creativity while exploring the exhibition [22]. There are many ways of implementing interactions and many benefits coming from them. An example of the interaction implementation might be via broadly known games, like Monopoly, adjusted to the topic of the exhibition. Those games can induce in visitors the feeling of achievement while providing entertainment at the same time [23]. An interesting and important case is creating interactions not with the historical exhibits themselves but with copies or objects related to them. Those interactions often make people more interested in seeing the original piece, at the same time introducing another very important element in exhibition design - context [23].
The context in the case of social museum exhibition has many angles. Firstly, the context in the information given around the exhibit - it might be the political or social situation in which the piece was created or the reference to contemporary times. The visitors are very sensitive to the informational context while creating their opinions and perspectives [22]. Not only what the information is, but also how it is given matters. The narration should be fitted to the museum theme (e.g. patriotic or scientific) so it creates a complete whole and does not disturb the perception of the exhibition. This coherence is important so that the narrative enhances rather than detracts from the visitors' understanding of the exhibition [22]. The media used to pass the information also plays a role. The visitors tend to connect the exhibits that were presented using the same media and interpret them as telling one story [24]. The way the museum space looks like has a huge impact on how much the audience enjoys the exhibition as well. For example, the science museum is expected to be based in a building that is associated with technology. If this context in the form of a building in which the exhibition takes place is not consistent with its topic, the audience satisfaction is lower. Even the smallest details, like colors of the background and frames' shapes matter [25]. The way the space looks like also influences emotions people develop towards the exhibit and the memory retention [26] [27]. Of similar importance are the "additional" objects that are in close neighbourhood to the exhibits. Exhibitions created as "neutral" in principle can gain another meaning, not intended by the curators, because of the context given by other objects around them. An example is described in the research "Interconnecting: museum visiting and exhibition design" by S. Macdonald where the exercise bike made people believe that the exhibition is about "health education", while in reality the theme was neutrally valenced "food additives" [24]. The last interesting feature of context is that it can come from outside the museum. Some objects are already incorporated into specific contexts in people's minds, which can be used for the benefit of the museums. It usually demonstrates in a form of comparison, when people know some similar objects from their childhood. These memories influence the narrative and their perception of the story presented in the museum [24].
In the case of passing information, context is only one of many aspects that should be taken into account while designing the social museum exhibition. Firstly, text is not the most effective way of communicating the message. People tend to skip reading many panels in the museum, and even if they read the descriptions, they are often not really attentive to what they read [24]. Even adding other visual means, like pictures or posters, seems not to be enough. Auditory information given by a museum guide also does not do the trick anymore. The only solution is to introduce a multisensory experience - trying, touching, feeling, hearing and seeing. The content of the information is as

important as the way of communicating it. Ideally, the information should be suited to visitors' own interests [22]. It should also be given in a way that encourages them to think and use their imagination, which is both: pleasurable and educating [23].
Unfortunately, the next important aspect of the exhibition design is not so easily adjustable. The exhibition layout, being the topic at hand, strongly depends on the construction of the building itself - in the end, the curators are not able to move walls to ensure the best experience for the visitors. However, it is important to mention the importance of the layout, as the way people move through the space has considerable influence on the order visitors watch the exhibits, and hence their interpretation of the exhibition [28] [24]. Taking this into account it would seem that the best solution is to organize space in such a way, that the visitors always follow the same, carefully designed by the curators path. The research suggests though that the visitors themselves like to have the freedom to decide how they will move around the museum space and how much time they will take. They want to have the opportunity "to find their own way of getting to know the ideas which the museum wants to get across" [22]. Unfortunately, it seems that this visitors' need stands in opposition to the idea of strictly guiding the audience through the route that gives one, upfront formulated story. The literature gives idea for the solution: creating a main path, which will always be followed by the visitors but will also include sub-paths, that create small experiences within the main branch giving more freedom of choice, but finally always guiding the guests back on the intended path [28]. The space layout can also induce social behaviours in people. For example, some spaces produce an effect in which people re-encounter each other. It might not be even noticeable to the guests on a conscious level, however, unconsciously, it makes the museum visit experience more socially exciting [24].
Sociality, next to making humans excited, has also another influence on the way people experience exhibitions. The companion of a museum visit has a huge impact on how the individual perceives and interprets the exhibits. Sometimes the interaction with their companions can even determine if they notice something at all [24].

2.1.3 Design of social museum exhibition focused on fashion heritage

As already mentioned, clothes are a special case in a museum setup. They function somewhere in between art and life, creating a link between those two, seemingly distant worlds [29] [30]. While creating a fashion exhibition it is important to show this link and use it to tell the story behind the garments. Experts claim that clothing can tell us much more about the people who used it than any other historical object. It can tell the story about their lives, feelings, and tastes working as the "remaining outer shell of a living person". Giving this almost personal context of the garments attracts huge amounts of visitors [29].
Context in general is very important while exhibiting fashion. Firstly, by comparison, we can show how the designers were inspired by other garments and explain where some trends came from [29]. Comparison can also show how contemporary clothes are strongly influenced and inspired by historical garments, how past designers shaped the way people dress nowadays - years after their projects were proposed to the world [31] [32]. Giving people the context of times they live in helps

them understand the garments they look at and their purposes, but also explains why the clothes they wear nowadays look the way they look. Comparison is not the only way to show the inspiration for the garments. Showing the creative context of the designer's work can explain to the visitors how the look of the exhibit was shaped and where all of the ideas of the artist came from. This context can be presented for example via sketches, notes and personal objects of the designer [32] [31].

Archive materials placed around the garment are effective in giving information not only about the inspirations of the designer but also in general about the exhibit: what was its purpose, how was it used, what materials is it made from and so on [31]. The question that remains is how to present the exhibit itself. Firstly, it should be possible to see it from all sides - clothes look differently in the front than in the back, and to fully appreciate them visitors need to see the object from all angles [31]. Also seeing garments from up-close enhances the visitor experience [29] [32]. It not only results in the excitement of seeing valuable objects from a really small distance, but also allows to see details, which is really important in a fashion museum, as some garments might look completely different from afar. An example might be Balenciaga's graduated pink evening coat (1967) shown in Figure 2 with pearls and teardrop- and feather-shaped sequins topped with Swarovski crystals that create a shimmering effect that makes it look as if it is made from the spectacular fur of one of the characters from "The Muppets" [31]. One element that often restricts visitors from seeing exhibits in detail is the glass around the objects. Getting rid of the glass can strongly benefit the exhibition experience not only by allowing a better view of the exhibit, but also by avoiding ugly light reflections and creating an increased sense of intimacy between the visitor and the garment [31]. This kind of intimacy is important for the presentation of fashion artefacts, as clothes are created to be close to our bodies. This fact also influences that in their designated environment (which is being on a human body) their shape is different than while put on a hanger. This is why it is important to give the garment a body-influenced shape while it is being exposed in the museum [31]. But even giving them shape does not show their full potential. Clothes are so strongly associated with living, moving humans, that putting them on a static display still feels a little bit unnatural. It is important to introduce some elements of the exhibition, that would make the garments feel more "alive", like animated patterns or material replicas [31]. Another solution is to give life to mannequins wearing the garments - they may be, for example, mechanically moving around the exhibition and their faces might be animated with video projections [32].

Figure 2: Balenciaga's Evening Outfit (1967).

2.1.4 Digital social museum and social Virtual Reality

The switch to a social museum was not the end of the institution's transformation. Nowadays, museums have started to use digital technologies to further attract and satisfy visitors, emerging into so-called digital social museums [20]. Digital technologies help create interactive exhibitions and "improve the relationship between the museum and the user". Some of the technologies used by museums include mobile devices, touch tools, audiovisual scenographic elements, 3D screens, fog screens and spherical projection, and Augmented and Virtual Reality [20]. In this thesis, a type of Virtual Reality - social Virtual Reality - will be considered and discussed based on the benefits it could bring to fashion exhibitions.

Firstly, many issues described in the literature can be addressed by using (social) VR. The most important is the interaction between the visitor and the object. In Virtual Reality the user can freely manipulate the object, or even try it out, which might make the experience of interacting with clothes more "real". Moreover, the progressing achievements of the technology of haptic gloves might enable one to actually feel the surface of the material with one's hands, which would make the interaction with the clothes more realistic [33]. The decision of which part of the clothing to show and how to present it would not need to be taken as the visitor could rotate the piece, disassemble it into parts or put it together, zoom it in and out and so on. Another benefit of VR is the possibility to constantly display all of the exhibits. As mentioned above, historic clothes are prone to destruction

and need to be regularly taken out of the exhibition for conservation reasons [7]. The VR version of the exhibits would be available all year round. Moreover, it would be possible to show the visitors pieces that are never available to them in the real world: either because they are destroyed, are too delicate to be displayed in the museum or are not available at the location [34]. This brings up new possibilities for creating logic in the exhibition itself. For example, the museum could interactively present how the certain themes were persisting in fashion over time. In her work, Alexandra Palmer gives an example of the T-cutting technique. The idea was to present its appearance in different periods, but without keeping the chronological order, so that the pieces could be freely exchanged (when some of them will be taken to conservation) without disrupting the visitors' experience. The problem that appeared, however, was the amount of work and staff members that were needed to implement the rotations [7]. Using VR all of the three encountered problems would be eliminated: 1) The chronology could be maintained, as 2) the rotation would not be needed, and hence 3) no additional staff members would be required to maintain the exhibition. Adding on top of that, the cooperation between institutions could result in a very detailed time journey, helping people understand how fashion evolved. It would be also possible to show the clothes at different stages of the renovation process or how they might have looked like right after sewing.
As described in the literature, simply displaying the object is not enough [34] [7]. To engage the visitors and enhance their understanding, the information that explains the object is crucial. The information should provoke users to think and relate, and be communicated in an appealing way [11]. VR provides interactivity in delivering information which helps to fulfill those requirements. It would be possible to make the visitor click on parts of the exhibit to get more information, move them to a narrative-driven, gamified environment to learn the history behind the piece, create a virtual guide from the times of the clothing to tell the visitors about it (maybe even wearing it) - the options here are unlimited and depend mainly on the imagination of the creators.

2.1.5 Study of the exhibits

Even though the main focus of the museum as an institution switched towards the visitors, studying the exhibits is still a very important part of the curators' job. It is also very challenging. The exhibits are often delicate, which makes them vulnerable to destruction. According to the literature, many of the conservation measures required are underdeveloped [35]. The European cultural heritage is deteriorating faster than it can be conserved, restored or studied. Some of the destruction might even be the result of conservation procedures of which the long-term effects are not well understood [36]. It is clear that there is a need for a method to study the objects without exposing them to the dangers of further deterioration, as well as ensuring that we will be able to pass the possibility to explore them to future generations. This is another case in which social Virtual Reality can come at hand. Placing scanned garments in the virtual experience could provide a comfortable and attractive environment for curators and researchers to work with the exhibits without the need to touch the physical objects. The virtual scans are also free from deterioration problems, which means even after years their structure would not be changed at all.

2.2 New opportunities created by social Virtual Reality

VR offers possibilities that would not be possible in the real world. An example worth mentioning is the potential for personalizing the exhibition. Research shows that the knowledge of the field may increase the positive impression [12]. VR allows tailoring information to match the visitor's knowledge level and even catering to their specific interests. Somebody more interested in history might be presented with the events behind the costume, shown by interactively highlighting the marks that were left on the piece during important events (like stains or holes), while a person interested in the clothing design would get information about materials, types of cuts, sewing techniques and so on. This can further contribute in making the VR experience more entertaining which, in turn, might make the whole museum visit experience more interesting [16].

Another significant element adding to the favorable experiences is social presence [16]. It increases immersion [37], improves learning [34], boosts well-being [38], increases engagement and helps to interact with the exhibits [6]. All those qualities are moved to the virtual world by implementing the interaction between the participants in social Virtual Reality. The social interaction in VR often has an even bigger impact on participants than the one in real life [39]. Some researchers argue that the social component in the museum visit is even more important than any other factor [40]. It is important for people to have a companion with whom they can share their opinions and search for validation of their reactions. For many visitors, it is also the main motivation for going to the museum, and some of them regret the museum plays only a passive, background role, in their social interactions [40]. It is an occasion to strengthen the bonds with family members, friends or a partner [40]. As social VR experiences are proven to positively influence the relationship between people [41] we can suspect that social VR museum might have a big impact on building and improving connections between individuals and groups of people, also by introducing more active participation of the environment in shaping relationships between users. The social aspect of the VR exhibition might have yet another influence on the visitors: it might encourage them to actually take part in the experience. Some individuals may prefer sharing this new experience with a close person, while others, familiar with Virtual Reality technology, may find the novelty of being in the environment with other people an exciting addition to their experience. Moreover, as most people go to museums in pairs or groups, creating an experience that is designed for more than one person would be more fitted for the context of their visit. Of course there might be people whose preference would be to experience the Virtual Reality exhibition alone - it might feel more private and gives more space for personal reflection about the exhibits [15]. Cited literature suggests though that for the majority of users the social aspect of the VR experience would be definitely beneficial and encouraging. However for those, whose preference lay in having a really private experience, without anybody there to disturb them, VR could introduce the possibility of visiting the museum completely alone. In physical museums, having the whole museum space for themselves is not possible for the vast majority of visitors.

2.3 Social interactions in virtual environment

The social interaction in the VR environment brings to the table many interesting questions. One of them is whether the social norms that usually apply in museums, will still be present in social VR exhibition. In their paper Yee et al. present the results of a study indicating that social norms of gender, interpersonal distance and eye gaze transfer into virtual environments [42]. But, next to the social norms encountered in almost all social situations, museums have its own rules - the social norms that are specific for this context. In the literature those social norms have been defined [15]:

1. People-watching - museum visitors constantly pay attention to others being in the same social space to learn how to behave properly, and to be able to apply this proper behaviour in practice (e.g. standing in a way that is not disturbing to the other visitors);

2. The physical navigation of space - the need of watching the exhibition in a specific order (suggested by the museum) and holding back from touching the exhibits;

3. The experience of this environment as a shared and social space - balance between conviviality (sharing, exchanging ideas and being friendly) and introspection (observation and analysis of one's own mental states and emotions, interaction with an art piece).

In the experiment conducted in Anise Gallery, Parker and Saker found that the social norms usually encountered in museum persisted in VR exhibition [15]. However, the session was conducted in the gallery building itself, which the authors point out to have a possible influence on the adaptation of museum social norms in the experience.

2.4 User experience in social Virtual Reality

While designing the social VR museum, there are many aspects that might influence the user experience. First is the *atmosphere*. The museum environment has the power to influence visitors' attitudes, their will to revisit and their intentions to recommend it to others. Effect on these have both, ambient aspects (lighting, color and signage) and design (spaciousness, orientation and visitor flow) [13]. It is also possible to notice the influence of the environment surrounding the exhibition. One of the studies gives an example of the building in which the exhibition was placed, which seemed to have a huge role in the overall experience of the visitors [14] - the villa was very often mentioned in the reviews of the museum. It is reasonable to assume that the *atmosphere* in the social VR museum would also play a significant role in shaping the user experience. Going further, these characteristics should be treated as a chance - in VR there are much broader possibilities for shaping the environment. It would be possible, for example, to fit the surrounding of the exhibits to the era from when the object comes from [11]. Another important aspect of user experience is freedom. The visitors generally enjoy being free to explore the environment, but also have some guidance, so that they do not miss important parts of the exhibition. This problem has been described in the literature as Narrative Paradox [43]. The goal here is to have a good balance between the freedom of the user and the control of the storyline, using, for example, Navigation Aids (elements helping the user to be aware of where they are in space and plan their next actions, e.g. minimap, current

location indicator), Navigation Instructions and Movement Options (ways in which user can move around the environment, like walking or flying) [11] [12]. What is also important is the embodiment. The way the users, and their companions, look like in the virtual environment strongly influence their immersion and presence. The full body mirroring is expected to let the visitors communicate in a non-verbal way, help to connect to the environment, to other users, and also - to themselves making the whole interaction more realistic [44].

Overall museums are standing in front of a big challenge and, at the same time, a big opportunity. Providing more interactive and accessible for a broader audience experience, for example, as proposed in this work - using social VR - they may find their place in the fast-changing world and be able to compete with ever faster-growing entertainment industry [34].

3 Expert survey

Social Virtual Reality is appearing more and more often in the cultural heritage sector, showing promising applications for fashion heritage in both visitor satisfaction and curatorial research. To evaluate the validity of these assumptions, expert survey has been conducted. The primary goal of this survey was to determine whether the expected positive impact of social VR on the fashion heritage sector holds true, and hence to address the first research question:

RQ1: What do experts think of the use of Social VR for fashion exhibitions?

To approach this topic in a systematic manner, it was decided to start with creating a set of possible use cases and benefits of social VR in fashion heritage field based on the literature review:

1. **Synergy** The section of the literature review considering the design challenges of (a fashion) exhibition in a social museum discussed many elements that should be included to make the exhibition attractive for the visitors. One important, and very difficult part, is connecting all of these elements in a way that makes the most sense. Firstly, the interactive element of the museum has to be complemented by well-curated information. On its own, it does not give the visitor an understanding of what is the purpose of this interaction. The situation is even worse when the given information is not sufficient or understandable for the spectator. Seeing, for example, a physical experiment and then reading an explanation which uses complicated language and requires high-level knowledge from the visitor might be very frustrating [45]. Finding an optimal amount of interactivity in the experience is also important - too many interactive elements can overwhelm visitors [46]. Finally, it is important to remember that the main element of the exhibition is still the exhibit. Too many additional elements, like archive materials and other information panels or interactions, pose a threat of the exhibit moving to the second plan and not being really paid attention to. Hence, it is important to find a good balance between all of the exhibition elements and create synergy, in which they complement each other creating a great overall experience. Social Virtual Reality is expected to help in maintaining this synergy.

2. **Exhibits study** One of the challenges the scientific environment faces in the field of fashion heritage is the fast deterioration of the artefacts, which eventually leads to limitations in the examination of those objects. As already mentioned, the solution here might be using good-quality 3D scans of garments, which will be able to preserve the exact shape, structure and appearance of the original objects. Placing those scans in social VR could create a friendly and natural environment to study them, at the same time enabling cooperation between scientists, even if they are based in remote locations.

3. **Exhibition story** The story is very important in communicating the information the museum wants to pass. It helps to remember things, illustrate points and engage the audience but also emphasises meaning, understanding and feelings [47]. As already mentioned, it is often difficult to present a coherent story in the museum, either because of the lack of exhibits, or the need

to take them out for the restoration. Social Virtual Reality has the potential to prevent those holes in the storyline by allowing the presentation of missing exhibits in digital form. The technology also allows to introduce new, interactive elements that can make the story feel more realistic and allow the visitors to immerse themselves in the world of the exhibit.

4. **Accessibility** The topic of accessibility can be approached from various different angles. Firstly, individuals from remote locations and disabled people often have difficulties accessing cultural heritage exhibitions. Social Virtual Reality exhibitions could make it much easier for them to access cultural heritage artefacts. Secondly, the digital exhibition could be created in a much more flexible way. It could be fit to the users' level of knowledge, area of interest or age. On top of that it would provide the tools, like interactive games or information components, that would make it easier for the visitors to understand the concepts behind the garments that the museum wants to communicate.

3.1 Survey questions

Reflecting on above explained ideas, the questions for the survey have been developed keeping in mind the goal of finding out whether the expected positive impact of social Virtual Reality on the fashion heritage sector is accurate:

1. Would usage of social VR in the creation of a fashion exhibition enable synergy between exhibits, information and interaction?

2. Do you think that placing 3D scans of fragile costumes (e.g., items that cannot be touched or interacted with anymore) in a social Virtual Reality setting would allow the museum curators and researchers to continue the study of these exhibits?

3. Do you think that using social VR by placing within it pieces (e.g., that are not physically in the museum), would help create a consistent story and improve showing the story (context) in general?

4. Would using the social VR make the fashion exhibition more approachable to the regular visitor?

The survey questions were asked in the form of a Likert scale. Apart from them, there were two demographic questions given: one about the level of experience in Extended Reality, and the second about the XR technologies the participants have experience working with.

3.2 Data collection and analysis

The topic of social Virtual Reality is not widely known, so it was really important to get the answers to these questions from experts having experience working with Extended Reality solutions and having an idea about the possibilities such a tool can provide. The Immersive Tech Week 2023 that took place in Rotterdam between November 27th and December 1st provided the possibility to find many XR experts in one place and allowed to gather lots of responses to the survey. 44 experts correctly filled in the survey providing data that was later analysed and visualised using Pandas and Seaborn libraries in Python.

3.3 Demographics

16 out of 44 gained responses chose 1 or 2 (on a scale 1 - 5) as the level of experience in XR as shown in Figure 3. After careful consideration of whether the answers of those participants should be taken into account, it was concluded that, participating in the event, they still meet the definition of expert. Most of the participants (72,7%) had experience with Virtual Reality. Also many - 61,4% - had worked with Augmented Reality. Mixed Reality was quite a popular choice too - 40,9% of respondents picked this answer. Three participants stated they did not have experience with any of the given technologies, while one selected "Marketing communication". The distribution of responses to the second question is shown in Figure 4.

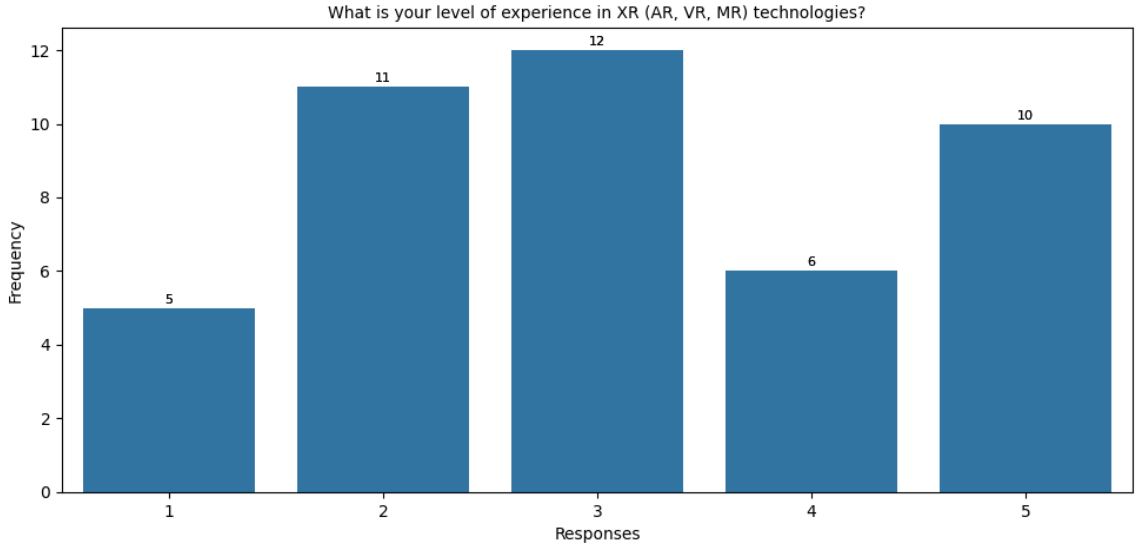


Figure 3: Expert survey, question 1: What is your level of experience in XR (AR, VR, MR) technologies? - results.

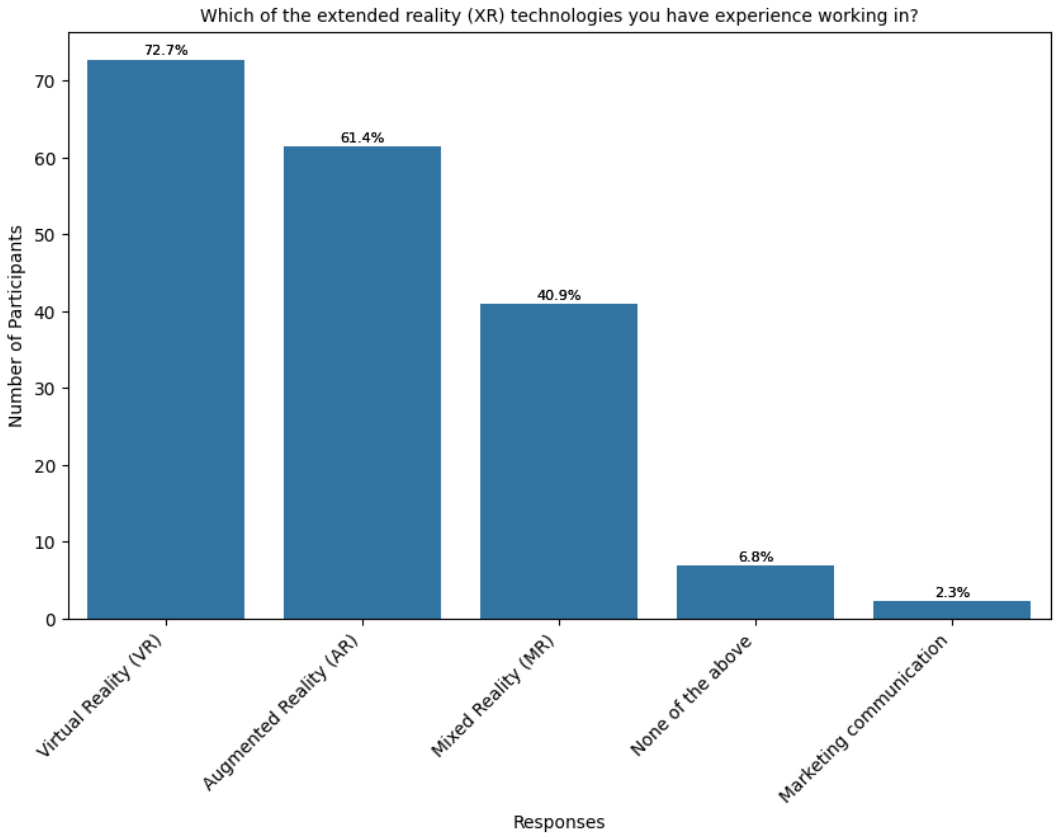


Figure 4: Expert survey, question 2: Which of the extended reality (XR) technologies you have experience working in? - results.

3.4 Results

Generally, the results gave an optimistic view on the perspective of using social VR in fashion heritage. Firstly, as shown in Figure 5, most of the participants (66%) agreed or strongly agreed that using social Virtual Reality would enable synergy between exhibits, information and interaction when used to create a fashion exhibition. A big part, almost one-third of all responded, declared to have a neutral opinion in this matter. Only 4,5% did not agree with the statement. For the second question, concerning the usage of social VR to allow further research on fashion artefacts, even more people responded positively. As much as 79,5% of respondents agreed or strongly agreed with this idea. Around two-thirds of the remaining participants did not have an opinion on the matter, while one-third disagreed, as shown in Figure 6. The respondents were most in agreement in the case of the third question. Figure 7 shows that 86% of them stated social VR would help create a consistent story and improve the way the story is told. 9.3% of the participants answered "neutral" and 4,7% - "disagree". The most surprising results, presented in the Figure 8, were obtained for the last question. Even though most of the experts (65,1%) still believed that social VR would make the fashion exhibition more approachable to the regular visitor, a big portion of them - 23,3% - disagreed with this statement. The probable reason for that is the disbelief of the general public capabilities in using Virtual Reality controllers. 11.6% of the participants did not have an opinion in that matter. Overall, results suggest a positive reception to the incorporation of social VR technologies into museum experiences by the experts. They are particularly optimistic about the social VR potential to enhance the quality and consistency of the story, and to expand the possibilities of exhibit studies. Those positive results, along with answering the first research question, confirm a need of developing currently missing set of requirements for the design of social VR fashion exhibition. This issue was addressed by described in the next section focus group session.

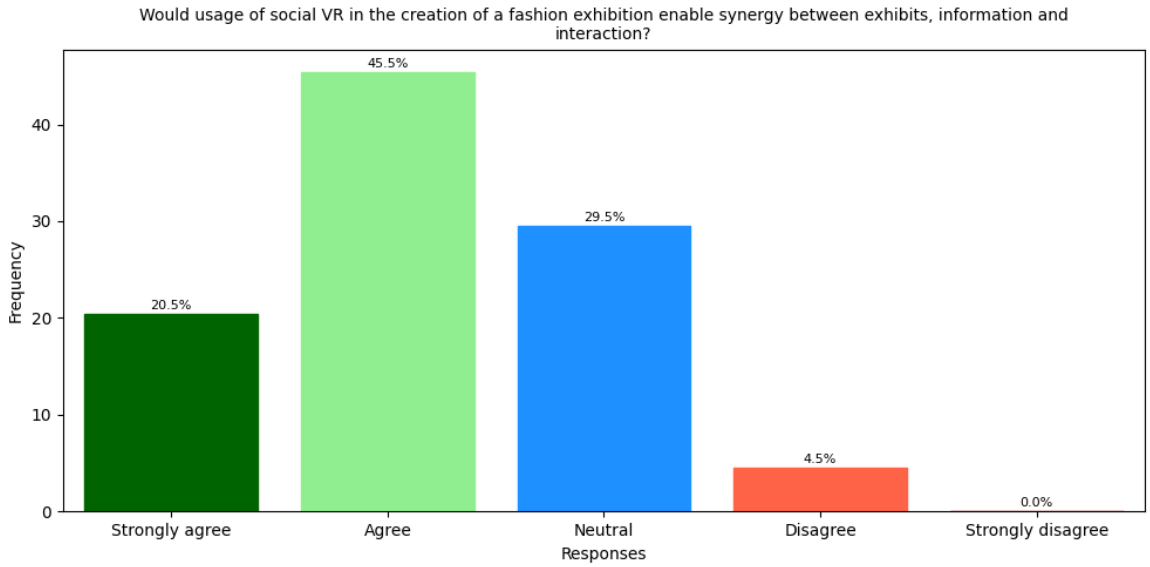


Figure 5: Expert survey, question 3: Would usage of social VR in the creation of a fashion exhibition enable synergy between exhibits, information and interaction? - results.

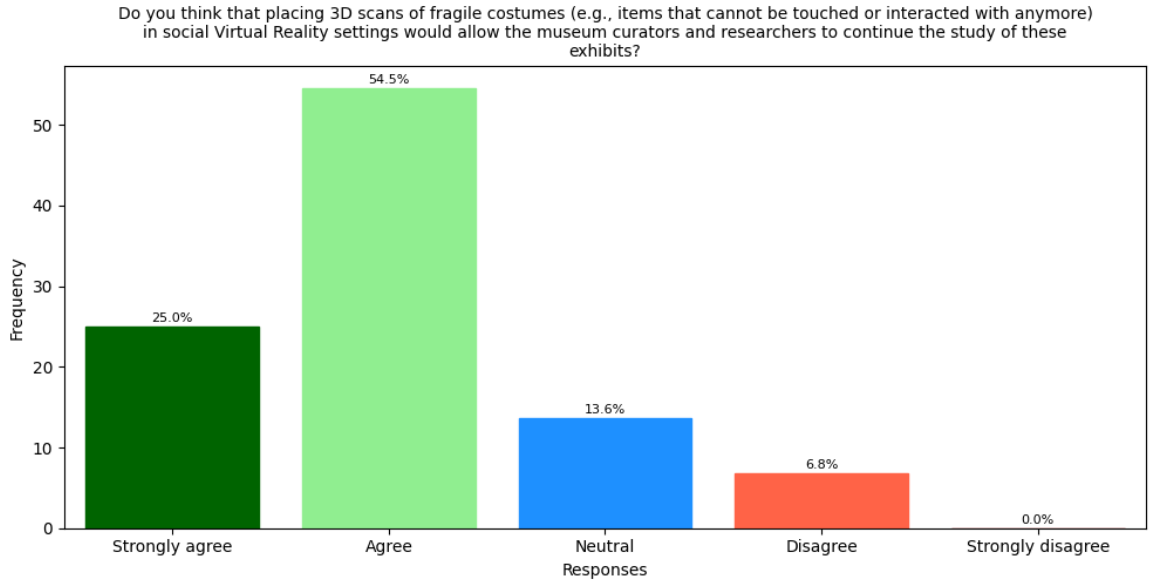


Figure 6: Expert survey, question 4: Do you think that placing 3D scans of fragile costumes (e.g. items that cannot be touched or interacted with anymore) in social Virtual Reality settings would allow the museum curators and researchers to continue the study of these exhibits? - results.

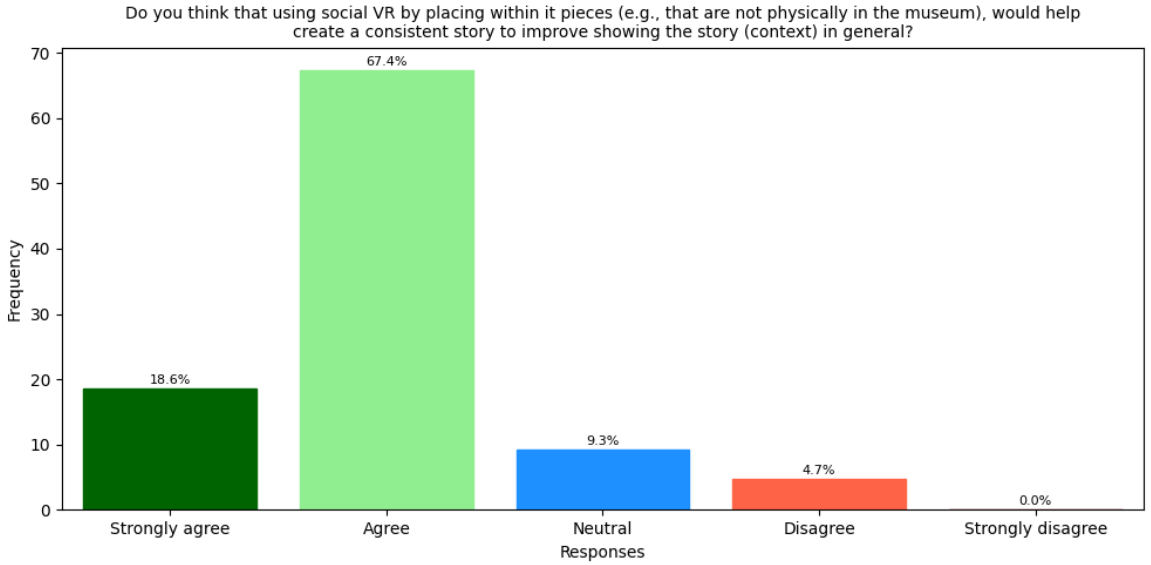


Figure 7: Expert survey, question 5: Do you think that using social VR by placing within it pieces (e.g. that are not physically in the museum) would help create a consistent story and improve showing the story (context) in general? - results.

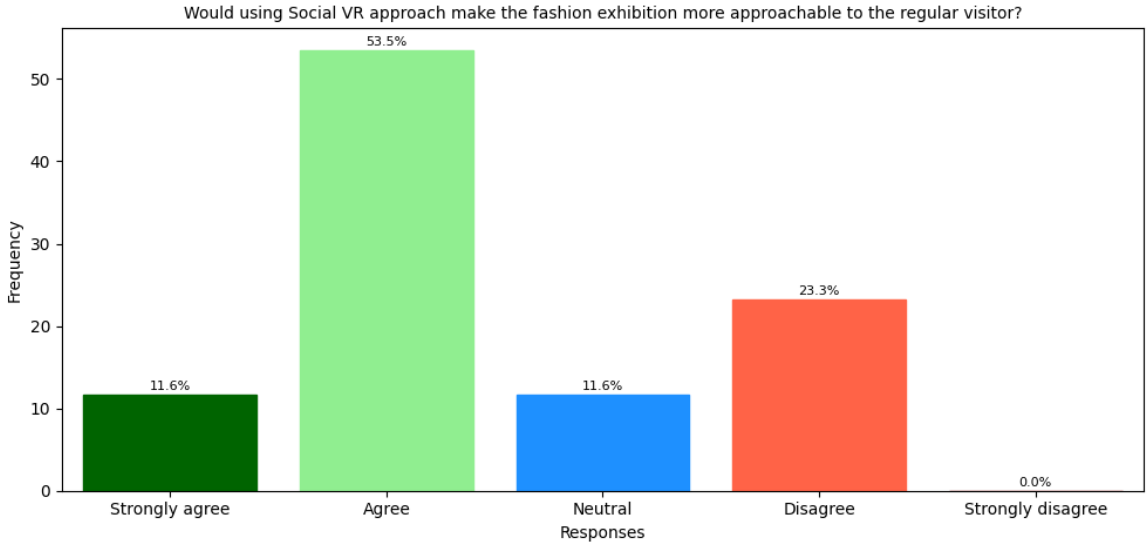


Figure 8: Expert survey, question 6: Would using social VR approach make the fashion exhibition more approachable to the regular visitor? - results.

4 Focus group

The literature review provided base knowledge about what is important while designing social museum exhibition as well as what should be taken into account additionally if the topic of the exhibition is fashion heritage. There was also many works defining how to design good (social) Virtual Reality experience. However, as already mentioned, there is lacking knowledge of how to connect all of these pieces together and design a good social Virtual Reality fashion exhibition. To define what is important while designing this type of experience, it seemed crucial to take into account the knowledge of experts, whose daily work is mainly focused on resolving problems within a museum, its exhibits and visitors. Four curators were invited to take part in the focus group organized for the purpose of deepening the idea of the social museum exhibitions' challenges and opportunities and the way of resolving them by good social VR experience design. Two of them represented the Centraal Museum in Utrecht, one was from the European Fashion Heritage Association - both institutions being the partners of the 5Dculture project [48], within which this thesis is written. The fourth curator was from the Netherlands Institute for Sound and Vision and in his work he was not focused on fashion - it seemed important to have the opinion of an expert who can take a bit different perspective than people working primarily with clothes. The last participant of the workshop was associated with the Netherlands Institute for Sound and Vision, but was not a curator. The reason for this choice was similar to the previous participant - to get an independent perspective and be able to steer the conversation in unconventional directions.

4.1 Focus group goals

The main goal of the workshop was to answer the second research question:

RQ2: What issues should be taken into account while designing a social VR fashion exhibition?

In order to do that, the following goals were set:

1. Learning about challenges that museums encounter nowadays.
2. Gathering ideas about how could we answer those challenges using social Virtual Reality.
3. Setting the requirements for the exhibits that should be chosen for the social Virtual Reality exhibition.
4. Discussion about exhibits and information presentation.
5. Brainstorming about interactions (user-object and user-user).
6. Open discussion about all other design elements.

4.2 Focus group data analysis

The workshop lasted 2,5 hours and consisted of a short social VR technology introduction and interactive exercises. Due to lively discussions, it was possible to go through only half of the prepared material. However, this scenario was expected and the workshop was arranged to first cover the most important topics. The meeting resulted in ideas written on upfront prepared worksheets and a recording of a two-hour-long discussion.

The results from worksheets were rewritten into Excel, and the recordings were transcribed using Dovetail [49]. After re-listening to the audio files and correcting the transcription mistakes, the analysis was made based on Constructivist Grounded Theory [50]. As the results of the analysis, a few concepts important for the research emerged: context, emotion and familiarity, learning, experience, and vulnerability. Two of those, namely learning and experience, manifested as goals that the museum would like to achieve through the utilization of social VR exhibition. Vulnerability was chosen to be the main topic of the exhibition and the requirement in the selection process of the garments.

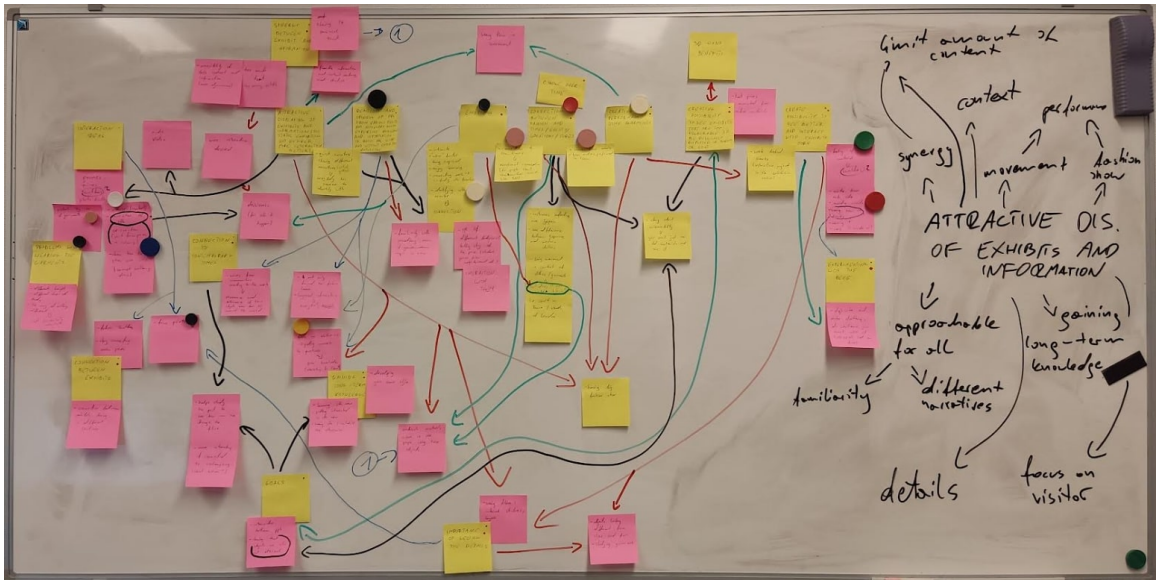


Figure 9: Focus group data analysis.

4.3 Results

Before delving deeper into how the results connect with each other and with the literature, a brief analysis of the findings will be demonstrated. The first topic that emerged from the evaluation was the importance of emotions. It was manifested by the concepts of control, connection and familiarity, but also just by the potential benefits of enjoyment during the visit. Another big subject during the focus group was user experience. The presented ideas in this area included the connection between exhibits, using performance to present the objects, focusing on showing details and

introducing interactivity. The curators agreed that in order to achieve an attractive user experience the synergy between exhibit, information and interactivity is essential. Improved learning outcomes - the next important topic - appeared as a result of a well-designed experience and introduction of familiarity. Above mentioned aspects are also strongly connected with context. Some of them, like the connection between exhibits or performances, can be a tool in building the context. On the other hand, user experience, for example, is influenced by it. Context is a very important element in achieving immersion, which, in turn, strongly influences the experience. Finally, the vulnerability was concluded to be the important topic of the exhibition. It is important for curators to be able to still present extremely fragile pieces without risking their destruction. Vulnerability is also a story on its own, which on top of that has the potential to evoke strong emotions.

4.3.1 Experience

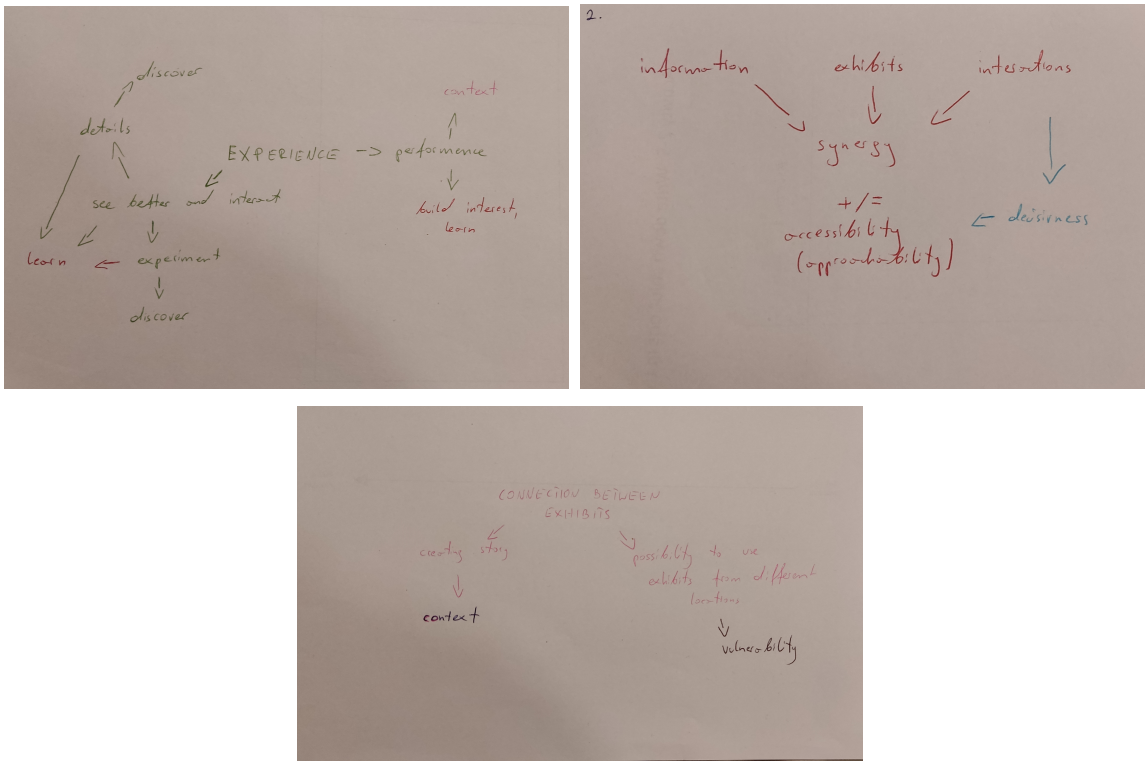


Figure 10: Concept maps: experience, synergy and connection between exhibits.

User experience defies a singular definition [51]. However, throughout various explanations some concepts are constant. Those concepts are divided into two categories: the fundamental elements of the interaction (user, system, context) and typologies of experience (ergonomic, cognitive, and emotional) [52]. One, specific study that focused particularly on museums, points out that the experience is influenced by various socio-cultural, cognitive and psychological factors, as well as physical and environmental conditions [53]. They can be expressed as:

1. Socio-cultural
    (a) Cultural identification
    (b) Continuity of theme and story
    (c) Conversation and story building from evaluation of stimulus
    (d) Variation of stimulus
    (e) Social interaction
2. Cognitive
    (a) The creation of mindful activity
    (b) Involvement and engagement
    (c) Inner reflection and imagination
    (d) Variation of stimulus to create a meaningful whole
    (e) Perceived authenticity
3. Psychological orientation
    (a) Scene setters
    (b) Routeing and mapping
4. Physical and environmental
    (a) Crowding
    (b) Seats
    (c) Noise

During the focus group many ideas emerged, clearly relating to various of above mentioned elements, topologies and factors.
Firstly, the synergy between exhibit, information and interactions turned out to be an important part of the experience. Curators are convinced that a good balance and well-designed connection between an object, information about it and an interesting interaction can lead to a very pleasant, interesting and easily approachable experience for almost every visitor.
Also connection between the exhibits seems to be of high importance. It helps to create a consistent story across the exhibition, which in turn has a positive effect on the whole experience [53] [54].
Another idea of how to enhance the experience was creating a performance with the museum objects playing as props. Curators mentioned the possibility of making a fashion show or presenting to the public the "work behind the scenes" - the restoration process that normally happens behind closed doors. One of the experts mentioned an example of the exhibition she saw at the Victoria and Albert Museum in London - "Hollywood Costume" [55]. She mentioned it was an amazing experience as she could see the costumes integrated into the iconic movie scenes, admire how they are used as props inside those movies. Both of these examples, the stories and the creation of performance using the

exhibits, lead to a very important element that strongly influences the experience - context [56]. A more detailed explanation of the role of context in the success of fashion exhibition in social Virtual Reality will be given in Section 4.3.4 .
Finally, according to curators, the possibility to see the exhibits better and interact with them would have a beneficial influence on the experience. Crowds in museums can cause physical discomfort and irritability, and noise and the violation of distance norms often result in frustration [53]. When the museum is filled with people, it makes it hard to see the exhibits, which can ruin the experience [53]. According to the literature, the visibility of the exhibit strongly impacts the amount of attention people pay to this object [57]. Hence it seems important to provide good visibility of the exhibits in the museum, also taking into account cognitive aspects. On the other hand, seeing small details that are usually not visible from behind the glass and experimenting, maybe even discovering something about the exhibits might improve the experience drastically. Those last findings have a significant influence on yet another important for museums area - learning.

4.3.2 Learning

Learning here has a two-fold significance: passing on known information to the visitors and discovering new insights by the specialists.
As mentioned above, experience has a significant influence on visitors learning. Watching a performance is proven to make the audience build interest in the underlying topic and makes gaining knowledge more effective compared to traditional learning methods [58] [59]. According to the literature, performing in the act and taking an active part in creating it, is even more effective in sparkling curiosity and developing a long-term understanding of the subjects explored in the performance. One example considered Social Studies course for secondary school students. 250 students were involved in the project, out of which 125 took part in classes taught through performing arts activities, while the remaining students followed a regular learning path. The results revealed that students following the performing arts track got better academic achievement and knowledge retention compared to traditional teaching methods [60]. A similar study was conducted with university students. Two innovative courses at the university level incorporating performing arts into their curriculum were introduced. The first one was an engineering course for Master level students at Ecole Polytechnique Fédérale de Lausanne in Switzerland and included workshops exploring improvisation in dance, theater and music, followed by improvised performances. The second one, taking place at the University of Neuchâtel, aimed at presenting the field of Migration Psychology. During the course, students created a theater play based on books and discussions. Both courses resulted in better learning outcomes compared to traditional learning methods - students had a better understanding of topics in question and their motivation in the learning process was higher. On top of that they improved their creativity and communication skills and enhanced their teamwork abilities [61]. Using social VR could make taking an active part in historical clothing-related performances accessible for everybody, which, in the physical world, is usually not possible.
Having better access to the exhibits and seeing the details also improves learning. When there are no crowds in the museum, it is easier to investigate the object without feeling stressed out about

taking too much time in front of the exhibit [53]. Lack of physical distractions, like noise and limited physical space, also helps to focus on the exhibit. When adding onto that the possibility of seeing details, that are difficult to spot or even not visible to the naked eye, the interest and possibilities of learning grow drastically. In the end, people can experience things they would not be able to spot normally.

The possibility to see details and interact with the exhibits can be also beneficial for museum curators and researchers. Experimenting with the object can help them discover new features of the exhibits. Unfortunately, this is often difficult due to the high historical value of the objects and their vulnerability. As one of the curators mentioned, some of the exhibits cannot be even touched anymore, because of their fragility or toxicity. Also seeing details can help curators reveal so far unknown facts about the pieces.

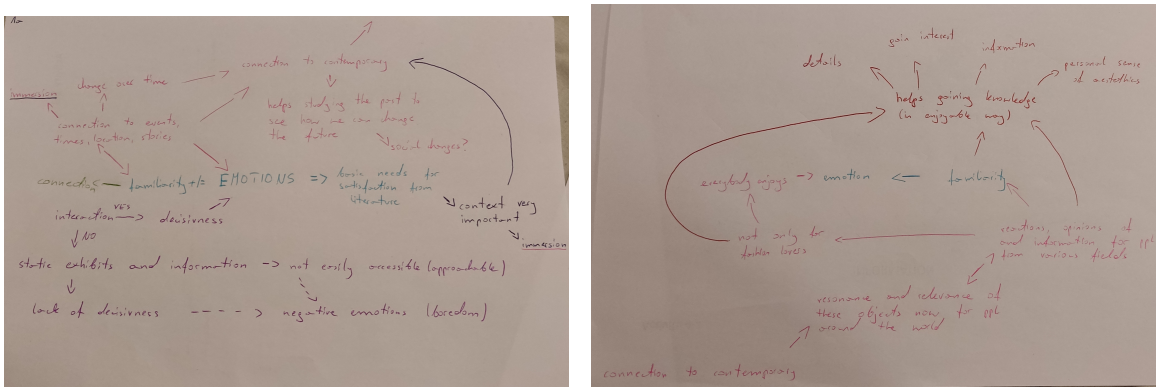


Figure 11: Concept maps: emotion, familiarity, learning.

4.3.3 Emotions

Throughout the analysis of the focus group data, the topic of emotions emerged multiple times. Many, seemingly different paths, led toward the broad subject of emotion's influence on people and the way human perceives and interacts with the world, and help understand their impact in the areas of experience and learning.

Satisfaction The topic of satisfaction appeared in this analysis multiple times already. The considerations of what influences the satisfaction of the visitor are important for building the success of the museum. As it turns out, emotion is one of the ways through which it is possible to access and manipulate the level of satisfaction. This influence has already been investigated in plenty of fields. An example is the research on primary emotions in the mountaineering experience [62]. In their research, they find that emotions, specifically fear and joy on which the study was focused, both influence the subjects' experience and their resulting satisfaction. They also find the direct proportion in the valence [63] of experience and its influence on satisfaction: joy makes the experience more satisfying, while fear has a negative impact on it. Another example refers to satisfaction during movie consumption, which, the same as fashion museums, lies in the field of art. The research proves that emotions have a strong impact on satisfaction level [64]. Similar relationships appear in

the field of healthcare [65], sales [66], and heritage tourism [67]. In this context, the last one holds special importance, as fashion museums exemplify institutions where visitors have the opportunity to engage with heritage through the medium of historic clothing. This particular research focused on cities having significant heritage meaning - Seville and York, taking a broader approach towards heritage - in the end, each of these cities provides multiple types of heritage institutions and sites.

Interaction and control As emotion seems to be an important ingredient on the way to satisfaction, it is important to consider how positive emotions can be evoked in the social Virtual Reality experience. One path that leads toward emotion is the sense of control [68], which, in VR, is often achieved by the possibility of interaction with objects. This concept is well explained in the work of Ted Friedman [69] on the example of "Adventure and Zork" computer game. He points out "exploring the settings, talking to the characters, acquiring and using objects" as an example of actions that build a sense of control. However, it is important not to overwhelm the visitor with interactive elements. Too much control over the exhibition might be tiring for the user, as long usage of interactive tools is suspected to require lots of cognitive load - there is no scientific consensus though about the interactive tools' impact on the cognitive load in comparison to traditional ways of information transfer [70] [71] [72] [73] [74]. Too much interactive elements can also result in losing consistency and introducing chaos into the exhibition [46]. As already mentioned, it is important to maintain the synergy and good proportions between interactivity, information and the exhibits themselves.
Interactions help with yet one more aspect: approachability. During the focus group the problem that experts often identified was that many museums struggle to be visitor-friendly: they are big, with many exhibits, and hence overwhelming. The way of presenting the objects is often very static and the information is communicated by long blocks of text. The interactivity might provide solutions to those problems: it might break down the routine, and make the presentation of the exhibits and information more entertaining. The research already confirmed that interactivity has a huge impact on user experience and users are strongly attracted to the interactive features [75].

Familiarity Another aspect that was often raised during the focus group was familiarity. Curators emphasized the relevance of connecting the exhibits to events, times, locations and stories. The specific case that they frequently highlighted was the importance of relating the stories behind the exhibits to the present day, showing their resonance and relevance for people around the world nowadays. Those connections should enable visitors to establish emotional connections with the objects. The existing literature also explores the links between familiarity and emotions. In their study, Pereira et al. [76] found that while listening to familiar music the broad emotion-related limbic and paralimbic regions as well as the reward circuitry were significantly more active than while exposed to unfamiliar music. Together with improved experience, the benefit of gaining knowledge appears. Relating the exhibits to contemporary times might improve understanding of past events, help people connect with them and treat them more seriously, which in turn can educate people on how to make (socially) responsible choices nowadays [77].
The important part in the context of familiarity, that the experts pointed out and that also appeared in the Background chapter of this work, is the familiarity with the topic of the exhibition [12]. In the

eyes of curators, it is important to adjust the information to people with different levels of knowledge, but also adjust the narrator of the story based on who is the addressee. So not only the information should contain familiar parts, but also the person from whom this information comes should be relatable to the visitor. This familiarity is expected to make the experience more joyful and hence positively impact the experience. However, familiarity does not only influence the experience. It also has a huge impact on learning by both: topic familiarity [78] and connection with the speaker or context, which indirectly enhance learning by sparking interest [79] [80].

4.3.4 Context

According to Cambridge Dictionary, context is "all the facts, opinions, situations, etc relating to a particular thing or event" [81]. When looking at the analysis done so far it is easy to spot, that those elements were appearing throughout it constantly.

Let's start with performances - they seem a perfect opportunity to build context around the exhibit. While creating the performance the authors have the freedom of shaping the environment around the object due to their needs. They have various tools: scenography, props, lights, music, story, and more, that can make the world around the exhibit more authentic and present. During the focus group, one of the curators described a performance-based museum exhibition as follows: "It was like stepping into another world and seeing the garments and how the garments were worn, and how the actors performed into them". She also mentioned an exhibition that took part in Antwerp, in which the movement specialist and dancer worked with old garments to create an accurate fashion show. They studied the garments, pictures and times of the objects, and then replicated the way of walking of people from this period who were actually wearing this type of clothes in their everyday lives. She says it was very impressive to see how different the movement of the body was and how the material movement corresponded to this old way of walking. This is a clear, really interesting example of how the context can be used to show the information about the object that otherwise is difficult to uncover and how much positive influence on the experience it has. This is also important to note the benefit of knowledge retention here - in the end, she still remembers those exhibitions and claims they were one of the best she had seen.

Creating a story is not only achieved by performance. The curators can rely on connections between exhibits that might build the context of events, people and times (e.g. change over time). This method promotes a deeper visitor engagement with the exhibits, encouraging them to perceive these exhibits as integral components of a broader, interconnected narrative or theme, rather than as standalone items, which in turn positively influences experience and learning [82]. This is also of special relevance for social VR exhibitions, as the technology would allow the use of exhibits that are not placed at the same location but connect together and create a consistent story.

The context seems an especially interesting topic in the area of social VR, as the presence of another person can change the situation drastically. Literature shows that the inclusion of an additional individual improves the immersion and realism of the experience. Those findings are usually based on the environments in which the main goal is communication [83], or at least consider situations in which having your partner beside you would be a normal thing also in a physical life. However,

when the situation that is presented in a Virtual Reality environment does not fully match with the companion or way of interacting with them, the context might be disturbed (e.g. social interaction in underwater seascape exploration) [84]. It is interesting to explore, how sociality would influence the context in fashion Virtual Reality exhibitions and consider how can we design it, so that the interaction and other elements balance each other, achieving already mentioned synergy, and creating a good user experience.
But why actually is context important? According to multiple studies, human perception of the object does not depend only on the object itself. Instead, the brain takes into account the contextual information provided by the scene surrounding the object and interprets it as a whole [85] [86]. Even though the researchers do not agree on whether the recognition of the object is dependent on the context, the way we perceive and interpret the object seems to be highly influenced [87] [85] [86]. Another important influence context has on the experience is immersion and realism. Contextualization helps people dive into the world of the exhibit and engage in its story [88]. Context can also be used to evoke the phenomenon of contextual priming [89] [90], which is based on familiarity, and which is proven to improve the sense of presence [91].

4.3.5 Vulnerability

The last, very important conclusion from the focus group workshop is the main characteristic of the garments to be chosen for the exhibition - their vulnerability. Museums own pieces that are so fragile that cannot be put on display or even touched by the curators. It is important to note that the topic of enabling people to see really fragile garments is becoming more and more popular. Just a few weeks after the focus group meeting, Vogue announced the topic for the 2024 Met Gala and The Met's innovative spring 2024 Costume Institute exhibition "Sleeping Beauties: Reawakening Fashion". The exhibition focuses on presenting pieces that are too fragile to be worn, using technologies such as video animation, light projection, soundscaping, AI and CGI [92]. The exhibition aims to show the garments in a way that "heighten our engagement with these masterpieces of fashion by evoking how they feel, move, sound, smell, and interact when being worn, ultimately offering a deeper appreciation of the integrity, beauty, and artistic brilliance of the works on display". The fragility does not always mean that the pieces cannot be displayed - sometimes it is still possible, but it is not an option anymore to transport the garments between locations. That is also what types of pieces the project is going to aim for: precious exhibits, that cannot be borrowed anymore. This way multiple museums will still be able to show these garments, either for their high value or the possibility to create a consistent story with the exhibits they have in their own collection.
Not only fragile garments might gain a possibility to be seen again. Anticipating good background research and engagement of fashion modelling artists, it is possible to show the pieces that do not exist anymore, that are either lost or destroyed. An example of how to reconstruct the lost items may be found in the work of Maria Cybulska [93]. The important points of the methodology are collecting documentation of the object, determining raw materials and dyes, structural analysis, and finally, the virtual reconstruction of fibers, yarns, and woven structures. Another research shows a similar approach, this time using CAD tools and VR technology to present the resulting models in

an attractive way [94]. This research is of particular interest to this thesis, as it shows that Virtual Reality is an effective tool for presenting historical garments. These actions not only contribute to the preservation of the fashion and possibility of showing people the lost garments but also have high educational value. The models can offer valuable perspectives on the initial structure and appearance of archaeological textiles. This can enrich the understanding and admiration of these artefacts, both among experts and the broader audience, as well as provide a research tool for historians [95] [94].
Vulnerability can be also a story itself. Presenting people with objects that cannot be touched anymore can tell a story about transience, showing that objects are also not eternal. There are multiple studies showing, that strong emotions are triggered when people perceive vulnerability in other individuals [96]. One could assume that showing the story about the fragility of objects would also cause at least a slight emotional reaction, which is desired to create a better user experience.

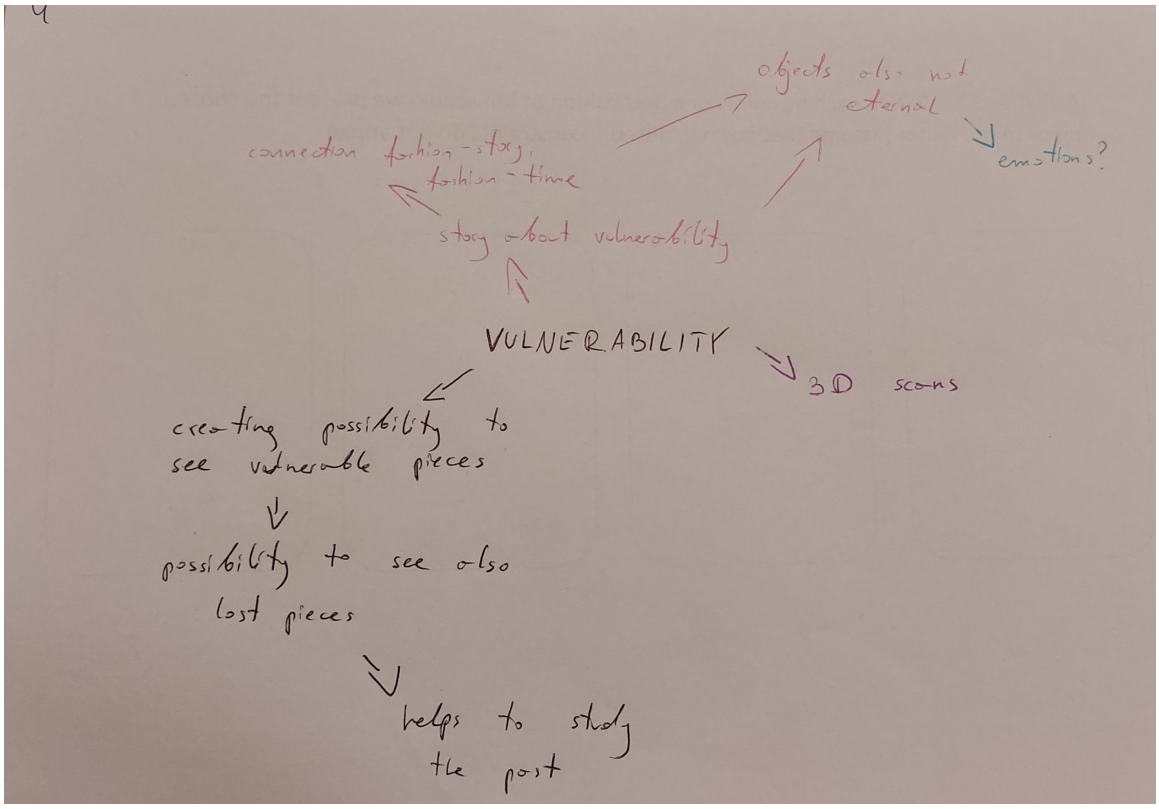


Figure 12: Concept map - vulnerability.

4.4 Design requirements

As described above the focus group provided many requirements and important for the experience design elements. Firstly, as user experience plays an important role in the exhibition's success, the participants pointed out ideas of how to ensure a good user experience. Two main elements were selected by them as important to incorporate in the design of the exhibition: context and interactions. Context, based on the results from the experiment, can be introduced using performance, showing elements familiar to the visitors or creating a story. For the interactions, curators listed two types of interactions with the objects: direct (directly impacting the presented piece, like rotation or virtual try-outs) and indirect (more focused on elements around the garments, like games or knowledge quizzes). The idea of virtual try-outs of garments was heavily discussed, however was finally dismissed based on the problem with historical accuracy: people in 19th century had different height, shape of the body and way of walking. Showing the participants dress from these times displayed around their bodies and saying that is how they would look like in the 19th century would be a lie. Curators strongly stated the importance of the connection between exhibits and synergy between exhibits, information about them and interactions. They listed plenty of requirements when it comes to the exhibit's display and passing of information. To begin with, it should be approachable for everybody. The concept of familiarity could be used to achieve that by, for example, introducing various narratives that fit a broader audience. Secondly, they pointed out the importance of showing the details of the exhibits, introducing context while presenting the object and giving information, but at the same time limiting the amount of content to not overwhelm the visitor. The exhibition should be focused on the visitors and allow them to gain long-term knowledge. Finally, while talking about the exhibits themselves, the curators decided that instead of using models created based on the garments, we should use the scans of actual objects. This way the visitors would be given an opportunity to see actual pieces, with all the elements exactly the way they are in the physical objects and curators would gain a chance to further study the artefacts. Similarly, it was decided the objects selected for the exhibition should be (or soon become) too fragile to be physically displayed in the museum, so that by placing them in VR exhibition we could still show them to the public. All of those elements have been taken into account while designing the environment. However, during many of the co-design sessions with stakeholders taking part in the project, some of the ideas changed, were adjusted or completely dropped, while other concepts emerged. Nevertheless, many of the elements determined by the focus group were directly implemented into the final design of the experience.

5 Design

The literature review and focus group with curators introduced the background knowledge on what is important in the design of the experience. However, to ensure the best possible outcome, we decided to take a user-centered design approach. During the seven months of the design and development process, multiple meetings took place. Their goal was to consult the curators at each stage of the design and development process, adjusting the project based on the outcomes of these discussions.

5.1 Co-design sessions

During the process of the design and implementation of the project, eight co-design meetings took place. A total of fifteen experts participated in the meetings in various configurations. Among the participants, there were four curators whose main professional focus lies in fashion heritage: two from the Centraal Museum in Utrecht and two from the European Fashion Heritage Association. On top of that there were two curators from the Netherlands Institute for Sound and Vision, whose focus still lies in the cultural heritage, but not specifically in the field of fashion and three employees of the Netherlands Institute for Sound and Vision. Like in the case of the focus group, their presence ensured diverse points of view and helped steering discussion in new directions. In this stage of the project one more expert joined the team - experience designer specialized in fashion. From the side of social XR, there were five professionals from Centrum Wiskunde & Informatica taking part in meetings. This group of, in total, fifteen people created a diverse team with abilities to cover all of the important from the perspective of the project topics, ensured a variety of ideas and lively discussions during the meetings. Each of the meetings had a little different form, however they were mainly based on discussion and presentation of ideas. Most of them were held online, with a few exceptions taking place in CWI (9.02.2024) or NISV (19.09.2023). A short summary of each of the meetings can be found in the Table 1 shown below.

Date	Focus
19.09.2023	Getting curators familiarized with social VR, first discussions about the potential design and interactions, deciding about the exhibits selection process.
25.10.2023	Discussion about physical set-up of the exhibition, deciding about using additional content (pictures, videos etc.) in the experience.
7.11.2023	Discussion about the additional content.
22.01.2024	Deciding to engage a designer specialized in fashion to take part in the project, presentation of the first design concept, talking about the interactions in the experience, discussion about file formats.
9.02.2024	Presenting the social VR system to the curator and designer, discussion about the design and storyline, and interactions possibilities.
22.02.2024	Deciding about the direction of the storyline and concept: number of garments, connection between them and connection to societal issues. Discussing technical challenges, like sizes of files and rendering times. Adjusting the plan of physical set-up of the exhibition to the existing possibilities. Discussing the hardware requirements.
29.02.2024	Presentation of and discussion about the design concept prepared by the designer.
14.03.2024	Presenting the changes in the design concept. Discussing the details of the experience's interiors design.
30.04.2024	Interview with one of the curators to understand the traditional museum exhibition design and creation process.

Table 1: Co-design meetings.

5.2 Traditional exhibition design

Before diving into the design process of the social Virtual Reality exhibition, it is important to look into how (fashion) exhibitions are designed in their traditional - physical - form. To get into this information an interview with a specialist was conducted. The curator in question has many years of experience working with big museums (for example Victoria and Albert Museum in London) as well as being an independent freelancer offering curatorial services to private galleries and companies. She was able to provide us with an overview of (fashion) exhibition creation methods which, in turn, helped us guide the design process of the digital experience and allowed us to spot differences between the creation process of traditional and digital exhibitions.

Firstly, she pointed out that it is important to remember the process differs between the institutions. The most significant difference is the approach to the strategy of building exhibitions between big, public institutions and private museums and galleries. This difference comes mainly from the goal the different types of museums have. For the former ones, as also defined by the International Council of Museums, the focus is really on the public service that a museum or an institution offers. Big, public institutions tend to have a well-defined strategy and path they follow while creating exhibitions. The curator shared with us a description of a general, simplified path the museums follow. The graphical representation of the path is presented in Figure 13. The process starts with

a concept - a general topic of the exhibition. This might be an artist whose life and creation the museum wants to present, something more physical, like "exhibition about butterflies" or, on the contrary, something abstract. The concepts are really various and are meant to work as a starting point of the design process. Then, from this concept, the research is done in order to find themes and objects fitting those themes. The way the research is conducted may vary, as it depends on the background of the curators who perform it. For example, the curator we talked with is a historian, so to find the themes she conducts the historical research.

After the themes were found the objects fitting these themes need to be selected. Then, those objects are put into a hierarchy. Firstly, there are star objects that are meant to lead the narrative. The exhibitions are usually divided into sections, each of them showing the sub-section of the story. Each of these parts is driven by one or two star exhibits, that communicate the story in a stronger way than the other exhibits. The star exhibits also have another role: they are meant to draw people to the museum. They often happen to be famous or particularly interesting pieces, that people desire to see, which makes them come to the museum and, in the end, experience the whole exhibition. Next to star exhibits there are other artefacts that complement the story with what the curators want to share with an audience. They do not need to be directly connected with the concept or a theme - here everything depends on the curational explanation and the meaning of these objects that they want to pass on to the visitors. Sometimes, the selected artefacts are not owned by the institution building the exhibition. In that case they need to be borrowed from the owners, and all of the actions associated with this needs to be taken: contacting lenders, developing loan agreements, creating condition reports and so on.

After all of the objects are collected, the important part of curatorial work begins: organizing the artefacts in a way that communicates a narrative. As the curator said, it is like creating a journey through these objects. This part of the exhibition creation process also contains writing labels describing exhibits and producing necessary graphics. The next step is designing the exhibition space. This is usually done in cooperation with exhibition designers. Design of the exhibition space is strongly dependent on the space available for the exhibition. This might be a museum room, which does not allow for many changes to adjust the space to the curators' wishes or a big open space that gives a possibility to arrange according to the needs. It is possible to either divide the space into smaller rooms or use the available space without splitting it. As already mentioned, when there are lots of exhibits it is a good idea to divide the exhibition into smaller sections. The space design can help with that by introducing the smaller rooms/areas where the exhibition subsections can be presented.

After having the space built the last thing to do is bring the collected artefacts and install them in selected places. As already mentioned, they are grouped together into smaller clusters to tell a sub-story. Altogether, they create a whole, complex narrative that constructs an exhibition's message. Of course, every project is different and the process differs slightly every time. For example, the time allocated for different stages of the exhibition creation process differs between projects. Sometimes it might take a lot of time to collect the artefacts and formalize landing agreements, while another time museum might decide to use only exhibits they already own. Then, the time of collecting objects is relatively short.

When talking about private museums and galleries, the curators have much more freedom. The curator mentioned their work is usually project-based, utilizing trial and error method. The possibilities of choosing a topic are much broader, and the way of designing the exhibition more elastic - they can go on with it any way they want.

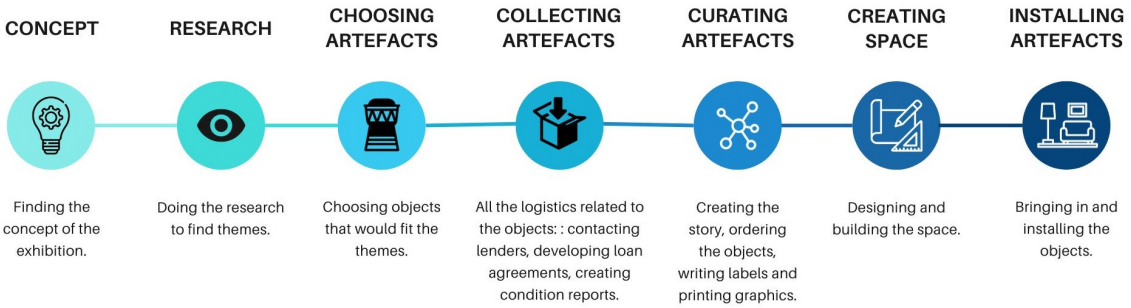


Figure 13: Timeline of exhibition creation process.

5.3 Social VR exhibition design

As the specification of the virtual exhibition differs significantly from the traditional one, it was not possible to follow the process described in the previous section. There are some similarities in the creation process and together with the differences, they will be described in this part.
Firstly, the starting point of our process was collecting the exhibits. In the experience, the scans of garments are used, which are not so easily available at the moment. We were limited to choose mainly from the objects that were already scanned. Only a few garments were scanned purposefully for the sake of this project to make the story more coherent. So the research to find the themes was based on the garments that were available for the exhibition. Similarly to the process described above, the curators needed to negotiate the conditions of using the scans with museums owning them. After collecting the exhibits and conducting the research the curators working within the 5Dculture project and the designer specialized in fashion created the story connecting all of the collected exhibits into one whole. The scanned garments play the role of star exhibits. They lead the narrative, and other artefacts, described before as decorative objects, further expand on the exhibition story. The curators and the designer also shared with us information about the exhibits that could be placed in the social VR experience. An advantage that social VR exhibition has is the freedom in shaping the space. Here it is possible to arrange the exhibition rooms in any desired way. There are not any physical or financial restrictions, the only limitation is the time that is needed to develop the space. Keeping in mind the research question to be answered, it was decided that the exhibition will consist of three rooms, each of them providing a different context. In each of those rooms a sub-story of the exhibition is told by the artefacts, together creating a big and more complex narrative. After creating the space the garments were placed in the rooms. In the context of social VR exhibition it was not the last thing to do though. The system still needed to be integrated with the VR2Gather technology. This process will be described in Section 6.1.

5.3.1 Experience design

The design that was concluded from all of the co-design meetings consisted of a training area and three exhibition rooms. Each of the exhibition rooms was decided to introduce a different context. There were many ideas on how to introduce the context, however for the purpose of this thesis, it was decided to build the environment in three, very different from each other styles: a modern museum inspired by the Netherlands Institute for Sound and Vision, a neutral gallery room and a historical room, respectively shown in Figures 14, 15 and 16.
As already mentioned in the introduction, for the majority of people, visiting a museum is a social activity. It is important that the virtual museum also allows to visit the exhibition with a companion and fulfills the need for social interaction. Hence, the experience is designed for two or more participants.

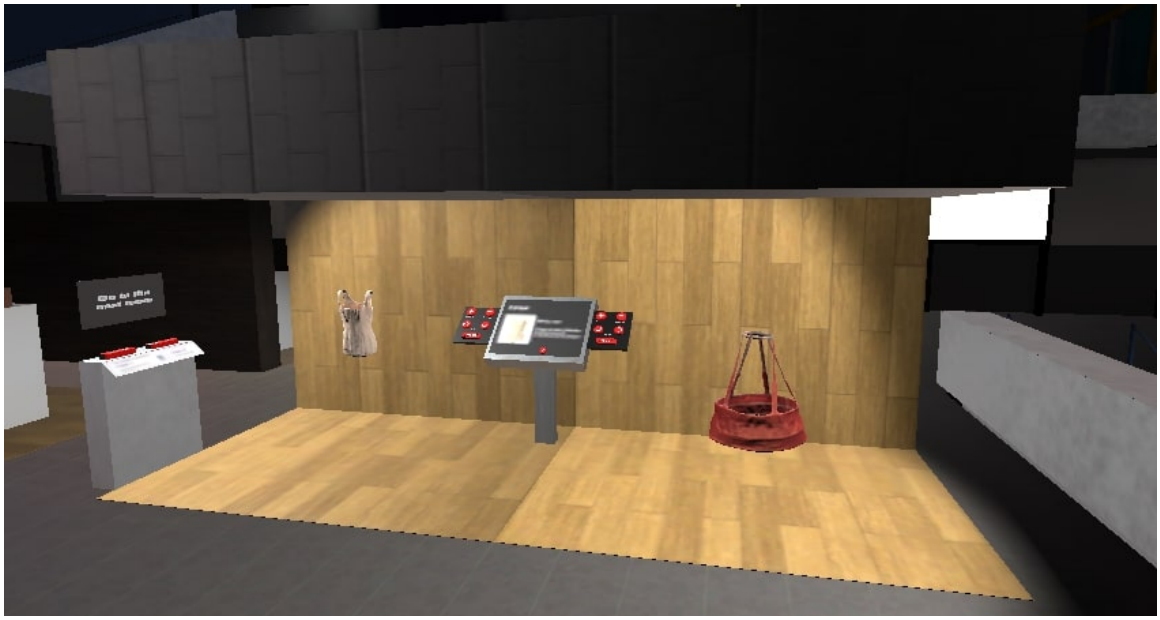


Figure 14: Modern room.

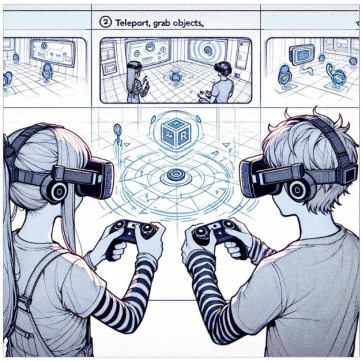
Figure 15: Neutral room.

Figure 16: Historical room.

After deciding on the general concept, context introduction and sociality of the exhibition, the experience timeline was created. It is shown in Figure 18. The idea was to start the visit with a training. The participants are expected to come from various backgrounds, so many of them might have never used Virtual Reality before. This part is expected to teach them how to use controllers to move around and interact with the environment. After getting familiar with the controls, the participants start their journey through three exhibition rooms. The order of the rooms was designed to introduce as little confusion as possible - hence the neutral room is in the middle between the modern and historical. This design allows for a smooth transition from a very modern space into

historical surroundings.
After the training area the participants move on and explore the first exhibition room. Here, at the beginning of their path, they encounter a virtual mirror shown in Figure 21, in which they can see how they look like - for this experience their virtual bodies are created using point cloud volumetric video. It allows their virtual selves to look exactly like their real bodies, so it is important for the visitors to check out the effect. The realistic representation of their bodies positively influences their immersion and sense of presence in the environment [97]. More details about the point cloud technology will be given in Section 6.1.3 .
After the participants are finished looking into the mirror, they move on to the exhibits' display. There, two garments are shown. The users can closely look at and interact with them. More about the interaction can be found in Section 5.3.4. The visitors are also provided with the basic information about the exhibits.
When the participants decide that they already explored the room and want to move to the next space, each of them needs to click the teleportation button assigned to them. The buttons are presented in Figure 19. This action moves them to the second exhibition room, which is designed as a neutral space. There, similarly as in the first room, the visitors explore the space, interact with the exhibit (this time one) and read information about it. When they are ready to go, one of them clicks the teleportation button and both visitors are moved to the last room - the historical space. Here they once again explore the space, inspect and interact with the garment and get information about it. After finishing those activities, one of the participants clicks the teleportation button and they are moved back to the training area. This is the end of the fashion exhibition experience.

Users put on the headsets and start the experience



In the training area they learn how to move around and interact with objects

Users explore the modern exhibition room and interact with exhibits

They click teleportation buttons to transfer to the second room

Users explore and interact with neutral and historical rooms

Participants finish their social VR experience

Figure 17: Storyboard.

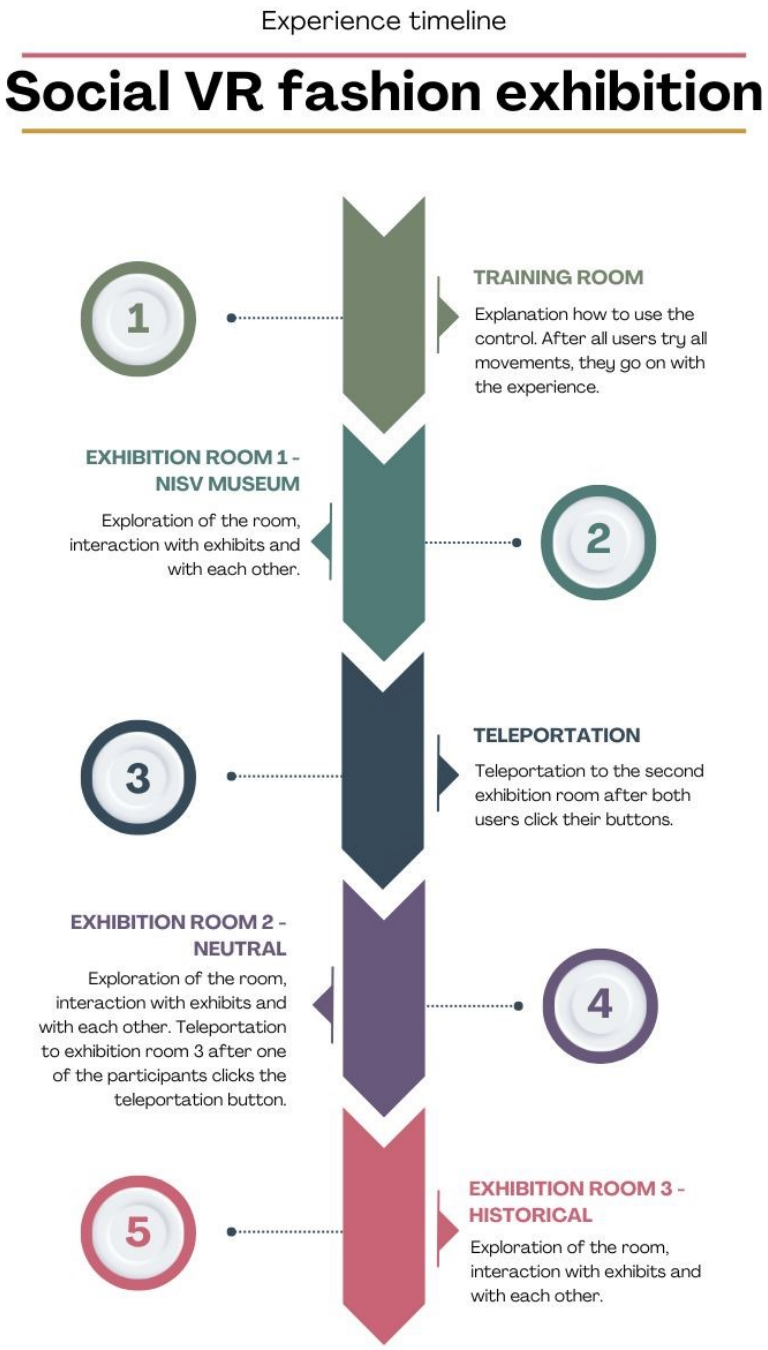


Figure 18: Experience timeline.

Figure 19: Teleportation buttons.

5.3.2 Design of the rooms

The first of the rooms, the modern room (shown in Figure 14), is the biggest space in the whole experience. Its design was inspired by the Netherlands Institute for Sound and Vision building in Hilversum. The choice of using this space was not random: the institute is one of the partners of the project. The design was originally created for another project that both CWI and NISV were working on: Mediascape [98]. Some adjustments were implemented to fit the space better to the new project. Mainly, the changes were applied to the exhibit display area: it had to be fitted to the purpose of displaying clothes. Two exhibits that are placed in this room are displayed on a wooden background. The space itself is huge and pretty dark, so a well-defined display was needed to make the exhibits well-visible. For the same reason stronger lights are pointing to the two garments. In between them one can find the information display with two interaction panels attached on both sides. The information display contains text with basic facts about the garment and a picture of it. At the bottom part of the display, one can find a button with an arrow, which allows to switch to the next information page (describing the second garment). The interaction panels consist of two rotation buttons, zoom-in, zoom-out and reset. The information display with attached interaction panels is shown in Figure 29b. Apart from the exhibition part, the room consists of two other important zones shown in Figures 20 and 21: training and mirror areas.

Figure 20: Training area.

Figure 21: Mirror area.

The second room, presented in Figures 15 and 22, was designed to have a neutral atmosphere. The colours are maintained in the grey scale, the space does not include any decoration except of the posters related to the exhibition topic. The space visible behind the window was left unchanged from the Unity's default blurred horizon and blue sky. Only the position of the sun was adjusted to improve the lighting inside the room. This decision was based on the assumption that placing any specific background behind the windows could disturb the neutrality of the room. The exhibit is located in the corner of the room and is placed on a pedestal. In front of it one can find an interaction panel shown in Figure 29c. This time the rotation is possible only in one direction. The

other interactions are exactly the same as in the previous room. The information is displayed on a black screen placed on a similar panel as the interaction buttons.

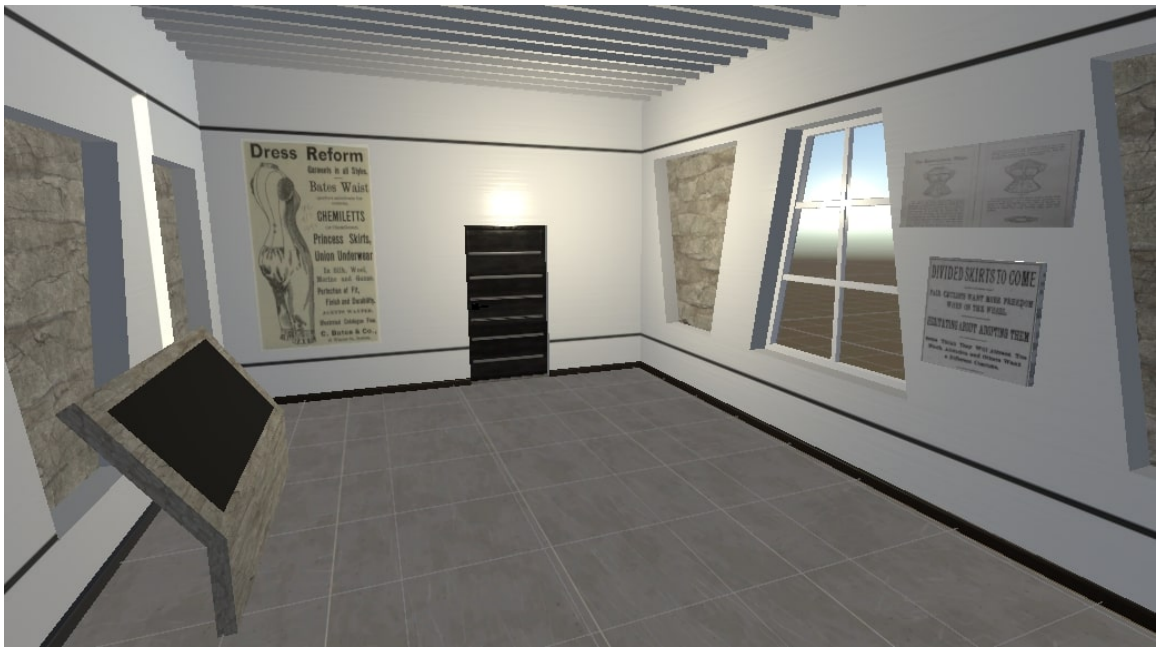


Figure 22: Neutral room: posters, information panel and view behind the window.

The last room, presented in Figure 16, was designed to recall a 19th-century house. The floor is wooden, the walls are covered with Victorian-era floral wallpaper and the ceiling is decorated with elegant tiles. Around the room one can find many objects from the epoch: a big, wooden wardrobe, a decorative chandelier or a gold-covered clock. A screenshot presenting part of the room with those objects can be found in Figure 23. One of the more interesting parts is the cabinet containing arsenic rocks shown in Figure 24. The reason for the presence of this additional exhibit is the history of the dress presented in the room - to achieve the deep, green colour of the garment, arsenic was used. Behind the window the panorama shows Amsterdam townhouses. The exhibit is located in the corner of the room on a wooden pedestal. The interaction panel is placed on the wall next to the exhibit, as presented in Figure 29a. Similarly to the one in the previous room, it has zoom-in, zoom-out, one-direction rotate and reset options. The information about the garment is displayed on a semi-transparent black screen hanging in the air on the right side of the space. The information presentation is shown in the Figure 24.

Figure 23: Decorations in the historical room.

Figure 24: Cabinet with arsenic and information display.

5.3.3 Virtual museum exhibits

The garments that have been chosen for the social VR fashion exhibition all share one important characteristic: they are very fragile, usually even too vulnerable to be displayed on the physical exhibition. They all come from the Dutch museums: Centraal Museum Utrecht, Kunst Museum The Hague and Amsterdam Museum. The garments have been scanned using photogrammetry. The process involved taking between 400 and 1000 pictures of each garment and then processing the pictures into 3D models using Agisoft Metashape. One of the 5Dculture curators and the designer have been exploring various ways to integrate the 3D scanning process into the virtual exhibition system. They photographed each object in slightly different conditions to check what works best. Three of the garments were photographed on its museum displays, with different lighting setups. Another two were captured in the photography studio, with one considering the goal of finding the minimal lighting conditions. The models obtained through this method have around 1-10 million polygons. The curator and the designer optimised the models using Cinema 4D to polygon count around 10-50 thousand. The models' final file format is .fbx
Four garments have been chosen to be displayed in the social VR fashion exhibition:

1. Corset (shown in Figure 25)
   (a) Dating: ca. 1830
   (b) Description: Corset aimed at bringing comfort and self-confidence to the wearer.
2. Crinoline (shown in Figure 26)
   (a) Dating: 1825 - 1875
   (b) Description: Crinoline aimed at externally manipulating the silhouette. Crinolines were worn by the elite but also by the working classes.
3. Gown (shown in Figure 27)
   (a) Dating: 1870-1873
   (b) Description: The gown has an imposing silhouette and deep green colour that was gained from the poisonous metal - arsenic.
4. Reformation Gown (shown in Figure 28)
   (a) Dating: 1912
   (b) Description: The Reformation Gown was developed by 'Association for the Improvement of Women's Clothing'. It prioritizes simplicity, wearability, minimal cutting of fabric, and the use of lightweight, breathable materials.

Figure 25: Corset.

Figure 26: Crinoline.

Figure 27: Gown.

Figure 28: Reformation Gown.

5.3.4 Interactions with exhibits

The design of interactions had to be approached carefully, taking into account their importance as well as keeping in mind the need to maintain the synergy between elements within the experience. Based on the goals of the experience two types of interactions with the exhibits have been chosen: the possibility of scaling them up and down as well as rotating them. For most rooms the rotation happens only in one direction. The exception is the first room, where you can rotate both objects in both directions. Figure 29 shows the designated buttons the participants have to click in order to perform described above actions. On the interaction panels there is also a "Reset" button, which reverts the exhibits to the original size and position. The scale-up operation is executed by increasing the current object size to 110% of its starting dimensions. Respectively, to scale down, the object's size is reduced to approximately 90.9% of its starting dimensions by dividing it by 1,1. The rotation of an exhibit is performed by 45 degrees per one click of the rotate button. Every modification of an object by any of the users is visible to all of them.

(a) Interaction panel - historical room.

(b) Interaction panel - modern room.

(c) Interaction panel - neutral room.

Figure 29: Interaction panels.

5.3.5 Interactions between visitors

Another type of interaction that is possible within the environment is the interaction between visitors. Here, we have three types of interactions: guided interaction, natural interaction and environment-triggered interaction. The first type, guided interaction, is represented in the experience by the teleportation mechanism in the first room. To move to the next space two of the visitors need to cooperate as each of them has to click one of the teleportation buttons. The buttons are placed on the board next to each other, as presented in Figure 19. Natural interaction is every communication, verbal and nonverbal, that emerges between the users on its own, simply because of the fact that they are in the same virtual space where they can see and hear each other. The last type of interaction - environment-triggered interaction - describes all of the actions the users take together that are directly influenced by the elements of the virtual world. An example of such interaction is throwing a virtual training ball at each other or trying to adjust the size of the dress by one of the participants while the other one plays the role of a model.

6 Validation and evaluation

The designed experience required validation from the cultural heritage sector experts. In this section, the whole process of implementation, validation and evaluation will be described. The achieved results were highly positive, with experts showing strong engagement in exploring the rooms, interacting with objects, and socializing. They were very impressed by the whole experience. Based on their reactions and statements it is clear that the social VR fashion exhibition was validated positively.

6.1 Implementation

After the design choices had been made the whole experience had to be developed. Firstly, the rooms and interactions had to be implemented in Unity (described in Section 6.1.1). As it was decided that live point cloud representations of the visitors would be used as their avatars, the system had to be integrated with VR2Gather. More details on this process will be given in Section 6.1.3.

6.1.1 Unity

For the development purpose Unity version 2022.3.21f was used. Using the engine, three rooms were created as separate scenes. The modern room was taken as an example to set up the two remaining scenes. Firstly, the historical scene was created as it had been expected to take the longest time. The neutral room followed. Those two rooms were built completely from scratch. Firstly the floor, walls and ceiling were arranged. Then, the garment and the decorative elements were placed in the space. The assets used to decorate the rooms are open-source resources available online. The interaction panels were created and the buttons were equipped with Colliders XR Simple Interactable components. It is important to mention that in the case of social experience built with VR2Gather package, the special type of buttons had to be used. This button will be described in more detail in Section 6.1.4. Colliders were also added to almost all other elements in the scene. It gave them the feature of "physicality" - blocked users from teleporting behind the walls or appearing inside the wardrobes. The lighting was adjusted using the probe groups. It made the lighting look more natural, creating effects like shadows and reflections. For the historical room also the skybox was added, creating the view of Amsterdam townhouses behind the windows. The modern room was mostly ready, but it needed some adjustments. The exhibition display area had to be enlarged and cleaned from unnecessary elements. Then, two garments and the information display with interaction panels were placed there. At the end, the lightning was adjusted.

6.1.2 Scripts

After the rooms were built it was time to introduce the interactivity in them. The first thing that was necessary for a smooth experience was the possibility to move between the rooms. For this purpose a VR2Gather script was used - PilotController.cs. The script was created to manage the local copy of the scene, such as fading it in and out at the beginning and end, and to manage the transition to a follow-up scene, ensuring that those actions happen for all participants in a coordinated manner.

The scripts were needed also to introduce interactions in the experience. The script responsible for rotating the object allows to assign the value of the rotation angle to the component through Unity, and then every time the script is triggered, the rotation value Y is updated by adding this assigned value. Another script had to be created to change the size of the objects. Here, similarly, the desired scaling value is assigned in Unity component, and then after the button trigger, the script updates the size of the objects by multiplying the X, Y and Z Scale values by the assigned float. The last script, introducing the functionality of resetting the object to its original size and position, upon being triggered simply retrieves the original values of the Transform component of the object and assigns them back to the rotation and size variables. All of the above-described scripts were written in C#.

6.1.3 VR2Gather

As already mentioned in the background part of this thesis, photorealistic reconstructions have been shown to increase the sense of presence with respect to synthetic avatars [97]. That is why for the social VR fashion exhibition we decided to use live point cloud volumetric video for visitors' representation in the experience. For this purpose VR2Gather was used. VR2Gather is a Unity package created to allow the use of this kind of user representation in VR experiences.
Instead of relying on a central cloud-based game engine, while using VR2Gather each participant runs a local copy of the application. Communication and synchronisation is handled through *Orchestrator* - a central cloud-based instance that manages the forwarding of control messages, point cloud streams and conversational audio between the participants. The orchestrator also helps with synchronizing the experience between participants, by allowing to find the offset between local system time (NTP-based) and orchestrator system time as well as handles the creation and advertisement of sessions. For some actions in the experience, coordination is very important. To ensure this coordination, one application instance is designated as the master. Actions that need to be coordinated are always done first on this instance. In the current version of VR2Gather the master instance is always the instance that created the session.
The architecture of the system is presented in Figure 30. Firstly, the participant is captured by cameras (the number of cameras might vary, in this project the setup with 4 cameras has been used). The point cloud is created and time-stamped. If more than one camera was used (which is the case in this project) the point clouds from different cameras are aligned and fused. Then, optionally, the point clouds are split into tiles and encoded into a stream of compressed timestamped data packets to feed the transport send modules. The transportation of the data can be handled in multiple ways, for example using TCP, DASH or SocketIO. The more detailed description will be given only to the last protocol, as it was used in this project. SocketIO protocol uses the orchestrator to send the media streams (point cloud, voice and so on) to the other participants. After the data is delivered, the receiver feeds compressed time-stamped data packets to the decoder for decompression. Then the data is synchronised across all modalities and the point cloud tiles are put in the queue to the render module, which synchronously renders the individual point cloud tiles. After this last step the user can see the point cloud of the other person taking part in the session [97].

6.1.4 PFB_Button

As the virtual fashion exhibition has been designed to be a social experience, the actions happening in it need to be consistent for all participants. It is also applicable for actions that are triggered by the visitors - like the results of clicking the button. That is why the normal buttons could not be used - they do not ensure the needed synchronisation between the instances. VR2Gather provides a button that does have this functionality - PFB_Button. It is equipped with *NetworkTrigger* component which ensures consistent behaviour. So, for example, after one of the participants rotates the garment, the other can see the results of this action as well - in their instance of the experience the object is rotating.

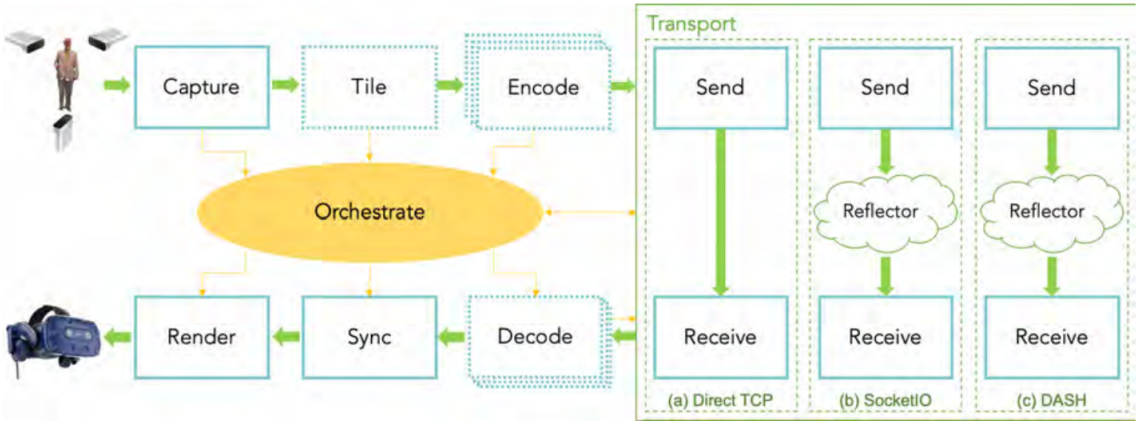


Figure 30: VR2Gather system architecture [97].

6.1.5 Hardware

Next to the software that was described above, to be able to run the experience the specific hardware is needed. Firstly, VR headsets and controllers need to be used. In the setup that we used for the experiments they were Meta Quest Pro sets. Then, there have to be cameras to capture the users' point clouds. In order to ensure a full 360 degree view, at least 3 cameras are required. Here four Microsoft Azure Kinect cameras per participant were applied. The spacing between them is approximately 3.5m, which gives an area in the centre of about 1x1m where the user is fully visible. As the user leaves that area some cameras will not be able to catch them fully anymore - the user's feet (and then legs and so on) will not be captured. The cameras are positioned high enough that the participant's upper body (and especially head) will remain visible to all cameras in an area of at least 2.5x2.5m. Obviously, computers and an internet connection are needed to run the experience. For the experiments we had two computers with local versions of the system and one orchestrator machine. They were linked with a 1000Mbps ethernet connection.

6.2 Validation session

After the experience was implemented, it had to be validated and evaluated. For this purpose the validation session was organised. It took place in CWI on the 26th of March 2024 and lasted three hours. In this experiment, similarly to the focus group session, there were some participants whose focus lies on fashion (four people) and some having expertise in different areas (two people). The reason for that was also the same: introducing new points of view and steering the conversation in novel directions. The total of six participants took part in the study, out of which there was one curator from Centraal Museum Utrecht, two curators from European Fashion Heritage Association and one curator from the Netherlands Institute for Sound and Vision. On top of that, there was a designer specialized in fashion and an employee of the Netherlands Institute for Sound and Vision. The data was collected by recording audio and video of the session. The think-aloud protocol with some guiding questions was applied during the experiment. The main goal of the experiment was to answer the third research question:

RQ3: How can we design a social VR fashion exhibition taking into account the context?

Apart from that the session aimed at discussing the design of the environment, the presentation of the objects and information about them and deciding on how to improve the whole experience (including interactions, story, navigation etc.).

6.2.1 Procedure

To begin with, the participants were asked to read the participation information sheet and sign the consent form. A short introduction was given about how the experiment will be conducted.
The session was divided into two parts. Firstly, the participants tested the experience in pairs. The think-aloud protocol [99] was adapted for this part of the experiment: the subjects were asked to comment out loud what they do and what they think about the experience. To address the specific, important issues some additional questions were prepared. In order not to disturb the experience, the participants were first given time to explore the room, play with exhibits and interact with each other. Then, before they moved to the next space, the prepared questions (per room) were asked:

Room 1:

1. Environment:
   (a) What do you think about the design of the room?
   (b) Is the lighting good? What do you think about colours?
2. Object:
   (a) Are the exhibits of a good size?
   (b) Are they placed well? (position, direction)
   (c) What do you think about the interactions?

(d) Are the buttons easy to use?

3. Information:

   (a) What do you think about the information panel?

   (b) What do you think specifically about its: position in the room, size, readability and appearance?

4. What do you think about the other objects that are placed in the room?

   (a) Do they fit in?

   (b) Are they positioned well?

   (c) What about their size and appearance?

5. Navigation:

   (a) Is the moving to the next room mechanism and task division clear?

Room 2:

1. Environment:

   (a) What do you think about the design of the room?

   (b) Is the lighting good? What do you think about colors?

2. Object:

   (a) Is the exhibit of a good size?

   (b) Is it placed well? (position, direction)

   (c) What do you think about the interaction panel? Its size and positioning?

3. Information:

   (a) What do you think about the information panel?

   (b) What do you think specifically about its: position in the room, size, readability and appearance?

4. What do you think about the other objects that are placed in the room?

   (a) Do they fit in?

   (b) Are they positioned well?

   (c) What about their size and appearance?

5. Navigation:

(a) Is it clear how should you go on with your visit? Is the teleportation button well positioned and signalled?

Room 3:

1. Environment:
   (a) What do you think about the design of the room?
   (b) What do you think about lighting and colours?
2. Object:
   (a) Is the exhibit of a good size?
   (b) Is it placed well? (position, direction)
   (c) What do you think about the interaction panel? Its size and positioning?
3. Information:
   (a) What do you think about the information panel?
   (b) What do you think specifically about its: position in the room, size, readability and appearance?
4. What do you think about the other objects that are placed in the room?
   (a) Do they fit in?
   (b) Are they positioned well?
   (c) What about their size and appearance?
   (d) Is it clear what is shown in the showcase?

While two subjects were actively participating in the experience, the rest of the attendees was present in the room as well. They were following what their peers were doing by watching the activity on the computer screen and also commenting on the experience. As there were six participants the whole procedure was repeated three times. For this part of the validation the sound and video recordings of the computer screen showing what the participants were looking at were taken. The reason for that was the need to know what element of the experience the participant was talking about at a particular moment.
The second part of the validation session was based on discussion. Each of the participants was asked what they think about the experience, what they find well-made and what should be improved. After each given opinion, there was a small discussion about the aspect pointed out by the speaker. Only audio was recorded of this part of the session. It was based mainly on the discussion so recording of the video was not necessary.

Figure 31: Participant testing the social VR fashion exhibition

6.3 Data analysis

After the data was collected during the validation session it had to be analysed. For this purpose it was firstly transcribed using Dovetail [49]. The transcription was then re-listed to and corrected by hand. When the data was cleaned further analysis was performed using Constructivist Grounded Theory [50]. Firstly, the themes describing similar issues were found and grouped together, and then they were connected with each other creating a coherent whole. The results of this analysis let us understand how the context should be used in designing the social VR fashion exhibition for a museum and answered some of the design questions.

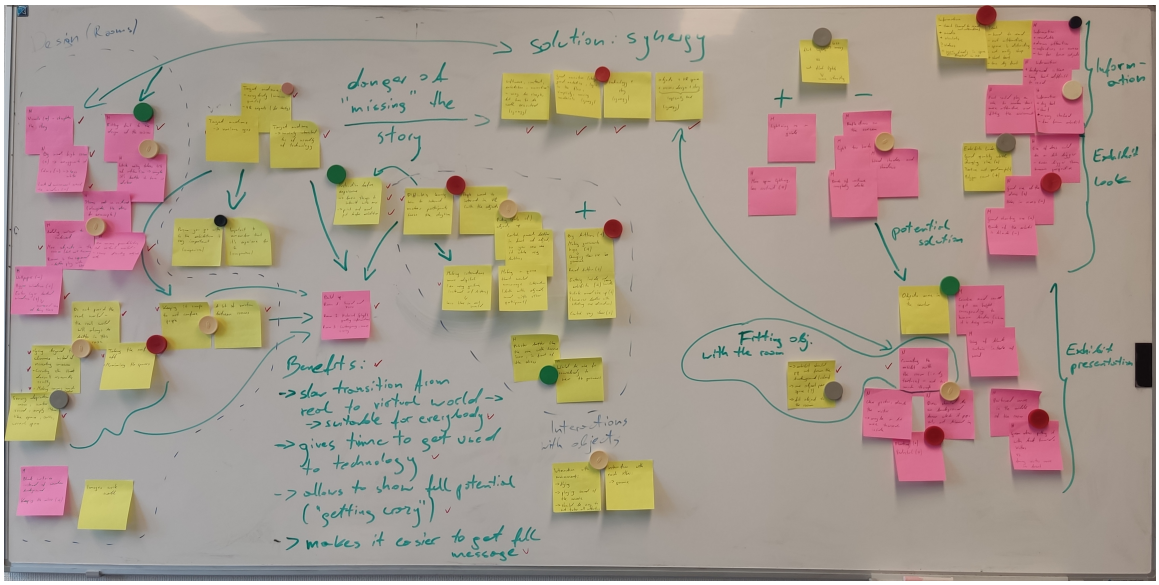


Figure 32: Data analysis after validation session.

6.4 Results

At the beginning it is important to mention that the experts were very impressed by the design of the experience. They loved the diversity of the rooms, found interactions enjoyable and the whole experience "great". While commenting on the appearance of the rooms they often used words such as "really cool", "beautiful" or "really nice". They were very engaged in the interactions, trying to cooperate while performing them and complementing on how well-designed and implemented they were. Overall, the experts spend a long time in the experience, immersed and socialising with each other. The first pair of participants engaged in the experience so much, that they spent almost an hour exploring the exhibition. The experts approved the approach and highlighted how well it was developed. One of the participants upon finishing the testing concluded the activity with the words: "Wow. What an experience, huh?".

While analysing the data, it became clear that one of the most important goals that the museum would like to achieve through utilization of a social VR fashion exhibition is passing on information: sharing knowledge and building an understanding of the exhibited objects and history associated with them. As long as social Virtual Reality seems to be an amazing tool for achieving this goal by allowing to present and interact with objects that cannot be presented in the physical world anymore, as well as introducing the possibility of passing information in a more interesting way, it also poses a danger. Visitors of the social VR exhibition might miss the story that curators would like to tell them for a few reasons. Firstly, because of a diversity of the expected audience (visitors from various age groups and with diverse familiarity levels of VR) some visitors might not pay enough attention to the story. Part of them might be mainly interested in the novelty of the technology and hence focused on the way social VR works rather than the story presented in the exhibition. Other ones can have problems with using controllers which can be disturbing and cause

them to miss (part of) the narrative. During the expert validation session a few solutions to this problem have been proposed. The ones that the participants were most convinced about will be presented in the following sections.

6.4.1 Synergy

Let's start with a concept that was already mentioned in this thesis a few times - synergy. Synergy has the potential to help attract people interested mainly in the novelty of technology also to other elements of the experience, like, for example, the story. This time the participants mentioned mainly the connection and a good balance between technology, exhibits, narrative, space and room design (aesthetics). All of these elements should be logically tied together creating one whole, in which particular elements do not fight with each other but rather complement each other. The important element - the story - also needs to play by this rule. It is better for it to be simple, but well executed and fitting together with the whole exhibition. The examples of synergy given by the subjects during the experiment included, among others:

1. Connecting the exhibit with the room. Not only topic-wise but also appearance-wise. One example that participants gave was the structure on the walls - it could be fitted to the structure that the dress has. Important thing to remember here is that the exhibit needs to be connected with the surrounding, but not blurred into it. The object has to pop out and be well visible in order to ensure the visitors know what is the main artefact they should pay attention to.

2. Adding decorations connected to the main exhibit. Similarly like while creating the physical exhibition (described in Section 5.2), the star objects are accompanied by other, related to them artefacts, in the case of the virtual exhibition it is also important to add to the space other objects that would set the suitable background for the main exhibit or extend its story. Those additional objects might be closely or loosely related - the most important part is that they do fit the general flow of the exhibition and make the experience feel "fuller".

3. Fitting the font of the exhibits' descriptions to the design of the room. As the designer taking part in the experiment said, a good selection of a font could cause "the font and the text itself to become almost part of the design of the exhibition".

4. Adding an additional layer behind the windows. The participants noticed that the environment feels much more "real" if they can see a world behind the windows (like in the historical room) compared to having the default Unity void (like in the neutral room). It makes the virtual world being more "multidimensional", creating an illusion that there is something more to it than just this room with an exhibit.

Next to the aspects described in this section synergy has many more benefits that were already described in this thesis. A detailed description of those benefits and synergy importance can be found in Sections 3 and 4.

6.4.2 Simplicity

Another solution to the problem of variety in the target audience is keeping the environment, interactions and the story simple. However, there are also some challenges associated with this idea. Firstly, as the curators repeated many times: "Mirroring the real world is a bad idea. You would never have an experience that is better than the real world. The real world will always win". According to the participants we should create something that does not resemble reality - the best idea is going beyond the schemes instead of recreating the actual museum, "going wild". Also in the literature, it is described that people in Virtual Reality appreciate the "ideal place" more than the "real place". An example is people visiting a holiday destination in VR - seeing a turquoise sky and a vibrant rainbow, that they could never see frequently in the "real place", brought more enjoyment to the users than showing the place as it is in the real world [100]. The problem that appears here is that creating something simple and straightforward, but at the same time creative and out of our world is difficult. Those descriptions even exclude each other up to some level - for some participants being in a weird environment might be overwhelming. One of the curators gave an example of an elderly person, who might not feel comfortable entering the VR environment and in a moment be floating under the ceiling. The issue that appears is then how to find a balance between something simple and user-friendly and something interesting that ensures a great user experience. As it turned out during the experiment, to address this dilemma another approach is needed - the answer turned out to be the use of context.

6.4.3 Context

The third research question of this thesis concerns using context in the design of social VR fashion exhibition. The usage of context has never been tested for virtual social exhibitions before, and the possibilities given by VR were much bigger than what usually is available in museums for traditional exhibitions, so the answer to that question was almost completely missing in the current literature. During the expert evaluation session it turned out that using context may have many benefits for the experience. However, on the contrary to what was expected, the participants did not assess one environmental context as being better than another. Instead, from the discussion between experts it came up that the context can be used to gradually introduce the visitor to the virtual world. In the previous section (6.4.2) we pointed out the problem coming from the dilemma between making the story simple and straightforward and creating a captivating, out-of-the-world experience. The solution for that might be a slow build-up of the experience using context. The approach will be described on the example of this particular exhibition.

The first space that the visitor will appear in after putting on the VR headset is a museum room designed based on the Netherlands Institute for Sound and Vision building. This is the same space the exhibition will take place at, so putting the headset will move the visitors to the virtual version of the same space they are physically in. This, according to the experts taking part in the validation session, should allow for a smooth transition from the real to the virtual world. The participants will be able to learn how to interact with the environment in a safe space, without feeling of being overwhelmed. They will be able to get used to navigating in a virtual environment and the feeling

of being in this new situation. The second room is going to have the historical context - it is going to be the same room that in the previous design was visited as last. This space is already different from the room in which visitors are physically, but is still pretty normal - something that could exist in the real world. However, some "unnatural" elements are slowly being introduced there, like floating elements or a playful way of giving information. The space can also already employ a bit unusual elements. An example of an idea given by the curators is taking out the roof of the room. It is not an impossible element, but it already goes away from normality - it is not common to have a 19th-century house with a historical exhibition inside, without a roof. Another idea to implement in the middle room was putting some elements (like historical clothes) on the visitors. Again - nothing crazy and weird about it - but not common or easily achievable in the physical world. The environmental context in the third room is going to be designed in much more contemporary style. During the session the participants gave a few ideas of what this space could look like: "oniric", "crazy", darkness with light just on the exhibits or space without boundaries surrounded by a never-ending horizon.

This approach of gradual context build-up, however never used for VR exhibitions before, is already known from different areas. For example, games level progression works based on similar rules. It is known that player engagement and enjoyment require constant challenge, but at a level the player can handle [101]. More difficult tasks and more complex stories are introduced later on, when the player advances in the game. Similarly in the social VR fashion exhibition, the story and context become more complex with time as the visitor is getting more familiar with the VR and the rules of functioning within it.

This use of context can have multiple benefits. Firstly, as already described, it ensures a slow transition from the real to the virtual world. This gradual change in the environment makes the experience suitable for everybody. It helps to avoid the shock associated with a sudden appearance in a "crazy" space and allows to first focus on, already for many difficult, learning to use the controllers without being overwhelmed by the huge amount of "novelty" around. This use of context also allows to show the full potential of the technology - it is possible to show things "out of this world" to all of the visitors. According to the experts, it should also make it easier for the visitors to get the full message. As the story and information will be given gradually together with visitors' growing control skills and understanding of the virtual space, they should not be so distracted by the technology or handling the controllers, and hence be able to catch more of the prepared narrative.

To sum up, the answer to the third research question is using the context to build up the environment: from familiar, easy for the visitor's mind to cope with, up to complex and bizarre, but more interesting and attractive for the visitor.

6.4.4 Other ways to help visitors handle controllers

Apart from the extensive solutions described above, two more ideas of how to help visitors gain proficiency in using controllers emerged during the expert validation session. Firstly, some instructions on how to use controllers should be given before the visitors enter the virtual environment. The validation session participants proposed that short instruction on how to perform basic actions

should be printed on a piece of paper and placed in front of the physical exhibition setup. Another idea given by the experts was to make interactions within the virtual world more digital - without using the buttons like it is often done in the physical world. A proposition of a different approach was to use gestures. According to some of the experts this would make the interactions easier and, additionally, more distinct from the physical world. The difficulty here is that with the current technology it is very difficult to successfully employ gesture interactions in pointcloud-based social Virtual Reality. Experts also proposed using different buttons on the controllers to introduce various interactions instead of clicking virtual buttons. As long as this solution is technologically possible the question whether it is better than using virtual buttons remains unanswered. This approach would make it necessary for the visitors to remember more controller actions which may make the process of learning how to navigate through the experience longer and more complex.

6.5 Design refinement

The evaluation session, next to answering the third research question, resulted in many ideas and suggestions about how to improve the design of the experience. Firstly, many suggestions about the objects have been given. The arsenic stones were suggested to be put outside of the cabinet (for example around the green dress) and the wooden background of the garments in the first room is advised to be replaced with black curtains. The experts proposed to put black curtains behind the main exhibits also in other rooms. It is expected to ensure good visibility of the exhibits, make them "pop out" from the background. It was suggested to put more decorative objects in the historical room. According to one of the curators, the mirror, which was very appreciated in the first room, could also be added to the wardrobe in the historical room. Another suggestion about the historical room was adjusting the colour of the ceiling. The designer mentioned that the white colour that is currently used draws too much attention. One of the curators also mentioned that the room is too squared. She suggested playing with shapes more to improve the perception of the depth. As everybody was very happy with the background layer behind the windows they suggested to make the windows even bigger. They also said it would be great to add the background layers in other rooms as well. Another general comment was that the images work very well in passing on the information unlike the text, which in VR is difficult to read and discouraging to engage with. It was suggested that for the next iteration of the experience, we should focus more on the archive pictures and videos, and maybe consider adding information in a form of an audio guide. This might, however, disturb the social part of the experience so further analysis of this idea is needed.
All of the suggestions given by the experts have been analyzed in order to adjust the design of the experience. Some of the corrections have already been implemented, while others are planned to be realized before the final exhibition of the project that will take place in June 2024.

6.5.1 Out of the real world experience

One of the contexts that was decided upon during the validation is the "out of the real world" environment. During the evaluation session, experts came out with many ideas that they think could be applied while creating this space. It is possible to divide those ideas into three categories: 1) exaggerating reality, 2) adding unreal elements, 3) creating surreal interactions.
The first category contains ideas such as creating really big and high rooms - really maximizing the space, making it extraordinarily large as well as taking the roof off of the room and changing the sizes of the objects to unnatural dimensions.
Under the second category fall all of the craziest ideas: making the objects float around, information being fixated in front of the visitor's eyes or just appearing somewhere freely in space, creating a "sensory deprivation room" in which the visitor would be surrounded by darkness only with the sound of water appearing when they walk. All of the other ideas about oniric, unreal space should also be placed here.
The last group of ideas is everything considering impossible in real-life interactions. This includes interactions with the environment, like flying and interactions with objects, like wearing the exhibits or using gestures to interact with the artefacts.

6.5.2 Interactions

A big topic during the validation session was the fact that in VR, in contrast to traditional museums, people really want to interact with objects. While during visiting physical exhibitions the visitors are really hesitant to click any buttons and "carefully read all the instructions before trying to do anything", in virtual exhibition experience they just go on with trying to touch and interact with everything. During the meeting everybody agreed that this characteristic of the virtual exhibitions should be used in its benefit. The topic developed into further discussions about what interactions should be added to the experience and how the already implemented ones can be improved.
Let's start with the interactions with objects. Next to the interactions that are already implemented: changing sizes and rotating the garments, the experts suggested that they missed the possibility of picking up the objects. They were very happy that it is possible to enter into and see some of the garments from the inside. They said that it would be great if it was also possible to virtually "wear" some historic clothing. Finally, they proposed to create a game that would further encourage the visitors to interact with the exhibits. While talking about the interaction with objects it is not only about what can visitors do with the artefact, but also how. The dilemma between using buttons and gestures was already described. As for this prototype the buttons were used, the experts were able to provide some feedback about how to improve the buttons-driven interaction. Firstly, the interaction panels should be placed in front of the object - so that while clicking the buttons the visitor can immediately see the effect their action has on the exhibit. Secondly, the versions of the panels where the buttons were "huge" were more appreciated. The participants stated that it makes the interaction easier, especially if somebody does not have much experience in using VR controllers. Finally, they were very happy about the "reset" button being present and stated, that this is very important to have the possibility of resetting object to its original size and position in case of every

historical artefact that will be presented in the experience.
For the next type of interaction - interaction with the environment, what is important is its naturalness and simplicity. It should not occupy all the attention, instead, it should be intuitive and organic, as simple as in the physical world. The ideas of additional interactions with the environment that the experts had were, among others, flying and triggering playing the movie or sound.
For the last type of interaction - interaction with other users - the new proposition was a creation of a game, in which the participants would need to cooperate to win. This would encourage them to interact with each other, even if they did not know one another before.

6.5.3 Target audience

As already mentioned, the target audience of this exhibition is expected to be very diverse. Taking into account the specificity of the Netherlands Institute for Sound and Vision, people of all ages and all levels of VR technology knowledge are presumed to appear. It is important to remember, that the virtual exhibition is an experience created to be visited at one time by at least two people. The companion of the experience has a huge impact on how the other visitor perceives the whole experience. If they do not enjoy the exhibition, not only their experience will be destroyed, but also the person's that is visiting the virtual museum with them. Hence, it is important that the social VR fashion exhibition experience is suitable for all potential visitors.

7 Conclusion

In the course of this thesis three research questions were stated, investigated and resolved:

RQ1: What do experts think of the use of social VR for fashion exhibitions?

RQ2: What issues should be taken into account while designing a social VR fashion exhibition?

RQ3: How can we design a social VR fashion exhibition taking into account the context?

To begin with, the results of the first study - the survey among XR experts - showed that there is an overall positive reception of the incorporation of social VR technologies into museum experiences. In the literature currently available it is possible to find the benefits XR has in the cultural heritage sector [34]. However, the use of social VR for fashion heritage was never tried before this project was conducted. In the Introduction and Background parts of this thesis the important elements of the exhibition design were discussed. Among the most important it is necessary to list: exhibits, information and interactions. But having those elements, even if well prepared and presented on each own, is not enough to ensure a good visitor experience. They need to be logically connected with a maintenance of a good balance between them. Focusing too much on one element in comparison to others may result in the feeling of weariness or, on the contrary, being overstimulated and overwhelmed. This good balance is often difficult to achieve. According to 66% of the experts taking part in the survey using social VR can help to achieve the synergy between exhibit, information and interaction and hence improve visitor experience. All those elements of the exhibition connected together should create a narrative, a story that curators want to pass on to the visitors. Sometimes, the creation of this consistent story might be disturbed by problems with any of the exhibition elements, for example, the absence of some exhibits. Looking at the results of the survey social VR can also help with that. According to most of the participants (86%) using this technology would help to create a consistent story. The technology is able to complement the exhibition by showing the pieces that are not physically available for the museum. This, in turn, has the potential of improving the understanding of the whole exhibition by the visitors.
The results show that social VR has the potential to improve the experience of fashion exhibition visitors. Additionally, it is expected to make the fashion heritage accessible for broader range of visitors, for example ones having distance limitations or mobility problems. Moving the exhibition to the virtual world can also bring the possibility of adjusting the experience to the specific type of visitors. It looks like the usage of social VR would bring a general improvement for the visitors in case of experience and accessibility. However, it is important to check if this improvement is universal throughout all of the visitors. To validate the assumption that the virtual exhibition would be easily approachable for a regular visitor, we once again asked the experts what they think. The answers to this question were much more divided than in case of other queries. Even though the majority of respondents (65,1%) still agreed that social VR would make the exhibition more approachable to

the regular visitor, a big part (23,2%) did not agree with the statement. Our assumption is that some of the experts are concerned about visitors' skills in using VR controllers. This issue might indeed make the social VR exhibition less approachable than the traditional format to some of the visitors.

Showing the exhibits to the visitors is not the only goal of this project. One of the main tasks of the museum is the research and conservation of historical objects. The other aim of this project is then to allow the institutions to continue the investigation of the exhibits whose physical state does not allow to work on them anymore. Hence, the last question the experts were asked considered their opinion on social VR use in research. The question investigated whether placing 3D scans of fragile costumes in social Virtual Reality would allow the museum curators and researchers to continue the study of these exhibits. Here again most of the experts (79,5%) agreed that using social VR could positively contribute to this goal. The curators could not only continue researching the exhibits, but also do that in a comfortable environment and be accompanied by other researchers, even the ones physically based far away.

After confirming that creating a social VR fashion exhibition makes sense and is promising to provide many benefits, both for museum visitors and curators, it was time to answer the question of how to successfully design the experience. The second study, a focus group, was designed to answer the question of what issues should be taken into account during the design process of a social VR fashion exhibition. The literature review uncovered some aspects important in the design of social (fashion) exhibitions and some other crucial elements while creating (social) VR experiences. From a combination of both a set of issues that were expected to be important for the design of social VR fashion exhibition was created. This set included, among others: context integration, interactive experience, well-constructed way of information passing, good design of the space. Some of those elements were confirmed during the focus group, and some new aspects were added. Firstly, the experience was verified as an important aspect to take into account while designing the exhibition. According to the focus group results it manifests through also already described synergy, connection between exhibits, performance, focus on showing details and interactivity. One of the main goals of museums, according to both the literature and focus group participants, is improved learning. The important design elements that can positively influence learning are well-designed experience and familiarity, which is also strongly connected to context. Context, also already mentioned in the background part of this work, is another important element of the design confirmed by the focus group.

The results of the focus group allowed us to design and create the virtual exhibition and organize the experiment needed to answer the last research question. Based on the literature review it was expected that the context would play an important role in user experience, however it was not clear how to best use the context to achieve this goal. To examine this issue the experience containing three rooms built based on different contexts was created. First space was designed to look like a modern museum and was inspired by the NISV building in Hilversum - institute, in which the final exhibition of the project will take place. The second room had a neutral context, and the third was styled as a 19th-century house. The group of experts took part in the evaluation session of the experience based on a guided think-aloud method followed by group discussion. The results

pointed to an unexpected way of using context: instead of picking one that would have the most benefits for the experience, the curators decided it would be best to use all of them. The idea of a contextual build-up was created. According to the participants, the best way of using context is to start by having a room with context reflecting the physical space in which the visitors are located. It is expected to make the transition from real to virtual world more smooth and less shocking to the visitors. Then, the historical context is supposed to follow. This space should be designed to be different than the physical space where the exhibition is located, but still follow most of the real world rules. Some single "supernatural" elements should be introduced here, to give the users an option to gradually get used to the impossible in the "real world" phenomena. Finally, the last room should be really out-of-real world, allowing to show the visitors all the impossible in real world elements and give them new experiences that are not achievable outside of the virtual space. Here the context should be like taken out of a contemporary art piece, showing the visitors that they are in a different world where things they could not normally do are possible, and where different rules apply.

To sum up, the work allowed to firstly confirm the need of social VR fashion exhibition based on the experts judgment (RQ1). Then, during the second experiment, five elements important for the design of such an experience were appointed: context, emotion and familiarity, learning, experience, and vulnerability (RQ2). Those five concepts were then taken as core in the design and implementation process of the virtual exhibition. The main focus was paid to the context, as from both the literature review and focus group study it was clear this element has a huge impact on the user experience and learning rate of participants. The validation and evaluation session run after the exhibition was developed showed that the best implementation of context is the introduction of context build-up. The context build-up approach assumes that the experience should start in a virtual space similar to the room in which the participants are located physically. Then, they should move on to the space still resembling known to the participants world, but different from the one that they are physically in. Finally, the participants can enter a space that is completely different from the real world they know. Here, the creators are free to use their imagination and go beyond the rules of the physical world. This approach towards context provides several benefits: avoiding overwhelm by creating an easy and gradual transition from a real to a virtual world, allowing to slowly learn how to interact with a virtual environment and finally showing out-of-real-world possibilities one can have in the VR (RQ3).

The results of this work will be shown as an actual museum exhibition between the 25th and 28th of June at the Netherlands Institute of Sound and Vision in Hilversum. The experience will be available for visitors with a spot reservation required in advance. The participants will visit the exhibition in pairs. They will enter the virtual exhibition through specially prepared booths, each equipped with four cameras, a VR headset and controllers. Figure 33 presents the example set-up of the booths. The experience is expected to last about fifteen minutes per pair. In front of the booths a TV screen displaying the live view of the experience will be placed, so that other visitors, currently not taking part in the experience, can follow what other guests are doing. The view will be shown from a third-person perspective - a "spectator" additionally placed in the experience. This approach will ensure good image quality. Having the screen displaying live the action happening

in the virtual exhibition is important for three reasons: people coming in groups bigger than two will be able to follow what their peers are doing, visitors waiting for their turn will not be bored and people coming to the museum without prior planning of visiting the social VR exhibition will be able to understand what is going on, and maybe join the experience as well. The last point is important in the context of promoting the event. One day of the exhibition will be reserved for guests with special invitations. This guest list will include experts in the field of digitalization of cultural heritage, which will allow us to further assess the exhibition.

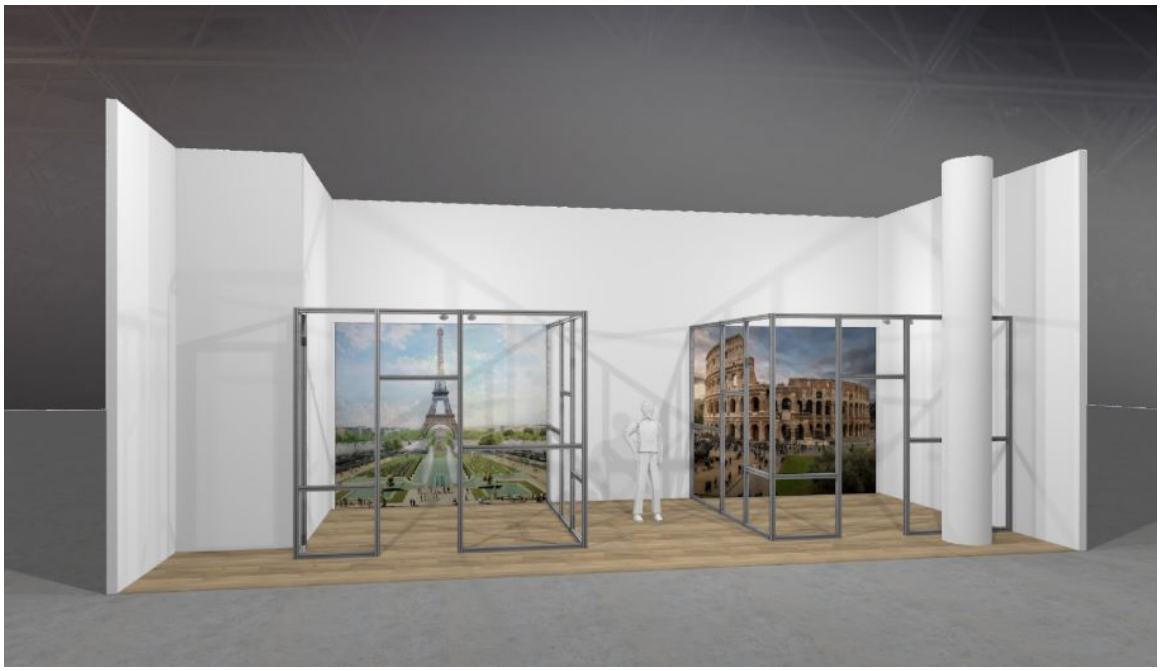


Figure 33: An example of the booths' construction.

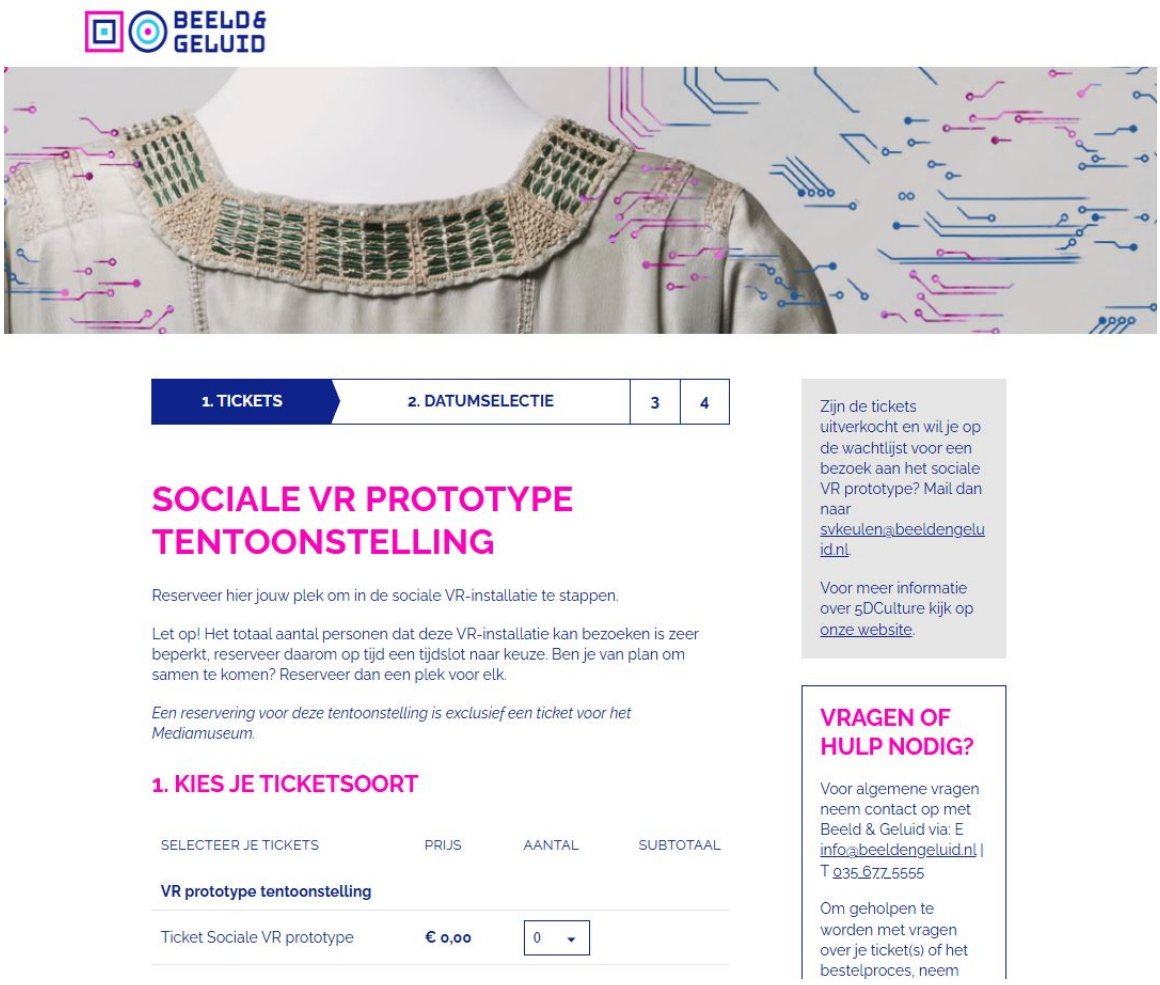


Figure 34: Social VR fashion exhibition tickets sales website.

The complexity of the topic made the choice of specific research focus challenging. The number of unexplored areas in the field of social VR use in cultural heritage (and specifically fashion heritage) is so big that it was difficult to decide what questions we would like to answer. Hence it is natural that the results of the study based on the selected research questions leave many opportunities for future research. Firstly, it would be necessary to conduct a user study to check the benefits of social VR for fashion exhibitions in learning and experience. According to the results of the expert survey the virtual exhibition is supposed to have a beneficial effect on these aspects, however, it cannot be fully confirmed before the study on the actual users. Similarly, experts suggest that using social VR could offer curators more opportunities to examine exhibits. However, a detailed study involving curators is necessary to verify this assumption. Secondly, another topic requiring further investigation is context. Even though the general idea of how to use context in the creation of social VR fashion exhibition was gained, the influence of each specific type of context on the users should be examined. The research checking the differences in experience and knowledge retention while using different environmental contexts in virtual exhibitions is planned to be a follow-up study after this thesis is

completed. Another element classified as important based on the focus group study - emotion and familiarity, requires confirmation in the form of user study as well. Based on the previous research and the curators' opinion emotions and familiarity have a significant impact on the engagement of the participants, which in turn positively influences experience and learning outcomes. However, the study checking how it influences users of social VR (fashion) exhibition in particular is still missing. The elements evoking emotion in VR exhibitions should also be studied. The candidate to examine here is sociality, which is expected to introduce positive emotions during the experience. The topic of familiarity also strongly connects with the context, which can induce positive emotions by introducing known to the user elements and hence positively influence engagement. Finally, many interesting topics that were introduced in the background part of this thesis still lack a broader understanding. For example, the presence of museum social norms in social VR exhibitions is an interesting topic that has not been studied yet. Researching this topic could not only change the approach of designing social VR cultural heritage experiences, but impact our knowledge about human social behaviours in virtual spaces in general.

To sum up, this thesis confirmed the need of social VR fashion exhibitions creation, discussed the important elements to be taken into account while designing the experience and, finally, designed and tested the experience focusing on the usage of the context. This work creates a basis for the creation of a framework for social VR fashion exhibition designs and starts the discussion about the context's influence on the users' experience and their learning capabilities.

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