Utrecht University

Department of Information and Computing Sciences

Game and Media Technology – Master Thesis

Using Painting Complementing Illusions to Enhance the VR Museum Experience

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Preface

This thesis focuses on painting complementing illusions in a VR museum environment and investigates if there is a relation between the illusions and the museum visitor types on the user experience. The idea of the painting complementing illusions started out as a topic for a small project for the Game and Media Technology master. The topic carried on as the topic for this master thesis. The major deliverable are as follows:

- **Scientific Paper**

  The scientific paper investigates the effects of the illusions on the user experience by looking at the museum visitor types.

- **Annotated Appendix**

  The annotated appendix contains related work on the scientific paper that was done as part of the first phase of the master thesis.

  - **Literature Study: VR Experiences and Museums**
    The literature study to find interesting areas for this master thesis to investigate.
  - **Study 1: VR Museum Emotion and Style Awareness**
    This study investigated the emotion and style awareness caused by the illusion. The study was done in collaboration with Ferdinand de Coninck as part of his small project for the master Game and Media Technology at Utrecht University.
  - **ACE Poster**
    This paper was written by Dr. Wolfgang Hürst based on the findings of Study 1 and got accepted by ACE 2016.
  - **Study 2: VR Museum Demo**
    This study was done to get general feedback on the illusions when placed in a VR museum environment. The study was done in collaboration with Ferdinand de Coninck as part of his small project for the master Game and Media Technology at Utrecht University.
  - **ACE Demo**
    This paper was written by Dr. Wolfgang Hürst based on the findings of Study 2 and got accepted by ACE 2016.

Other contributions and deliverables of this thesis include:

- **Source Code and Assets**

  The source code and the assets of the application that was used during the user studies for this thesis.

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Part I

Scientific Paper

Chapter 1

Scientific Paper

Museum Visitor Type Preferences of Artwork Complementing Illusions in a VR Museum

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Abstract

Virtual reality (VR) allows us to create illusions that complement the paintings to create new VR museum experiences. In this study, the the desire and preferences for these illusions is investigated by looking at a person's museum visitor type, and how these illusions impact their museum experience. The results indicate that those who don't visit museums prefer the museum setup with illusions over the traditional museum setup, while those who go to the museums with a content-related objective suggest that they prefer the traditional setup in a physical museum. While the VR museum is generally accepted positively, the experience gained from it is different than one physical museum.

1.1 Introduction

With Virtual Reality (VR) products on the market, VR has hit the mainstream consumer market. Companies such as HTC and Oculus released dedicated VR headsets [1, 2]. Samsung released the Gear VR [3] to make VR possible on their smartphones, but with Google Cardboard [4] developers were also able to create VR experiences for other types of smartphones.

While VR is often associated with gaming, it can also be applied in other areas. For example, Google Expeditions [5] uses Google Cardboard to take students on virtual tours, creating a new way of education. VR is also used for training. The British Army uses VR to simulate scenarios to train soldiers how they can handle situations in an appropriate way [6]. Not only does the British Army use VR for training, they also use it as a tool to attract recruits by showing them Army scenarios [7]. Another field where VR has been applied to, is in the cultural heritage sector. The American Museum of Natural History is remotely available through Google Cardboard. This makes it possible to visit the museum from home. Other museums, such as The British Museum and the Westfries Museum [8] provided VR experiences to let visitors visit the past. Instead of recreating existing museums or historical environments, VR can also be used to enjoy art in new ways. An example of this case is created by Boulevard [9], where they applied VR in the cultural sector by allowing visitors to enter the world of the art itself.

Inspired by how VR is being applied in the cultural heritage sector, our idea rose to use VR to create new ways of enjoying paintings. Because VR can overcome the physical constraints of the real world, it makes it possible to show things that are otherwise impossible. For this idea, a VR museum was created in a previous study [10]. This VR museum incorporates visual illusions that complement the paintings, to let the visitors experience the paintings in a new way. However, as art is a very subjective matter, the preference of the illusions differ from each person. This study focuses on the relationship of the preferences and enjoyment of these illusions and the type of museum visitors.

In the following section, information about previous studies and related work will be given. In section 1.3, the research goal and its questions are stated. Section 1.4 describes the experiment while in section 1.5 and 1.6 the results will be analyzed and discussed. This paper concludes with the conclusions and future work in section 1.7.

1.2 Related Work

The advantage of VR for not being bounded by the physical world makes it possible to create a new ways to present existing things. In a previous study [10], illusions were created accompanying

the paintings in a VR museum. There were three types of illusions. The first type of illusion was the Stylized illusion. This illusions used a photo of the same theme as the painting. The photo was projected on the wall behind the painting and slowly transformed into the style of the painting using the algorithm by Gatys et al. [11]. The second illusion was the Extended Illusion. The painting was extended using expansion software [12], creating new art that passed the original's frame and covered the wall behind it. The last type of illusion was the Weather Illusion. Snow, rain and falling leafs were simulated in the 3D virtual scene, matching the theme of the painting. Both the Stylized and the Extended Illusions were considered as 2D illusions because they were realized on the wall in the virtual scene. The Weather illusion covered the 3D space of the scene and was thus considered a 3D illusion. The focus of the research was to get a measurement if people would enjoy these types of illusions during a VR museum visit and if the 3D illusions were able to create connectedness, the sense of being in the world of the painting itself. Generally, the illusions were positively received. The participants did have their own preferences, which was expected with the subjectiveness in art. Participants mentioned the immersive effect of the Weather Illusions, giving it a reason to study further upon the effects of the illusions.

With the question in mind if the added illusions can let people view art differently, the study was continued. The second study [13] focused on the style awareness and emotional aspect of the illusions. The same three types of illusions were used in this study and indicated that the illusions seem to have an effect on the thoughts on an emotional level of a person viewing the painting.

The two studies were both conducted in a controlled environment, not much representing a real museum. From the first study, participants mentioned that they put value in how the virtual museum looks. Taking this comments into account, the study was followed up by a demo [14] with a more museum-like setting. This demo included a new 3D type of illusion, the 3D Scene illusion, that teleports the viewer into the world of the painting. During this demo, participants were the most positive about the 3D illusions.

In general, participants were positive about the illusions. However, as expected since art is subjective, each person had his or her own preferences. Because of the different effect of the illusions, the question raised if the illusions are more interesting to a certain type of museum visitor.

1.2.1 Visitor Types

Instead of using demographics to categorize the visitor types, Falk described a model for the museum visitor experience that looks at the motivation why someone would go to a museum, also called the identity-related needs and desires [15]. According to Falk, each museum visitor has his/her own needs. When these needs are fulfilled during the museum visit, they will have a positive effect on their museum experience. If once again they have a certain need and they know the museum can fulfill this, they will go to the museum again, creating the museum experience cycle [15]. The motivations to go to a museum can be clustered in five identity-related categories:

- **Facilitators**
  Visitors who are socially motivated. Their visit is focused on primarily enabling the experience and learning of others in their accompanying social group.

- **Experience Seekers**
  Visitors who are motivated to visit because they perceive the museum as an important destination. Their satisfaction primarily derives from the mere fact of having 'been there and done that'.

- **Professionals/Hobbyists**
  Visitors who feel a close tie between the museum content and their professional or hobbyist passions. Their visits are typically motivated by a desire to satisfy a specific content-related objective.

- **Rechargers**
  Visitors who are primarily seeking to have a contemplative, spiritual and/or restorative experience. They see the museum as a refuge from the work-a-day world or as a confirmation of their religious beliefs.

- **Explorers**
  Visitors who are curiosity-driven with a generic interest in the content of the museum. They expect to find something that will grab their attention and fuel their learning.

To satisfy the needs of the visitor, or giving the most suitable museum experience to the visitor, knowing their visitor type of the visitor might help. As with the illusions from the previous studies, each participant had their own preferences and some preferred no illusions at all. It makes sense that a visitor with the Professional/Hobbyist visitor type goes to a museum for the art itself and doesn't care about the added illusions. On the other hand, Explorers are looking for things that attract their attention and seeing these illusions that are difficult to realize in physical museums might pique their interest. Keeping these thoughts in mind, the illusions from the previous studies are likely more suited for certain types of visitors.

One type of visitor Falk did not include is the type that doesn't go to a museum on his/her own free will. These are either people who are not interested in museums and are forced to go by others. In this study, these people are called the Non-Visitors.

- **Non-Visitors**
  Vistors who don't go to museums on their own accord and are forced to go by others.

1.3 Research Goal

1.3.1 Research Question

The illusions in the VR museum were created with the goal to make new enjoyable museum experiences. Even though the illusions were generally well received, participants still had their own opinion and preferences. With the theory in mind that visitors have their own needs when going to a museum, and that if these needs are fulfilled it will have a positive impact on the museums experience, it might be wondered if the preference in the illusions can be related to the type of visitor:

- Q: *Is there a relation between the illusions and the visitor type on the user experience?*

The illusions in this question are defined by the illusions that have been developed in the previous studies. The visitor types are as described by Falk [15] including the Non-Visitor type defined in this study. Experience is a very broad expression, but in this study it will be mainly focused on the enjoyment level. As mentioned before, the preferences of the illusions are different per person. In this study, the preferences are generalized by categorizing them per museum visitor type and looking at their needs.

1.3.2 Relations Between Illusions and Needs

To be able to answer the research question, it is necessary to take a better look at what the VR museum and the illusions are able to do and how they can be related to the needs of the visitor. An overview of the expected suitable combinations of illusions and visitor types is shown in Table 1.1.

The Facilitator type is one that goes to the museum for a social reason. Since this study takes place in a VR setting with no social features whatsoever, it is assumed that VR museums of this type with no social features are not suitable for these types of visitors at all in terms of their needs. For this reason, this study does not focus on what the illusions can provide to the Facilitator type of visitors.

The Experience Seeker type of visitors go to a certain museum because they think it's important. However, since this VR museum is a fictional museum it is hard to consider it as an important destination. Unless the VR museum is known for something, the reason why the Experience Seeker might visit a VR museum is to have visited a VR museum itself. In this situation, the properties of illusions themselves might not offer anything to this type of visitors, but the visit of the museum with illusions itself might. In this case, their need is to experience a museum that is different from the physical museums.

Taking a look at the five visitor types, one might suggest that Professionals/Hobbyists have most interest in the exhibition pieces themselves and least in the added illusions. Their needs focus on the fact of seeing and learning about the paintings themselves.

	No Illusion	2D Illusions	3D Illusions
Experience Seekers		√	√√
Professionals/Hobbyists	√√		
Recharger			√√
Explorer		√	√
Non-Visitor		√	√

Table 1.1: Expected suitable content per visitor type. Multiple √ are expected to be more suitable.

The Recharger type of visitors go to a museum to escape from the reality or their everyday life. VR is a perfect way in general to escape from the reality. If a Recharger visits a museum just to enjoy the atmosphere of that, the current VR museum might not be the optimal solution as it does not include certain factors like other visitors. However, if the recharger goes to a museum for distraction to get his mind off things and accepts any type of reality there, the immersive types of illusions can offer a new world to escape to. Especially the 3D type illusions are meant to create a sense of presence in the world of the painting and in this case support in fulfilling the needs of the Recharger.

The Explorers type of visitors are the types that are open to what they see and look for something that grabs their attention. It is expected that the illusions will grab more of their attention compared to the standard setup without any illusions because the illusions make the VR museum different from the standard museums. This means they are the opposites of the Professionals/Hobbyists. For the illusions this means that they will look for those that interest them the most.

The Non-Visitors are expected to act very similar to the Explorers, with the exception that they do not go to museum on their own. However, the illusions make the VR museum different from the the physical museums. Because of this, the view that the Non-Visitor type of visitors have on museums can change, creating the possibility they gain interest in museums.

1.3.3 Subquestions

To get a better definition on the aspects of how the experience is measured, the research question is divided into four subquestions.

- SQ1: *Can the illusions make VR museums a 'must see' experience?*

The illusions are the most prominent factor that makes this VR museum different from physical museums. In a way, this can be considered as a different museum experience. The question then is if the illusions can make the VR museum into something that people can talk about and recommend others to visit. For the Professional/Hobbyist type of visitor, it is expected that they do not see the illusions as a reason to go to a VR museum as their main reason to see the art itself. For the other types of visitors, the illusions can be a reason to visit or experience the museum in a new way. This might especially hold true for the Experience Seekers to see and experience something they have never done before, including experiencing VR itself.

- SQ2: *Is there a preference or appreciation of illusions compared to the traditional museum setup?*

As mentioned before, Professional/Hobbyist type of visitors are likely to have the least interest in the illusions compared to the other type of visitors. The other types are likely to appreciate the illusions because it offers them something else than the traditional museum setup.

- SQ3: *Is there a preference of one certain type of illusion over others?*

While assuming the Professional/Hobbyist type of visitors do not prefer the illusions, the other types might have a preference for a certain illusion type. Rechargers, are likely to appreciate the immersive properties of 3D illusions more than the other illusions because of their need to escape the real world. Experience Seekers could also have this preference from the fact that they want to see something not possible in the real world. The 2D illusions are more straightforward as they can also be done in real museum with the necessary equipment, but the 3D illusions are something that

can only be done in VR at this point in time. Explorers and Non-Visitors are likely to appreciate the fact that there are illusions more over that there are none. They will base their preference more on their own taste instead of basing it on their needs.

- SQ4: *Do the illusions provide a better museum experience than the traditional museum setup?*

The main reason for Professionals/Hobbyists to go to a museum is to see the art itself. The fact the this VR museum is VR and that they do not see the real piece is one point the Professionals/Hobbyists might dislike already. Aside from not seeing the real piece, the illusions can form a distraction to the pieces. It is expected that Professionals/Hobbyists prefer a traditional museum setup in a physical museum over a VR museum with illusions. The other types, however are expected to see some value in the VR museum with illusions. The illusions create a different experience for the Experience Seekers, Explorers and Rechargers. This, however, does not necessarily suggests that it is a *better* experience than a traditional museum. As for the Non-Visitors, the illusions are expected to create a better experience than the traditional setup, because these illusions can be a new point of interest instead of the art pieces themselves. One might question if this is what the illusions are supposed to do, but the illusions also show this group a new way to enjoy museums and creating a chance that their view on museums will change. Ideally, it changes their view in the way that they think museums are interesting for them as well.

1.4 Experiment

To answer the research questions a user study was conducted. In section 1.4.1 the framework and the materials that were needed for the experiment are discussed. The experiment procedure is covered in section 1.4.2.

1.4.1 Materials and Framework

VR Museum Design

For this study, a VR museum was used to showcase the exhibition pieces including the illusions (Fig. 1.1). The museum is a modified and upgraded version of the demo from the previous study [14] and includes all types of illusions that have been developed until now. However, this museum also includes paintings without illusions. Museum labels are added to provide information about the paintings, stating the artist, the year of where the painting dates from and the technique used to create the painting. Extra care was taken to make the VR museum visually appealing. Small details and decorations such as couches, spotlights and ceiling details were added to create the feel of a real museum.

Figure 1.1: Screeenshots of the VR museum.

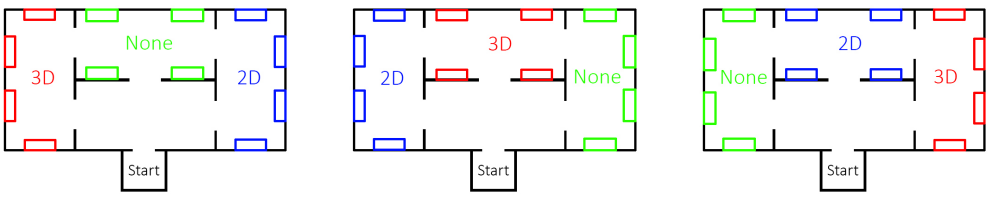


Figure 1.2: A top view of the museum layouts.

To keep the paintings with illusions separated from those without illusions, there were multiple rooms:

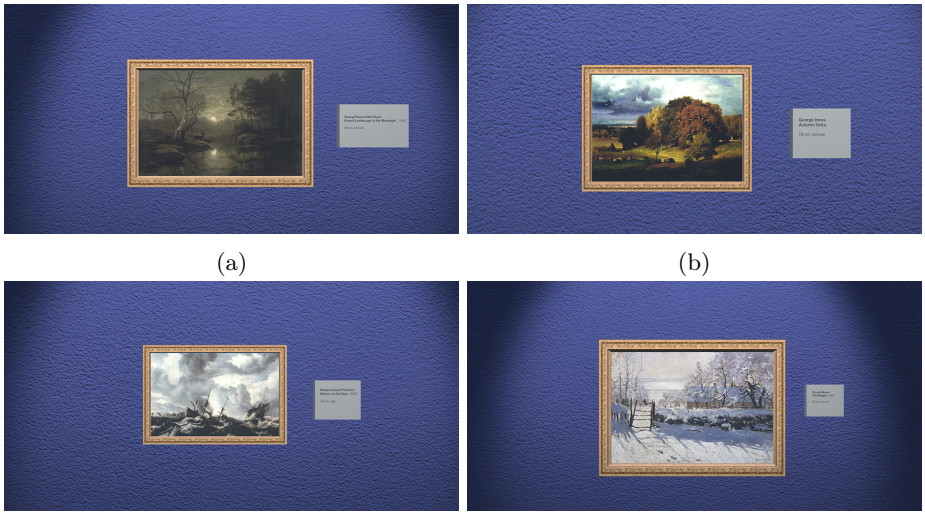
- **Start room**
  The room where the user started and where he/she got a navigation tutorial. It didn't contain any artworks.
- **Main room**
  The room connecting all the rooms to each other. It didn't contain any artworks.
- **None room**
  Aroom containing four paintings without any illusions.
- **2D room**
  A room containing four paintings accompanied by 2D illusions.
- **3D room**
  Aroom containing four paintings accompanied by 3D illusions.

Each room was connected to the Main room. Aside from this, the rooms with the paintings were also connected to at least one other room with paintings. This gave the visitor the freedom to walk around and choose where he/she wants to go. The reason to put four paintings in a room was to mimic the gallery atmosphere of physical museums.

There were three versions of the museum. The maps of the museum can be seen in 1.2. Each of them had the same content, but the location of the three rooms with paintings were different. The locations of the rooms were rotated according to the Latin square to compensate for any preferences the users had when navigating through the museum and avoid that everyone one saw one certain painting or illusion first.

Paintings and Illusions

The most positive paintings and illusions from previous studies were improved according to the feedback and used in this study. The collection was also expanded by a few new paintings. A total of twelve paintings were chosen from the Rijksstudio [16], Wikimedia Commons [17], Web Gallery of Art [18] or self made. Four paintings were without illusion (Fig. 1.3). Four other paintings were be accompanied by a 2D illusion (Fig. 1.4). Of these four, two paintings were complemented by the Expanding illusion while the other two were complemented by the Stylized illusion. Both Stylized illusion used a general fade-in and fade-out, unlike in the previous study where they used a pattern. Finally, a set of four other paintings were combined with the 3D illusions (Fig. 1.5). Two of these four were accompanied by a weather 3D illusion. To match with the theme of these two paintings, one of paintings was accompanied by a rain illusion and the other one by a snow illusion. The other two were accompanied by a 3D Scene illusion, showing a scene that depicted what was shown on the paintings themselves. All 3D illusions included ambient sound that fitted the depicted scene. When creating the illusions and sounds, fine-tuning them to fit the paintings was a very important aspect to create appealing illusions.



(a) (b)

(c) (d)

Figure 1.3: Paintings not accompanied by any illusion.

(a)

(b)

(c)

(d)

Figure 1.4: Paintings accompanied by 2D illusions. Paintings (a) and (b) are accompanied by Extended illusions. Paintings (c) and (d) by Stylized illusions.

Figure 1.5: Paintings accompanied by 3D illusions. Paintings (a) and (b) are accompanied by Weather illusions. Paintings (c) and (d) by Scene illusions.

Framework and Hardware

The VR museum was created using a personal edition of Unity 3D, version 5.5.2f1. The scripts of the application were written in C# using Microsoft Visual Studio 2015. 3D models were downloaded from Archive3D [19] and created or modified using Autodesk Maya 2017. Sounds were downloaded from Freesound [20] and merged using Audacity.

As for hardware, the HTC Vive was used as the VR system. One of the two controllers was used during the tests. An area of 5x5 meters was reserved for the Vive to let the user physically move around in VR. A setup of the area can be seen in Fig. 1.6. The Vive ran on a computer with an Intel Core i7 and an Nvidia GeForce GTX 1070. For the sound, a Sony MDR-ZX110 headphones was used.

Figure 1.6: The experiment setup.

1.4.2 Methods and Experiment Procedure

The experiment consists of the following parts:

1. **Consent Form**
   To inform the participant about experiment and warn him/her about the risks of VR.
2. **Demographic and Museum Interest Questionnaire**
   To acquire some general information about the participant and his/her interest in museums.
3. **Museum Visitor Type Questionnaire**
   Based on the museum visitor type questionnaire of Falk et al. [21] to determine the museum visitor type of the participant.
4. **Experience and Expectations of VR Museums Questionnaire**
   To determine the experience in VR the participant has and what he/she expects from a VR museum.
5. **VR Museum Visit**
   The participant visits the virtual museum using the Vive system.
6. **General Enjoyment Questionnaire**
   To measure the general enjoyment of the VR museum visit.
7. **PANAS Enjoyment per Illusion Type Questionnaire**
   An adapted version of the PANAS questionnaire by Watson et al. [22], to measure the positive and negative affect of each type of illusion.
8. **Interview**
   Open questions about the VR museum experience focusing on the personal experience, (illusion) preferences, and their general view on VR museums.

Before the test started, the participant was informed about the risks of VR: cybersickness may cause headaches and nausea. He/she was made aware of his/her rights to quit the test if this happened. The consent form stated these issues and also informed them how his/her data from the experiment got treated.

After the filling out the consent form, the participant was asked to fill out three questionnaires: Demographic and Museum Interest Questionnaire, Museum Visitor Type Questionnaire and Experience and Expectations of VR Museums Questionnaire. The second one was a modified version of Falk's [21] museum visitor type questionnaire. This questionnaire will be discussed in the next section.

Then, the participant was instructed to visit the VR museum on their own and stay there as long as they like. They also got instructions on how the headset works and that they are able to

move in the virtual space by physically walking. Because the safe area to move around was limited, the participant was advised to stay within the blue grid that the Vive will show in the virtual world when one gets close to the border of the area (Valve's Chaperone system). The participant was reassured that nothing would happen if he/she stays within the grid and that the experimenter will also keep an eye out on the safety of the participant. The participant was also explained on how to use the controller to navigate to areas in the virtual scene beyond the grid. Before the HMD was put on, the interpupillary distance was measured and applied to the Vive to create a clear view. When putting on the HMD, the experimenter makes sure the HMD rests comfortably on the head of the participant en not on the face.

Before the participant got to roam freely through the museum, they followed a small tutorial to learn and to test out the navigation controls by using the controller. This is done to lower the navigation struggles during the visit itself. They were instructed to go to a wall and stand within the semicircle under the wall and when they were there a welcome message appeared on the wall. The participant was told that more of these semicircles can be found in the museum, and that when he/she enters or stays within them something will happen, without directly telling them that the illusions will activate. When the participants understands the controls, headphones were given to the participant and he/she was free to explore the museum.

After the visit, the participant had to fill out two more questionnaires, the General Enjoyment Questionnaire and the PANAS Questionnaire. Both of these questionnaires were used in a previous study [10]. During the PANAS Questionnaire, the participant received images of the paintings and a map of the museum, specifying which painting was in which room and where that room was located. Finally, the test was concluded with an interview.

Measuring the Museum Visitor Type

To know the visitor type of the visitor, Falk et al. created a questionnaire [21]. This questionnaire contained twenty statements to determine the visitor types. Even though this study did not take account for the Facilitator type, the questions were left in to keep the questionnaire intact.

This original questionnaire was answered by visitors visiting a real museum. The visitor had to pick five of the twenty statements that reflected their reason for visit the best. In this user study, the participants will have no intention to visit the museum at that time. This makes it harder to question them about the reason why they go to the VR museum. Instead, the reason must be asked why they would go to a museum in general. Non-Visitors answered the questionnaire by the question: '*If* they were to go to a museums, what would be the reason'. For the five chosen statements, the visitor also had to rate the importance on a Likert scale.

The drawback of this questionnaire was that people had problems fulfilling the tasks at the same time. They had to read through all the statements, picking the five that reflected their reason for their visit and then rank them. Falk simplified the questionnaire by showing the visitor five cards [23]. Each of these cards contained a world bubble, reflecting one of the visitor types. Of these five, he asked the visitor to hand him the one that represent the reason why the visitor visited the museum that day. With this, the visitor does not have to read through all the statements at once. The simplification of the questionnaire was also done in this study. The twenty statements were split into four clusters, each containing five statements, one for each visitor type. After this was filled out, the participant had to choose one of the four he/she has picked that reflects the best reason he/she goes to a museum. This way, the most dominant museum visitor type of the participant was determined.

1.5 Results Analysis and Discussion

1.5.1 Participants

There were sixteen participants taking part in the experiment, aged between 23 and 32 with an average of 26,3. Ten of them were male and six of them were female. As the Vive makes it possible to let one wears his/her glasses while using the HMD, no participant suffered from near-sightedness and/or far-sightedness during the VR museum visit.

Thirteen participants expressed that they have interest in museums, and five of those mentioned specifically that they like to visit art museums. However, four of the thirteen mentioned that they do not go often. Of the nine participants who had interest in museums and had been to a museum

the past year, the number of times they went to a museum the past year lies between 1 and 10, with an average of 3,7.

For each participant, the interest in paintings lay lower than or equal to the interest in museums. Of all the participants, five participants showed interest in paintings (rated 4 or higher on a scale from 1 to 5). When asking the participants if they are willing to visit a VR art museum, 9 out of the sixteen participants rated a 4 or higher on a scale from 1 to 5, of which 5 of them mentioned that they had interest in art museums. This suggests that the idea of VR could have already made those with no interest in art more interested in the visit.

Six participants had very little or no experience (rated 2 or lower on a scale from 1 to 5) with VR. For those with experience, the Google Cardboard and the Oculus were the most common systems. However, five participants have experience with the Vive. Three participants had previous experience with VR museums due to participation in previous studies.

1.5.2 Museum Visitor Types

Based on the Museum Visitor Type Questionnaire and with the most relevant statement as the dominant visitor type, eight participants were considered to be an Explorer. There was one Recharger, one Experience Seeker, one Facilitator, two Professionals/Hobbyists and three Non-Visitors. All three Non-Visitor mentioned the statement "My wife/partner/husband/friends/family make me go" as the most relative reason why they would go to a museum.

The latent types, the non-dominant types of which the participant also choose from, were unfortunately not rated during the test. There was no telling which latent type was the strongest after the dominant type when the person had three or more visitor types. Because of this, the latent visitor types are not reliable to work with.

1.5.3 Enjoyment of the VR Museum Visit

According to the General Enjoyment Questionnaire, the participants were positive about the experience. In the Enjoyment Questionnaire, a higher rating on the positive statements and a lower rating on the negative statements indicates a more enjoyable experience (Fig. 1.7). On the positive statement "I enjoyed the experience", no one rated it lower than a 3. Ten participants even rated it a 5, while five participants rated a 4. Only one participant rated it a 3. The statement "I liked the experience" was almost rated the same. Again, ten participant rated it a 5. Four participants rated it a 4 while the two remaining participants rated it a 3. One of the participants who rated it a 3 was the same person who also rated a 3 in the previous statement. As for the statement "The experience was relaxing, four participants rated it a 5, ten participants rated it a 4 and two participants rated it a 3. Again, no one commented with definite negativity (2 or lower on a scale from 1 to 5) on this positive statement.

When looking at the negative statement "I don't want to experience this ever again", only one person rated it a neutral 3, giving the reason that it doesn't have a replay value. All the others rated a 1. The most interesting results are found at the statement "I was bored during the experiment". Five participants rated this a 3 or higher, but when looking at their interest in museums, all of them had no interest in art museums.

The results of this questionnaire indicate that the participants were positive about the VR museum. However, to those who have no interest in art, this experience was boring to them. As paintings were the topic of this museum and the fact that they have no interest in art, it can be generally assumed that they like the VR museum but not what was being exhibited.

1.5.4 PANAS Questionnaire

The PANAS questionnaire consisted of eight different emotions. The participants had to rate each emotion for each room with paintings between 1 (very slightly or not at all) and 5 (extremely). Four of these emotions were positive emotions, while the other four were negative emotions. The scores of each emotion were accumulated. With sixteen participants, this will give a score between 16 and 80 (Fig. 1.8). While most of the negative emotions for each room lie close to each other, the negative emotion 'Bored' was rated a lot higher in the No Illusions Room. This indicates that boredom was the most prominent negative emotion the participants felt in the No Illusions room. As for each positive emotion, there is the trend where each emotion in the 2D Illusions Room rated higher than the No Illusion room, while the 3D Illusions room was rated highest of all three rooms.

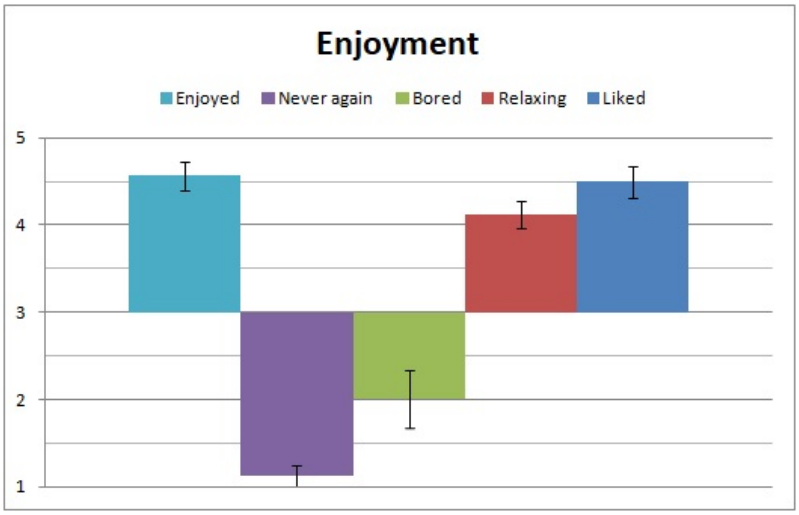


Figure 1.7: The average scores and the standard errors of the Enjoyment Questionnaire.

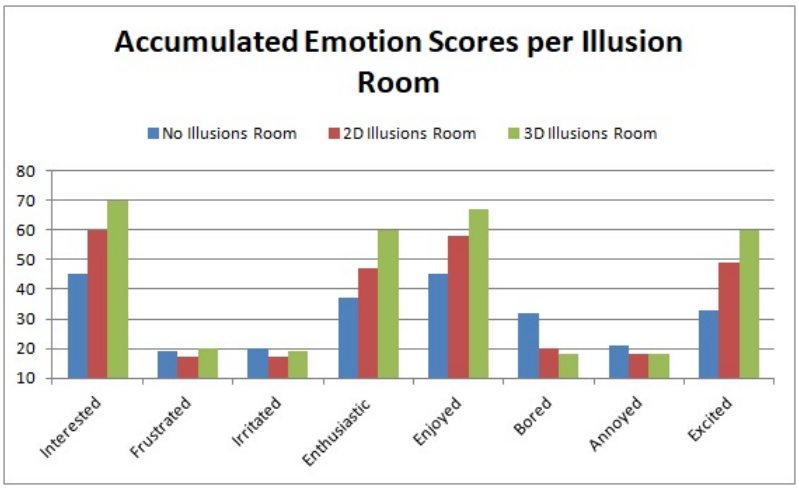


Figure 1.8: The accumulated scores for each emotion per illusion room.

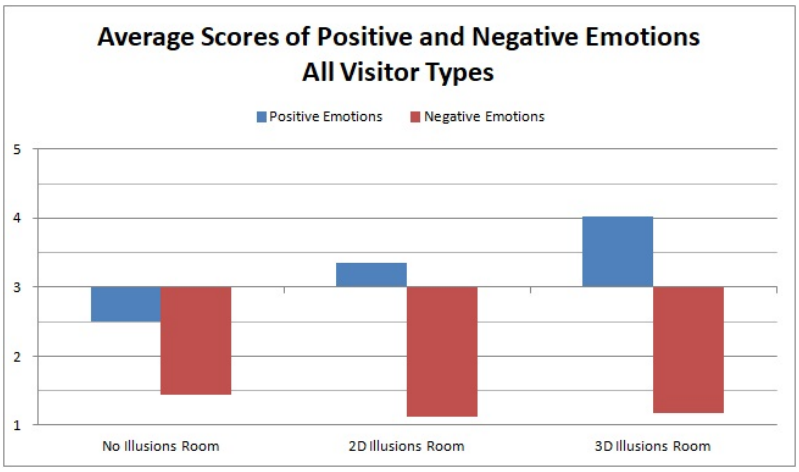


Figure 1.9: The average scores of positive and negative emotions per illusion room. A lower negative scores indicates a more negative effect, while a high positive score indicates a more positive effect.

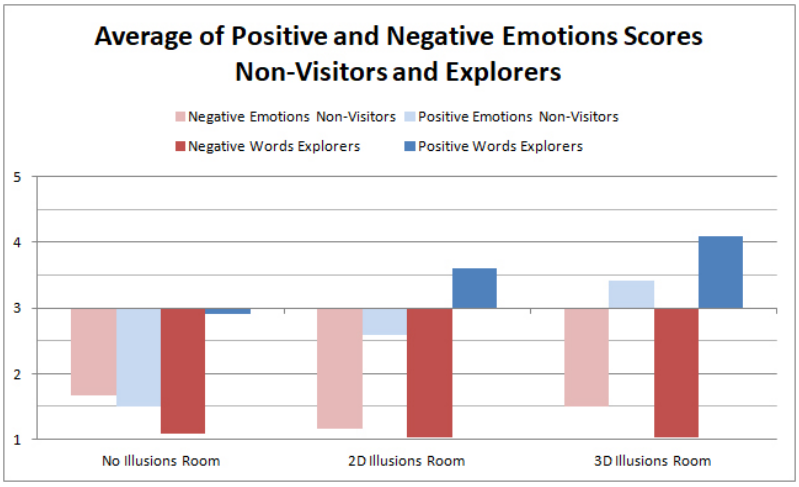


Figure 1.10: The average scores of positive and negative emotions per illusion room by Non-Visitors and Explorers. A lower negative scores indicates a more negative effect, while a high positive score indicates a more positive effect.

When the ratings of the positive emotions and the negative emotions are separately accumulated, the scores will lie between 64 and 320. The average of the scores per Illusions room can be seen in Fig. 1.9. Generally spoken for all visitor types, the PANAS questionnaire indicates that the 3D Illusions affected the participants most positively with a score of 4,0. The positive emotions in the 2D Illusions Room was rated slightly higher than the neutral score of 3 with an average of 3,3. The No Illusions Room, however, was rated below the neutral 3 with a 2,5. There was no significant difference between the negative emotions for the 2D (average of 1,1) and the 3D Illusions Rooms (average of 1,2). However, the rating of the negative emotions for the No Illusions Room (1,4) was significantly higher than the ratings of the 2D and the 3D Illusion Rooms, indicating a preference over the rooms with illusions than the rooms without illusions.

A remarkable point is that when looking at the participants with a Non-Visitor type, the positive emotions even scored lower than the negative emotions in the No Illusions room (Fig. 1.10). As for the other rooms, they also rated the positive emotions lower and the negative emotions higher than the average of all types. Only the 3D Illusions Room rated higher than the neutral 3. This indicates that Non-visitors do prefer illusions over no illusions, but that the only the 3D illusions have a positive effect on them.

The Explorers, however, were more positive about the illusions than the Non-Visitors. They rated higher than the average on the positive emotions and lower on the negative emotions. They were both positive about the 2D and 3D Illusions Rooms, while being slightly negative about the No Illusions Room. The negative emotions did not show much difference between each room.

1.5.5 Interview

Each participant was interviewed after the experience. The interview was used to gain a more in-depth view on the thoughts from the participants about the VR museum. The questions focused on their personal thoughts and their general view on VR museums.

Explorers All eight Explorers would recommend others to visit the VR museum. The Explorers would mainly recommend the VR museum to people who are interested in museums or to those who have never had a VR experience before. The main reason for the recommendation was not always because of the illusions, but they did play a part in their willingness to recommend the museum to others. Four Explorers gave another aspect they deemed important when recommending the VR museum to others:

- Two participants liked the idea of the VR museum, but saw the illusions more as a nice addition. The main reason they would visit a VR museum is for the paintings themselves.
- One participants would already recommend others to visit a VR museum simply for the fact that it is a VR experience.

- One participant specifically mentioned that the topic of the museum, or what is being exhibited in the museum, was an important factor to recommend it to others or not. She liked the experience and considers it as a topic she can tell her friends about.

The participants did like the illusions but that did not necessarily mean that they preferred the setup with the illusions over the traditional setup.

- One participant preferred the traditional setup over illusions.
- Four participants preferred the illusion over the traditional setup.
- Two participants could see the value of both setups with each their own strength and weaknesses while.
- Another participant mentioned the importance of what is being exhibited, since he thought that the illusions do not go well with pieces where one would look at for its craftsmanship (like paintings).

When asking if the experience in a VR museum is better than the experience of a physical museum, most of them thought that the experiences were different and not that one is better than the other.

- One participant preferred the real museum experience over the VR museum.
- Two participants mentioned that a VR museum would provide them a better experience than a real museum would.
- The other five participants see the two experiences as something different form each other, each having their own advantages and disadvantages. The experiences can't be compared to each other in that way, making it not possible for one to be better than the other.

Non-Visitors The three Non-Visitors were primarily more interested in the fact that it was a VR experience. While the illusions have created more interest during the visit, it didn't create interest in museums themselves. Their view on museum haven't changed after this experience and their interest in paintings haven't increased. However, if these illusions were also being applied in real museums, they could see it as a new museum experience and that it could be used to attract new visitors to the museum. Also, they might visit another VR museum again if the topic would be something else. The illusions, however, do play a role in their willingness to recommend the museum to others.

- Two participants would recommend it to people who have interest in museums. Another interesting point is that both of them also mentioned that the VR application might be useful to the elderly. In this case, they don't have to travel the distance anymore. Also, the VR museum is also considered as a better application to let one get acquainted to VR at such an age than for example, the archery game of The Lab on Steam.
- The other participant thinks the VR museum could be used by people around the age of 20-30 and don't have interest in museums. An experience like this with the illusions could be more interesting to them than a normal museum visit.

All of them preferred the setup with illusions over the setup without illusions. Without illusions they would be just like in the real museums, even calling it "boring". One participant specifically mentions that he saw the illusions as a distraction of the boring part. With the illusions, he would even look a little bit longer at the paintings. He sought more behind the paintings, thinking about the reason why the illusion was used in a certain way.

In the end, the illusions did give the Non-Visitors a more positive museum experience than a physical museum would. Aside from the novelty, the kind of experience they got is something they could not get in a real museum. One participant described it as that "the illusions could give the feeling that the paintings go beyond their painting frames and tickle more of your senses".

Professionals/Hobbyists There were two participants in the Professional/Hobbyist category and both of them would recommend others to visit it but with different reasons. One participant would recommend it to people with interest in museums to have experienced a VR museum once. The other participant didn't have much affinity for the illusions and saw it more as a tool to attract new visitors.

Both saw the potential of the illusions, but their personal preferences were mixed. One preferred the illusions over the traditional setup, because he was already too familiar with the traditional setup in physical museums. The illusions sparked his imagination, making it possible for him to more easily think and fantasize about the art pieces when looking at them. The other participant mentioned that the goals of the illusions were very important and thinks that 3D illusions could be very helpful to teach someone about the history of the exhibition piece. However, as she doesn't agree with the way how VR is currently (unnecessarily and without a goal) being applied in the cultural sector, she prefers the traditional setup over the setup with illusion. When mentioning the idea of applying AR to create the illusions in a real museum, she replied with: "that would be so much cooler".

Both participants agree that the VR museum experience is different from the physical museum experience. One cannot replace the other. The participant preferring the traditional setup also said that the illusions don't add anything to her experience, but gave a different one. She still prefers the experience from a traditional setup because she will get the feeling that she has learned more after going to a physical museum than to a VR museum.

Recharger The recharger would recommend the VR museum to others who are interested in museums or those who have never had a VR experience before.

According to the participant, the illusions added something to the paintings. It made them more alive and gave it interactivity. Without them he wouldn't have the tendency to visit a VR museum again and rather goes to the physical museum. He did see the potential issue with the illusions that if an old painting would be combined with an illusion, the painting would not be represented as how the painter would have liked. But if experts were included with the creation of the illusion, they could still keep the painter's wish in mind.

Just like the Professionals and a few Explorers, the participant thinks the VR museum offers a different experience than the physical museum. One very important aspect for the participant is to have the feeling of being in a museum. The VR museum does offer that in some sense, but differently because of technical issues of VR, such as the feeling of wearing a headset or being limited to move by cables. But at the same time, the illusions could add to the experience by showing things that are otherwise not possible in the physical museum. Each museum has its own appeal.

Experience Seeker The Experience Seeker sees this as a nice experience for those who don't have experience with VR before. For those with a love for art, she understood that they could prefer it without illusions. She would recommend the VR museum because of the illusions and not so much because of the idea of visiting a VR museum. Mostly, she would recommend her friends to try the experience, regardless of their opinion on art and considered it as a topic that she could talk about with friends. Her main reason to visit a VR museum was for the VR experience itself.

The Experience Seeker is willing to visit a VR museum again, especially because of the 3D effects. Those illusions were something she didn't expect to see and created a feeling of being in the painting instead of in the museum. They enhanced the art for her.

Again, the visitor mentions like the others that the VR museum experience is different from the physical museum experience. Both have their advantages. In the real museum you could appreciate the craftsmanship of the art. In VR she would mainly go because of the 3D illusions.

Facilitator While the illusions weren't made with the facilitators in mind, the Facilitator liked the illusions but also the idea of a VR museum with illusions. He would recommend his friends as he sees it as something new and innovative.

The illusions are according to him a necessity in the VR museum. Without them, the innovative properties will no longer be there. In that case he prefers visit the real museum instead. He preferred the setup with illusions over the traditional setup as the illusions created dynamic, depth and added new elements to the paintings.

The VR museum however, is not necessarily better than a real museum. While the illusions did have a positive effect on his experience, it would be the best to be able see the real artwork as well. In this case, the best solution would be AR in a physical museum.

The participants were generally surprised by the illusions, especially the 3D illusions. The illusions were considered as the added value of VR and without them many would not see the use of the application. A comment often made with the 3D scene illusions was that it gave them a feeling of being in the world of the painting. No participant complained about the ambient sounds, and some even praised them supporting the immersion. These comments show the immersive capabilities of this type of illusion.

During the tests, a majority of the people were not sure what the actual effects of the 2D Stylized illusions were. Most people considered them as backgrounds behind the paintings. This suggests that the illusions were too subtle. The subtleness isn't necessarily a negative aspect and in the end the different background was still preferred over none at all.

Half of the participants could see the application as a teaser for the real museum, and be useful to attract new visitors to them. The real museum can show the craftsmanship and the details of an exhibition piece, which VR cannot. This was also seen as the most common drawback of the VR museum. A commonly mentioned advantage, however, was the accessibility to visit a museum from home. When developing the VR museum, four participants mentioned that experts should be involved.

1.6 Discussion

In this section, the results will be discussed and reflected upon the research questions.

- SQ1: Can the illusions make the VR museum a 'must see' experience?

The participants were willing to recommend the VR museum to others and the illusions did play a role in that. The illusions, especially the 3D illusions, were seen as something new. However, other important aspects when recommending it to others were the fact that is was a VR experience itself and the topic of the museum. The participants would recommend the VR museum to mainly those who are interested in museums or those who have never experienced VR before. The interesting visitor type to look closer upon in this case, is the Experience Seeker. This is the type with the need to experience something new. Unfortunately, there was only one participant categorized as an Experience Seeker in this experiment. However, looking at the comments of this participant, they were as expected. The participant would already visit the VR museum just to have experienced VR, which was also the same reason he/she would recommend it to someone else. This could suggest what was expected: the Experience Seekers are more focused on the VR aspect than the VR museum and illusions themselves.

Another visitor type to look closer upon are the Professionals/Hobbyists because of their need to see the exhibition pieces themselves and not the illusions around them. The two participants categorized as Professionals had a mixed opinion about the illusions. One did not care much about the illusions, which was expected. The other participant however, welcomed the illusions because it was a new terrain for him. Looking at the visitor type Falk defined, this could be explained as the need to learn about something. Here it means he wants to learn something new about the way museums represent themselves, and thus the cultural heritage sector itself. Two other participants, while they were not categorized as Professional/Hobbyist but as Explorers, mentioned that their main reason to go to a VR museum is for the art itself. This reason sounds very much like what a Professional/Hobbyist would say. Their view on the illusions was also like what was expected from the Professionals/Hobbyists: the illusions are a nice addition but are not necessary. They will not be the main reason why they would visit a VR museum. Based on these four participants, their opinions indicate that those who go to the museums specifically for an exhibition piece do not need the extra content from the illusions. However, when one has seen it all, the illusions could create a new category of museums to explore and learn about.

- SQ2: Is there a preference or appreciation of illusion compared to the traditional museum setup?

The expectation was that Professionals/Hobbyists would prefer the traditional setup over the setup with illusions because of their need or goal to see the exhibition pieces themselves. As mentioned in the previous subquestion, one of the two Professionals/Hobbyists preferred the traditional setup because the aura an exhibition piece emanates cannot be experienced in VR. This is what was expected from someone who goes there to see the exhibition piece itself. The other Professional/Hobbyist, however, approved of the illusions because it was a new experience for him. When including the Proffesional/Hobbyist type of statements two Explorers made, it suggests that there is indeed a preference of the traditional setup. However, because of the low numbers of participants in this category, further research is needed to draw a conclusion from this.

For the other categories, the participants were generally positive about the setup with illusions. This, however, does not necessarily mean that they prefer it over the traditional setup. The opinions of the Explorers were mixed. A possible reason for this is that they do not have a certain need like the Professionals/Hobbyists have, and go to a museum to look at the things that attract their attention or that they like. In other words, they base their opinion on their personal preference as an Explorer. To get a better understanding of these visitors, it is necessary to know more about their personal preferences. For this case, Falk's Explorer visitor type could be too generic.

An interesting discovery about the Non-Visitors is that they all preferred the setup with the illusions. The traditional setup is what they called 'boring'. While there were only three participants in this category, the results show a trend that Non-Visitors prefer the setup with illusions over the traditional setup.

- SQ3: Is there a preference of one certain type of illusions over others?

While two participants didn't have a preference, the other ten participants preferred the 3D illusions. This illusion was also rated as the illusions with the highest positive effect. The 3D illusions created a sense of presence for them, and added something in how they experienced the art. Of the ten with a certain preference, there was no one suggesting that he/she preferred 2D illusions or no illusions over the 3D illusions.

For the Non-Visitors, the 3D illusions room was the only room that scored positively. This is likely because of the properties of the 3D illusions making them most different from what is possible in a physical museum.

As expected, the preference of the Recharger was indeed the 3D illusion. According to the participant, they added a new dimension to the paintings. While there was only one Recharger in this study, the result do seem to suggest that this type of visitor has a preference for the 3D illusions. A larger test sample with visitors from this type is needed to draw further conslusions.

Generally speaking, the 2D and 3D illusions were preferred over no illusions at all. The illusions were considered as the added value in VR. Without the illusions, the participants preferred to see the real piece in a physical museum instead.

- SQ4: Do the illusions prove a better museum experience than the traditional museum setup?

For the Non-Visitors, the VR museum experience was better than a traditional museum experience. For the others, the majority was positive about the VR museum experience. This however does not means that it is better than a traditional museum. They agreed that the VR museum gives them a *different* experience and that the VR museum and the traditional museum each have their own strength and weaknesses. One major advantage of the real museum is to be able to see the details of the exhibition pieces. Those who go to museums to see the details, such as the craftsmanship or the brush strokes in paintings, mentioned that they are not able to do that in VR. On the other hand, the illusions and especially the 3D illusions, could give them a new way to experience the art. A way that is currently not possible in a real museum.

The participants saw different usages of VR. The first one is the virtual version of the real museum itself. While it makes the museum more accessible, it might at the same time cause a problem that people won't go to the real museum anymore. Instead, using the VR museum as some kind of teaser is a better option. In this case, it is a tool to attract new visitors. The illusion could be included to give the people a different kind of experience as they would in the real museum. However, the option to see it without the illusions should be included to those who would like to see the museum as it is. If the application is used as a way of advertisement, the illusions should have a goal to make the paintings more interesting, and not create the situation where the real museum is a disappointment.

If the VR museum is not based on real museum, it is more important to think about what the museum is trying to achieve. For example, if the visitor goes to the museum to learn about something, the extra background information can be shown through illusions. However, for someone who only wants to see the exhibition pieces, they should have the option to turn off the illusions. The way VR museums can be used is to create multiple experiences in one building, where the visitor can choose what he/she wants to see. The illusions should be used in a way to achieve the needs of the visitor. When a museum curator or any other expert is affiliated with the development of the museum, they could create multiple experiences suiting the exhibition piece. And because it is VR, the number of experiences is not limited, giving the visitor the option to choose what he/she wants to see.

- Q: Is there a relation between the illusions and the visitor type on the user experience?

The opinions of the Explorers about the VR museum were mixed. The majority was still positive about the idea of the VR museum with illusions, but they also mentioned that the two experiences have their own charms. Because the Explorers are more open minded to what they are going to see and look for things that attract their attention, they are basing their needs on their own preferences. Because of this, it is very hard to generalize the Explorers as one group in their needs when being it is being related to the preferences of the illusions and the VR museum itself.

The Non-Visitors showed that they preferred the VR museum over a traditional museums, because the illusions gave them something interesting to see than the 'boring' paintings. They also mentioned other advantages such as the accessibility and that there are no other people standing in your way. While they prefer this setup over the traditional setup, the experience didn't create more interest in museums for them. This suggests that illusions in a real museum would be more interesting to them.

The Professionals/Hobbyists had a mixed personal preference of the illusions. One aspect they agreed to was that the illusions do have potential. When including the participants who mentioned some aspects that are related to the Professional/Hobbyist visitor type, they do think the illusions are not necessary to them. Also, when one goes to the museum with a need to see the details of the craftsmanship of the work, illusions and VR itself are not desired at all. They did mention that they would appreciate it more if the museums and a professional team were behind the development of the VR museum. Nevertheless, to them the VR museum would not be a replacement of the real museum. To get a better view on how the Professionals/Hobbyists think, a larger sample size of this visitor type is needed.

According to Falk, the Recharger cares about the environment he/she is in and sees the museum as a place to escape from the daily environment. The Recharger in this study mentioned the importance of having the feeling of the museum as well. While the VR did gave him a feeling of being in th museum, the feeling was different from the real museum. This didn't mean that the preferred the one over the other, but he saw that both museums have their own charm. For the VR museum this included the illusions. The 3D illusions gave him a feeling of being in a painting and created an extra dimension to the painting. This suggest that the Recharger indeed appreciates the 3D illusions because of their immersive features. To conclude this, a larger sample size is needed of this visitor type.

The Experience Seeker mentioned the importance of VR itself in her willingness to recommend it to others. The illusions were also an important aspect to her. The fact that this VR museum is a VR experience plays a role for more people to recommend it to others. This means that the illusions themselves are not the only reason to visit a VR museum and that experiencing something in VR is also important.

1.7 Conclusion and Future Work

Despite the small sample size, the results show a trend that Non-Visitors prefer the VR museum over the traditional museum and that people preferred the 3D illusions over the other setups. The results from the Professionals/Hobbyists suggest that there is no necessity of illusions for these type of visitors. On the other hand, the 3D illusions were interesting to the Recharger type of visitor. The Experience Seeker, however, was more interested in the VR Experience itself than the VR museum with illusions. To get a better understanding of the Explorers, it is necessary to get more information about the personal preferences of the visitors themselves. Because Explorers

don't have a specific need or a goal when going to a museum aside from just exploring, the illusions can't complement to their need. The most prominent usage at the moment is to create curiosity of what the illusions are going to show while they are getting judged by the visitor's personal preferences instead of their needs.

In future work, it would be interesting to continue the study with a focus on the Professionals/Hobbyist, Rechargers and Experience Seekers type of visitors. The Explorers, however, are hard to measure because satisfying or seeing something of personal preference is hard to determine beforehand. The research would get too personal about the participants if it focuses on these preferences. Instead, it is a better idea to look at the possibilities and the potential of the illusions themselves. The ideal part about this, is that when developing this that there is no need to pay extra attention to the Explorers because they pick the interesting things for themselves. There is no general rule that says what they like and what they don't like. So while focusing to meet the needs of the other visitor types, the Explorers follow along as long as we can give them something that can pique their interest.

A more interesting goal to work towards, is to look at how the VR museum can be used with the illusions to meet certain goals related to the needs and make the experience more personal. At the moment the 3D illusions are being to used to create presence in the world of the painting, but they can also for example be used to show people more about the background of the paintings and have an educative value. The advantage of VR is that both of these goals can be executed at the same time. By giving the visitor the option to choose, they will have more control in choosing what they see and a more personal museum experience can be created. By creating a VR museum with options for personalization, a larger target audience can be achieved. When designing and developing these experiences, including experts is a wise decision. A curator, for example, knows how to present the art pieces while an expert in education can think about how and what the illusions have to show to teach someone about the art pieces. Artists are needed to visualize the application and software engineers put everything together. The create the ideal VR museum, different disciplines must work together.

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Chapter 2

Appendix

Consent form

Experiment: Virtual Reality Museum 4

Experimenter: Xhi Jia Tan

Affiliation: Utrecht University

You are invited to participate in a research study that tests a Virtual Museum setup. In the experiment, you will be wearing a head-mounted display. You will explore a Virtual Museum. We use the capabilities of VR to add modifications to the museum.

Risks: The head-mounted display may cause temporary nausea and temporary dizziness in some users. The procedure will be stopped immediately when you indicate you are experiencing these or any other type of discomfort.

Participant's Rights: If you have read this form and have decided to participate in this experiment, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without penalty. You have the right to refuse to answer particular questions. Your individual privacy will be maintained in all published and written data resulting from the study.

If you agree with the above-stated conditions and are willing to participate in the experiment, please sign below. By signing the form, you confirm that you meet the following conditions:

- You have read the above consent form, understood it and you agree to it.
- You want to participate in the above-mentioned experiment.

Name:_____

Date:_____Signature:_____

Questionnaire 1

1. **Name:**

2. **Age:**

3. **Gender: M/F/Other**

4. **Occupation (if you are a student, please state your field of study):**

5. **Do you have a visual disability? (bad eyesight, color blind etc)**
   O Yes O No

   5.1. If yes, is this disability currently being corrected? (contacts/glasses)

6. **Please rate your interest in museums**
   Not interested O O O O O Very Interested

7. **Please rate your interest in paintings**
   Not interested O O O O O Very Interested

8. **What are your thoughts about museums?**

9. **Do you go to museums?**

   9.1. If yes, how many times have you visited a museum in the past year?

   9.2. Do you have certain museum or types of museum you like to visit? (e.g. history museums, art museums, science museums)

10. **Do you visit museums for paintings?**
    O Yes O No

    10.1. If yes, how many times have you done that in the past year?

Questionnaire 2

1. **Please choose the statement that reflects the best why you would visit a museum:**
   - 0 These are the kind of places people like me go to
   - 0 It is related to the kind of work I do and I find it useful
   - 0 I find going helps me get away from normal rush of life
   - 0 I like to support the learning of my children/significant other
   - 0 I wanted to be able to say that I'd been there

2. **Please choose the statement that reflects the best why you would visit a museum:**
   - 0 It is my hobby and I go all the time
   - 0 The museum is more inspiring than going to the mall or a movie
   - 0 My wife/partner/husband/friends/family make me go
   - 0 I want to have fun
   - 0 I go because it satisfies my curiosity

3. **Please choose the statement that reflects the best why you would visit a museum:**
   - 0 I don't get to be in a space like that every day
   - 0 This is a good way for my family/friends to share quality time
   - 0 I am told that it is one of the best places to visit around there
   - 0 I discover things about myself when I go there
   - 0 I hope to find out more about something in particular

4. **Please choose the statement that reflects the best why you would visit a museum:**
   - 0 My family/friends learn things here they can't in other places
   - 0 The museum is a landmark in its community
   - 0 I'm not an expert but I like to learn about things
   - 0 I'm knowledgeable but like to keep up with what's new
   - 0 I feel at peace in such surroundings

Questionnaire 3

1. **Do you have experience with virtual reality (VR)?**
   Not at all O O O O O Extremely

   1.1 If you have any experience with VR, with which systems?

2. **Do you have experience with VR museums?**
   O Yes O No

   2.1. If yes, what kind of experience?(e.g. participated in previous VR museum related studies)

3. **What do you expect to see in a VR art museum?**

4. **Would you like to visit a VR art museum?**
   Not at all O O O O O Extremely

Questionnaire 4

1. **I liked the experience**
   Disagree O O O O O Agree

2. **The experience was relaxing**
   Disagree O O O O O Agree

3. **I was bored during the experience**
   Disagree O O O O O Agree

4. **I don’t want to experience this ever again**
   Disagree O O O O O Agree

5. **I enjoyed the experience**
   Disagree O O O O O Agree

Questionnaire 5

This scale consists of a number of words that describe different feelings and emotions.
Read each item and then list the number from the scale below next to each word.
Please indicate to what extent you have felt during the test for each room.

Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
1	2	3	4	5

No Illusions Room

1. Interested _____
2. Frustrated _____
3. Irritated _____
4. Enthusiastic _____
5. Enjoyed _____
6. Bored _____
7. Annoyed _____
8. Excited _____

2D Illusions Room

1. Interested _____
2. Frustrated _____
3. Irritated _____
4. Enthusiastic _____
5. Enjoyed _____
6. Bored _____
7. Annoyed _____
8. Excited _____

3D Illusions Room

1. Interested _____
2. Frustrated _____
3. Irritated _____
4. Enthusiastic _____
5. Enjoyed _____
6. Bored _____
7. Annoyed _____
8. Excited _____

Interview

The interview focuses on two aspects of the VR museum:
- The personal experience and illusions preferences (8.1 - 8.4)
- A general view on VR museums and how they can be applied in real settings by posing a user scenario (8.5 -8.8)

1. **Was the museum what you expected?** ***Refer to 4.3.***
   Disappointed? Surprised?

2. **Did you like the illusions?**
   Which ones do you like? Why?
   Which ones do you dislike? Why?

3. **What are your general thoughts about the VR museum?**
   Do you like it more than physical museums?

4. **Would you like to visit such a VR museum again?**
   [] yes
   [] no
   Why? Because of the illusions?

5. **Would you recommend others to visit a VR museum too?**
   Who would you recommend and why?

Assume a local art gallery wants to make an exhibition showcasing the paintings you have just seen. For advertisement, they also want to create a VR museum-style app of this exhibition.

Now assume you are a developer who is approached to create such an app.

6. ***6.*** **Do you think such an app could be useful for the gallery?**
   Why and in which way? To whom?

7. **Do you think it would be better to add the illusions in the app?**
   Why or why not?

8. **Do you think it would be useful to add such illusions to the real paintings in the physical exhibition as well (e.g., via projections on the walls or handing out AR glasses)?**
   Why or why not?

Now assume you are a potential visitor for such an exhibition or user of the app.

9. **Would you prefer to go to the real exhibition, use the app (with or without illusions), both, or none?**
   Why?

10. **Do you have any other comments or ideas about this VR museum or VR museums in general? For example, are there other things you would like to see in a VR museum?**

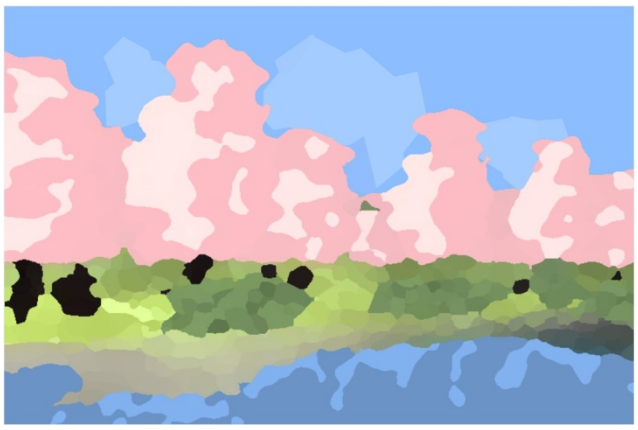
Memory Aid

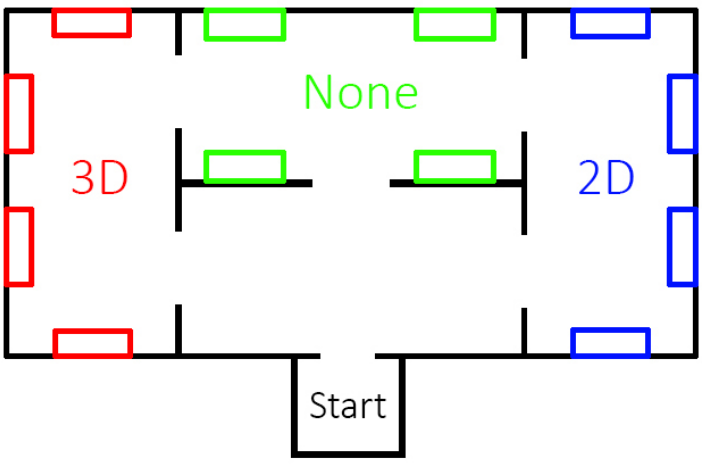
No Illusions

2D Illusions

Memory Aid (Setup 1 Only)

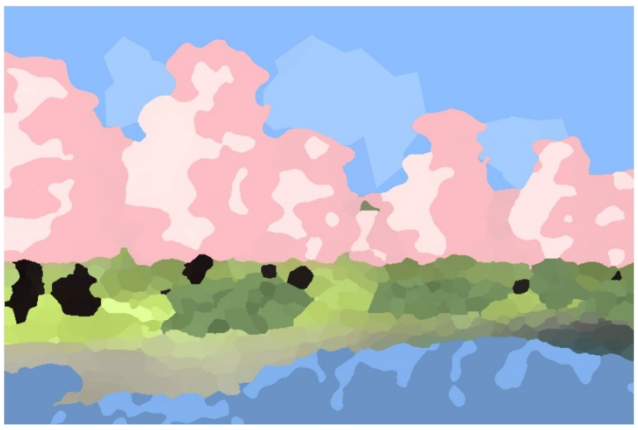
3D Illusions

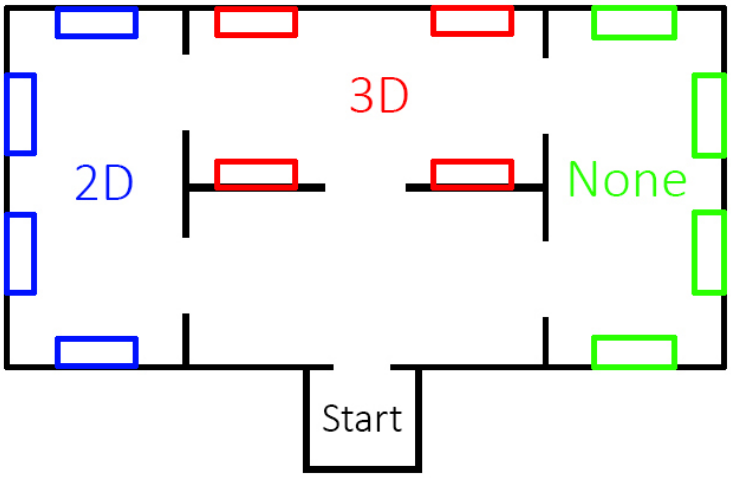




Memory Aid (Setup 2 Only)

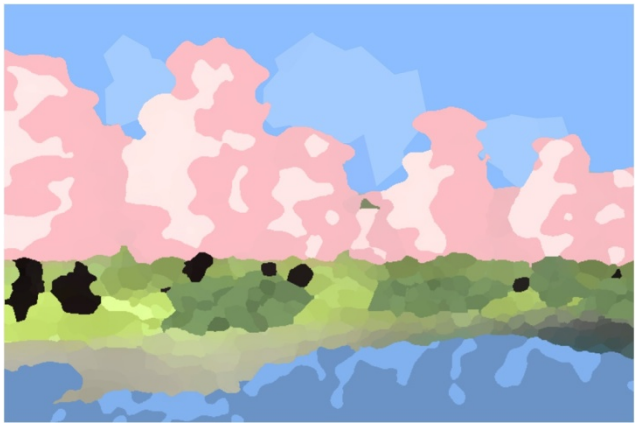
3D Illusions

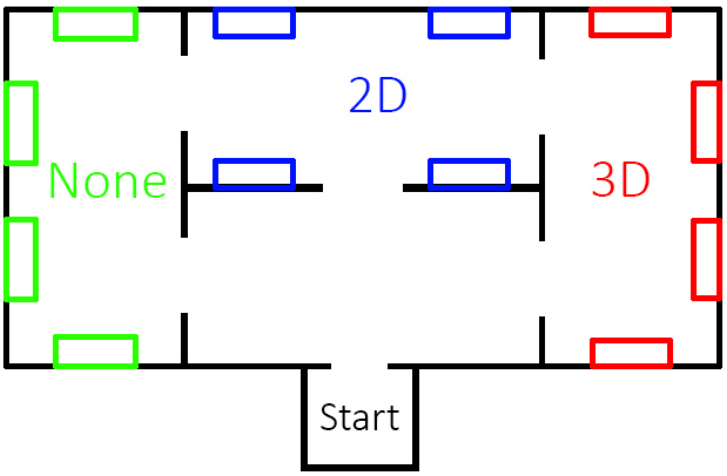




Memory Aid (Setup 3 Only)

3D Illusions





Painting Sources and Information

None

Georg Eduard Otta Staal
Forest Landscape in the Moonlight, 1861

Oil on canvas

http://hdl.handle.net/10934/RM0001.COLLECT.7521
71 × 110 cm

George Iness
Autumn Oaks, ca. 1878

Oil on canvas

http://www.metmuseum.org/art/collection/search/11227
54.3 x 76.5cm

Claude Monet
The Magpie, 1869

Oil on canvas

89 x 130 cm
http://www.wga.hu/html_m/m/monet/02/index.html

Bonaventura Peeters
Storm on the Sea, 1632

Oil on oak

58.5 x 84.5 cm
http://www.wga.hu/frames-e.html?/html/p/peetersb/bonavent/storm1.html

2D

Vincent van Gogh
The Starry Night, 1889

Oil on canvas

https://commons.wikimedia.org/wiki/File:VanGogh-starry_night.jpg#/media/File:Van_Gogh_-_Starry_Night_-_Google_Art_Project.jpg
92.1 x 73.7 cm

Johan Hendrik Weissenbruch
Wooded View near Barbizon, 1900

Oil on canvas

http://hdl.handle.net/10934/RM0001.COLLECT.6521
45.5 x 64 cm

Kawase Hasui
Autumn at Oirase, 1933

Color woodcut

http://hdl.handle.net/10934/RM0001.COLLECT.349568
38.7 x 26.1 cm

Jan Toorop
The Sea near Katwijk, 1887

Oil on canvas

http://hdl.handle.net/10934/RM0001.COLLECT.5599
86 x 96 cm

3D

Paul Joseph Constantin Gabriël
A Windmill on a Polder Waterway, Known as ‘In the Month of July’, ca 1889

Oil on canvas

http://hdl.handle.net/10934/RM0001.COLLECT.8456
102 x 66 cm

Anton Mauve
A Herdess with Cows on a Country Road in the Rain, 1848 – 1888

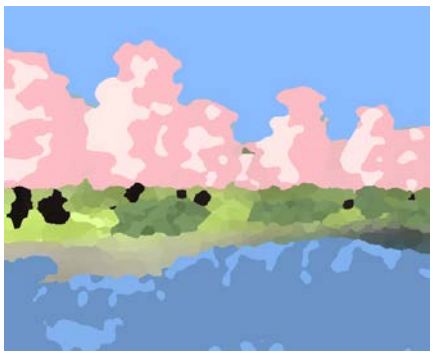
Brush

http://hdl.handle.net/10934/RM0001.COLLECT.9802
25.5 x 55.5 cm

Toyohara Chikanobu
General Sassa Narimasa in a Snowstorm, 1897

Color woodcut

http://hdl.handle.net/10934/RM0001.COLLECT.47319
35.8 x 71.5 cm



Xhi Jia Tan and Ferdinand de Coninck
Sakura Garden, 2016

Digital

Part II

Annotated Appendix

Chapter 3

Literature Study: VR Experiences and Museums

VR Experiences and Museums

X.J. Tan

September 11, 2016

Abstract

VR is being used by museums in different ways to create new museum experiences. According to Falk, museum experiences become memorable when the visitor's needs are satisfied. Personalizing the experience is a way to make the experiences fit the visitors better. When creating new experiences, museums must be careful not to make these experiences just to attract visitors, but also to fulfill their educational goals and take in consideration how the experience can aid the future of the museum.

3.1 Introduction

In these past years, big companies such as Samsung, Facebook and Google have been working on virtual reality (VR) technology. The improvement in this technology made it possible to create VR experiences on mobile devices, introducing it to a broader audience. Eventually, VR found its way to the consumer market. With shops selling VR accessories it is clear that VR had made itself known.

Games and simulators are well known uses for VR, but companies see this technology also as a chance to boost their sales. For example, IKEA has launched an application to try out your new kitchen in VR [1] and Alibaba wants to show the product in VR before you buy it [2]. VR can be applied in a lot of areas and in places where one might not initially think about, like in the cultural heritage sector. Museums over the world see potential in this technology and incorporate VR as part of their exhibitions. This paper will look at how VR is incorporated in museums, and discuss a few points one should consider when making VR experiences for museums. The paper starts with a museum visitor model to understand what makes museum experiences memorable and how personalization can add to that experience. In section 3.4, an overview will be given how museum nowadays use VR. Section 3.5 and 3.6 will consider a few aspects when creating a VR museum and VR museum experience. The final section will look at the future of VR and museums and what museum should keep in mind with this technology they have.

3.2 Museum Experience

Nowadays, museums have many roles for the visitors. Silverstone states that "museums are in many respects like other contemporary media. They entertain and inform; they tell stories and construct arguments; they aim to please and to educate; they define, consciously or unconsciously; effectively or ineffectively, an agenda; they translate the otherwise unfamiliar and inaccessible into the familiar and accessible" [3]. Whatever the collection of a museum is, educating the visitor is now considered as one of the primary functions of a museum [4]. Falk calls the memories the visible part of the iceberg that is learning. So creating memorable experiences is the first step to learning. Museums have been considering VR an attractive component in the arsenal of tools to educate, entertain and dazzle [5]. VR can be used as a tool to make museums more interactive for the visitors and enhance their museum experience. But each visitor experiences the museum in its own way, and creating one experience doesn't mean that it will be memorable to all. So when does a museum experience gets remembered?

In a qualitative analysis by Falk and Gilepsie [6], the researchers asked visitors what makes their museum visit memorable. They found four factors that influenced all of their participants:

- Things that supported their entering needs and interests.

- Things that were novel.
- Things that had high emotional content for the individual.
- Things that were supported by later experiences.

Falk described a model for the museum visitor that looks at the motivation why someone would go to a museum, also called the identity-related needs and desires [6]. The motivations can be clustered in five identity-related categories.

- **Explorers**
  Visitors who are curiosity-driven with a generic interest in the content of the museum. They expect to find something that will grab their attention and fuel their learning.
- **Facilitators**
  Visitors who are socially motivated. Their visit is focused on primarily enabling the experience and learning of others in their accompanying social group.
- **Professional/Hobbyists**
  Visitors who feel a close tie between the museum content and their professional or hobbyist passions. Their visits are typically motivated by a desire to satisfy a specific content-related objective.
- **Experience Seekers**
  Visitors who are motivated to visit because they perceive the museum as an important destination. Their satisfaction primarily derives from the mere fact of having 'been there and done that'.
- **Rechargers**
  Visitors who are primarily seeking to have a contemplative, spiritual and/or restorative experience. They see the museum as a refuge from the work-a-day world or as a confirmation of their religious beliefs.

When looking back at the four factors that make a museum visit memorable, they can be related to the identity-related motivations. First of all, the identity-related motivations have a direct connection with the needs and the interest of a visitor. The motivations and needs form the key parts of the so called museum experience cycle (Fig. 3.1).

Novelty will affect the museum experience in some way, but the impact of it depends mostly on their original goals to satisfy their needs. If the Explorer had the goal to experience something new, the novelty will satisfy his goal and also becomes memorable.

Other studies have proven that there is a relation between emotion and the memory [7]. In other studies of Falk and Gillepsie [8] and Staus [9], it has also been found that emotion plays an important part in museum learning. Regarding the identity-related motivation, the moments that the needs or interest are satisfied carry a high emotional value and are remembered.

Finally, later experiences, such as conversations and the reading of articles, can bring up the museum again and make someone remember their experience in the museum.

3.3 Personalizing Museum Experiences

Museum tours offer visitors a unique experience in the museum and give a special insight about the museum collection [10]. Basing on the museum experience model of Falk [6], leaving memorable museum experiences depends on if the needs of the visitor are satisfied. The research shows that general experiences that are often seen in museums, such as tours, can be accepted differently by each visitor. While one might be very intrigued by the provided information during the tour, another might get bored because he already has that knowledge. Looking at the model, it also explains the difference in preference to explore the museum. For example, the Professional can pick up an audio guide that specifically tells him more about the collection he wants to know about, while the Explorer swiftly moves trough the same collection until something catches his eye. This example illustrates that instead of creating general experiences for the museum, creating experiences befitting the needs of the visitors can provide a better museum experience to them.

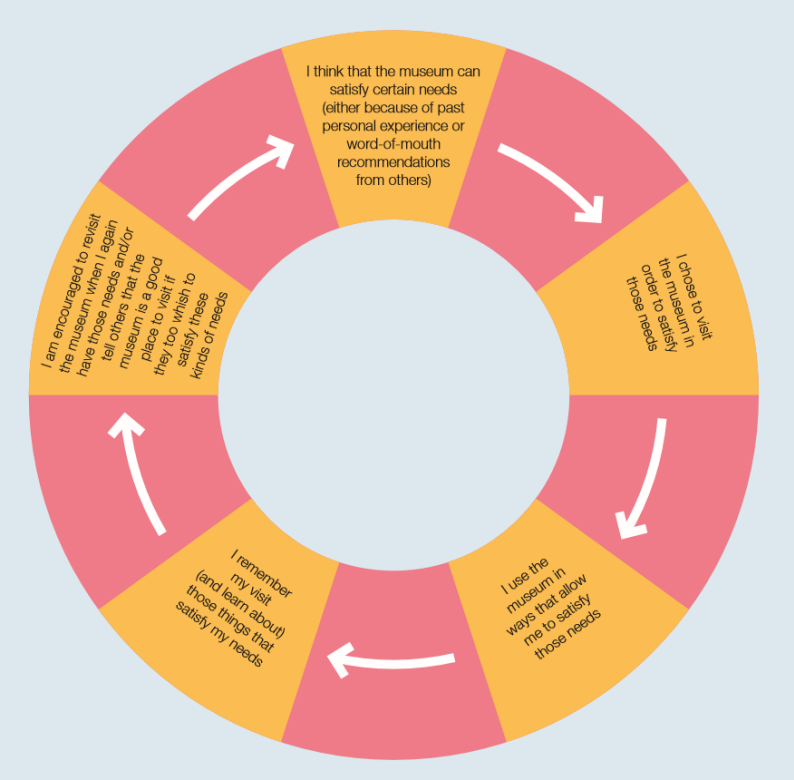


Figure 3.1: The museum experience cycle.

Personalization lets the museum monologue turns into a dialogue: the visitors teach the museum more and more about themselves, their interests and needs and, in return the museum proposes content and services that fit [11]. So to provide the best service, the museum must know about the visitor. Different methods and tools have been developed to do this. For example, Aroyo et al. developed the Artwork Recommender [12]. This is a web-based tool to rate artworks and topics of artwork. With the data, a user profile can be created and used for generating recommended artwork. With their Tour Wizard tool, a tour of recommended artworks in the Rijksmuseum can be generated based on the user profile. The researchers created these tools based on the assumption that the visitors spend time on preparing the museum visit, and that the visitors use this tool before their visit. This however, is not always the case.

The MIT Media lab created a wearable computer that adapts the audiovisual narration to the user's interest [13]. Compared to the user profiles of Aroyo, this system can handle the user's interest in real-time. The wearable computer tracks the path of the user and counts the length of stops to gather information about the user's interest. Based on the theories of Dean [14] and Serrel [15], the researchers classified the users in three types of visitors using the gathered information to select proper content:

- The busy types want to see a little of everything.
- The greedy types want to know as much as possible and don't have a time constraint.
- The selective types want to see and know in depth about a few preferred items.

The system is also able to adapt the visitor type during use when the user behaves differently.

Both studies of Aroyo and Sparacino classify the visitors on their interest in specific artworks. The classifications of Dean and Serrel are also based on how visitors look at the artwork and how they spend their time on it. They all have the assumption that the visitors are going to the museum for the actual content. Falk, however, also took the noon-content related motivations and needs in consideration. For some the motivations and needs are about the artworks, but for others it might be a more social aspect. An aspect that the other classifications did not consider, but are wise to take into account when making new museum experiences.

3.4 VR Museum Experiences

Cultural institutions such as museums have to attract visitors[16]. This task is not an easy one for a lot of museums and they could get financial struggles [17, 18]. In this digital era, internet has become a very important marketing channel [16] and with popular technology like VR, museums can make use of them to stay up to date.

3.4.1 Types of VR Museums

Museums around the world are already using VR as part of their exhibition to create more dynamic content for the visitors. In VR, there are different types of museums.

- **Based on existing Museums**
  When talking about museums, one might initially think about recreating the real museums in the virtual world. The WoofbertVR app [19] offers the user a VR visit to one of the most famous rooms in the Courtald Gallery of London. The scene in the virtual space is based on the real location, but whole existing museums can also be built and visited in VR.

- **Virtual Museums**
  Another way to use VR in cultural heritage, is to create a new museum. A museum that does not exist in the physical world. The Virtueel Museum App [20] is one of such virtual museums. The museum itself is not based on any existing museum, but created as a museum on its own. It lets the user creates his own exhibition from the collection of the Rijksmuseum, Museum Amsterdam and the Nationaal Archief, the national archive of the Netherlands.

  VR museums are not limited by exhibiting art from existing museums. In this technology rich time, digital art is not an uncommon type of art anymore, but are rarely seen in museums. The DiMoDa [21] museum is a virtual museum that showcases digital art and lets one experience the art in a VR context. This virtual museum aims to stay away from the white wall model and takes the advantage of VR to create something that you cannot see everywhere [22].

3.4.2 Practices of VR by Museums

VR is being used in museums for several reasons. In this section, a few examples will be given on how museums are using VR. Often, these fields are overlapping.

VR as part of the Exhibition

The Westfries museum in Hoorn in the Netherlands uses VR to create a new experience by recreating historical scenes. This experience brings the visitor back to the Dutch Golden Age, allowing him to relive the city of Hoorn in 1650. The application was well received, resulting in their second VR application release that lets one experience a sail on the ship De Eendracht in 1616 [23]. This example of VR usage shows the power of VR to recreate scenes that do not exist anymore but it also shows that the creation of scenes where one cannot normally go is also possible. These can include scenes like inside a volcano[24], in space or scenes on microscopic levels like in a human body.

Another very interesting way to use VR in museums is the possibility to enter actual art. The Woofbert app [19] on the Samsung VR platform, gives the user the possibility to enter a painting of Edouard Manet. The people in the painting are animated, and a narrator tells additional information about the painting. The Dali Museum in St. Petersburg also created an application that lets the user enter the world of the painting called Archaeological Reminiscence of Millet's Angelus [25]. This application shows the user parts of the world of the painting that could never been seen on the painting alone. In this case, the art was extended by the VR technology and new content has been created for the existing piece. One could also argue that a new kind of art is created using existing art.

Overcoming Physical Space

An advantage of using the virtual world, is that the required space in the real world doesn't have to be that large. If the Westfries museum had to show their Golden Age experience in the physical

world, they would have had some serious space issues. If museums have issues showing parts of their collection due to the space requirement, showing them in the virtual world is an alternative. This is especially a very nice solution to show collections that are too fragile to be on an exhibition in the real museums.

VR also makes it is possible to visit museums from home. The Woofbert app included a part of the Courtald Gallery of London, but whole museums can also be built in VR. The app is developed for the Samsung Gear VR and runs on a selection of Samsung smartphones. While this type of VR that runs on mobile phones are not as powerful as dedicated VR systems, it is more accessible to a much broader public. This way, people who cannot physically go to the museums can still visit them in VR.

Education

As mentioned before, education is one of the primary functions of a museum [4]. VR has already been used for education in several areas. For example in combat and flight simulators to train recruits in the Army and the Air force [26, 27]. Even Google has started its own education project with Google Expedition. Museums also start to see the value of VR and what they can do in terms of education. The British Museum collaborated with Samsung as part of the Samsung Digital Discovery Centre (SDDC) [28, 29] and created a VR exhibition. Since the Bronze Age is on the curriculum of England's National Curriculum, they have chosen this historic period for their exhibition. The exhibition showed three pieces from the Bronze Age which were scanned and modeled to create 3D versions of them. The virtual world contained a roundhouse from the historic period, resulting in that the objects were placed in context. The user could navigate through this world and when an object was selected, he received some narrated information about the object through the headphones. By exploring the objects in their original context, the museum wanted to let visitors understand their collection better. Context is important to tell the story behind the objects, and VR makes it easier to add context in general [30]. Note that this kind of VR experience is again a recreation of a scene in the past, but by choosing the Bronze Age as the subject, the museum also supported to the education sector in their country.

3.5 Creating VR Museums

As mentioned in section 3.4.1, there are different ways to implement a VR museum. VR museums that are based on existing buildings can be recreated by digital artists. However, virtual-only museums need another approach.

3.5.1 Exhibition Digitization

First of all, if the museum wants to exhibit physical objects in the virtual environment (whether the environment is based on an existing place or solely exists in the virtual world), the objects must be digitized. In the research of Lepouras [24], they used three techniques to digitize the exhibition pieces:

- **3D Photography**
  By making photos of the object from different angles and stitching them together, a model can be created.
- **3D Scanning**
  Using a 3D scannner, very detailed models can be created. Some objects, however, can be too large to fit in the scanner or their surfaces cannot be allowed to be scanned by the lasers of the scanner.
- **3D Modelling**
  Models can be created in 3D modelling software. Hierarchical models, like machines with movable parts, can be created with more flexibility for manipulation. 3D modelling can be very time consuming when the object has a lot of detail.

3.5.2 Exhibition and Architectural Design

The pieces must be placed and exhibited in the virtual environment, which can be a virtual museum or any other place that acts as the container of the pieces. Museums, in general, host exhibitions in order to spread their message to the public. Within the museum's environment the form of exhibited objects show the museum's message [24]. This communication is also influenced by the environment of the exhibition pieces, so designing the virtual environment must be carefully done.

Different tools exist to create virtual exhibitions and museum. Parent [31] described the Virtual Environment Task-Analysis Tool to plan an exhibition. It is a paper-and-pencil tool that puts down factors such as organizational-, user- and task-related factors that are often used when designing computer-based systems. Task requirements are used to design the environment and user requirements provide the basis to locate activities in the museum. In a system like ARCO by White et al. [32], users can manage and present their exhibition. The system can create the exhibition in a 3D space, but only offers it in the web browser.

Designing the museum building itself is a different task. Museums in the physical world are located in already existing buildings, or new buildings will be designed fro them. Lepouras et al. [24] built museums that mainly focused on the educational aspect of the museum experience rather than the aesthetic one. However, the aesthetic aspect of physical museums will not be forgotten by architects. The digital state of mind affect the industry, including architecture that today extends into the virtual world [33, 34]. Creating new virtual museums needs people from the architectural discipline with an understanding of the virtual environment as well. For cases like these, Bourdakis and Charitos [35] claim that there is a need to train virtual architects. A good collaboration is needed between cultural heritage specialist, information science specialist [36] and virtual architects to create the optimal result.

3.6 Creating VR Museum Experiences

In section 3.4.2, different uses of VR in museums have been mentioned. A lot of the experiences, however, have no personalization. The difference in the needs of a visitor makes it impossible to satisfy all the visitors with one-size-fits-all experiences. Personalization is needed to satisfy the needs of the visitors and give them a memorable museum experience. VR has the advantage that it is able to show the user things without others seeing it too. For example, if one user would like to see the labels near the paintings, but another user would like to just see the painting itself without any additional information, VR can satisfy both visitors at the same time.

3.6.1 Experiences for Visitor's Needs

Using VR, an experience can be created for the 5 types of visitors Falk mentioned [6]. A few ideas are now given how VR experiences can better fit the visitor's needs:

- **Explorers**
  These visitors go for the pieces that grab their attention and then want to learn about them. The moment the visitor found an interesting piece, information about the piece can be given. These can for example be information through audio or labels. Audio tours in physical museums are often static, but in the VR, the audio can be interactive and start when the user is detected near an exhibition piece in the virtual space. As for labels, they are restricted by the available space in physical museums. In VR, this restriction does not apply and it can even provide more information if the user wants it. Such experiences can give the user the ability to gain deeper knowledge about the exhibition piece, or it can provide him with information where comparable or related pieces can be found in the museum.

- **Facilitators**
  These visitors go for the social aspect to a museum. VR museums are often solo experiences, but that does not mean it cannot be used for this case. One might think about a gaming experience in VR with a co-op nature. The gaming experience does not only have to be entertaining, but can also be educative. Especially VR applications that require multiple people and are located in real physical museums can create a social experience.

- **Professional/Hobbyist**
  These type of visitors go for specific content in the museum. In VR, locations that are not

of interest can be skipped. One might implement a teleport mechanism to let the visitor instantly be at the desired location. Also, when they want more information about the exhibition piece, it is not limited to the labels and information can be given just as to the Explorers.

- **Experience Seekers**
  Experience seekers go with the motivation to "have been there and have done that". If they are satisfied with a virtual museum based on a real museum, an exact replica of the museum should suffice. But if only the physical museums count, VR can be used as a tool to create that experience that people want to see, but can only be done at the museum itself (e.g. the VR experiences of the Westfries museum [23]). In this case, it is also being used as a tool to attract new visitors.

- **Rechargers**
  Rechargers want a contemplative, spiritual and/or restorative experience. VR can be seen as a refuge from the everyday. If the recharger requires some moment of peace, VR offers a museum experience where no other visitors are in your way to look at the exhibition pieces. If one requires, a relaxing background music can also be incorporated.

The above mentioned ideas show how one medium, VR, can be used to approach different types of visitors. And when doing that, the different experiences are not hindering each other.

3.6.2 Limitations of VR

An advantage of VR is that things can be created that would otherwise be impossible due to the physical laws and creates opportunities to make new experiences for museums. However, VR also have its disadvantages and limitations. The research of Sparacino [13] used different kinds of hardware to make the tracking and audiovisual narration possible. In VR, the narration can also be done without the need of any specialized hardware. However, the aspect where the reality gets augmented is not possible in VR as the real world cannot be seen. Also, many VR systems do not give the user to physically walk around, so tracking where the user goes does not make sense. But if you consider making a virtual world like the real world, the enhancements can also be created in the virtual world. And instead of tracking the user in the physical world, the user can be tracked in the virtual world. This example shows that VR has its disadvantages and that it has its restrictions, but some issues can be solved using a different approach. Unfortunately, new approaches need research and time to find and create the best usability. Issues such as cyber sickness and haptic feedback are one of the many issues in the VR sector.

3.7 VR and the Future of Museums

VR museums have many advantages over physical museums, especially when creating context around the exhibition pieces [30]. Also, according to Hon [30], physical museums do not scale well. A museum can fit a amount of people in it, and at busy times famous artworks are hard to see through the crowd. To be able to cope with more visitors, a lot of money has to be invested that is often not available. The internet, however, is a medium built for scale. A medium on where VR can exist and be accessed from all over the world. VR museums have no space restrictions and also don't have to worry about physical costs such as guards and cleaners. Hon thinks that with advantages like these, VR will eventually break museums. He admits that even though a virtual museum can look a lot like the real museum, it is not the same. But aren't those exactly the thoughts that people will keep going to the real museums?

VR is still relatively new to the mainstream public and museums are using it as a tool to attract visitors. But what will happen when the mainstream public knows about it already? Museums can keep creating VR experiences, but there will be a time where those experiences are becoming one of the many existing VR experiences and lose their innovativeness. When museums incorporate VR as part of their exhibition, the VR experiences should be used in a way that they are more than just an attraction. Using VR, the visitor can interact with the museum. This creates new opportunities for different purposes such as education. They should inspire the users and give them motivation to look at the real objects in the museum itself. VR can be used to present these objects in a personalized way to satisfy the user's needs and create an interest in the real objects. This way, virtual museums will aid in the interest to visit real museums.

3.8 Conclusion

Museums want to entertain, educate and let the visitor have a great experience. According to Falk, the way to make a museum visit memorable is to satisfy the needs of the visitor. As the needs of every person is different, one-size-fits-all experiences won't do well with everyone. Instead, museum experiences should be personalized. Museums are already using VR to create new experiences, but most of them have no personalization. New VR museum applications should take this in consideration if they want to create memorable museum experiences.

The design of VR museums is a task that will need different disciplines to achieve the best. Creating new experiences is also no easy task as VR has its own limitations, and new approaches should be designed that work better in a virtual world. Museums should be careful when incorporating VR experiences in their exhibition that they not only make something just to attract visitors, but also have other purposes like education. An experience that creates interest in museums is probably what museums want to keep themselves existing the way they are in this digital era.

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Chapter 4

Study 1: Effect of Virtual Reality Painting Complementing Illusions on the Emotion and Style Awareness

This study was done in collaboration with Ferdinand de Coninck as part of his small project for the master Game and Media Technology at Utrecht University.

Effect of Virtual Reality Painting Complementing Illusions on the Emotion and Style Awareness

X.J. Tan

September 11, 2016

Abstract

Virtual reality (VR) can be used to enhance VR museum experiences. One of such enhancements are illusions complementing the paintings in the museum. This study investigates the effect the illusions have on the painting style awareness and the emotions of the user. Using Parson's theory to understand how people look at art, the results suggest that the illusions have an impact on the experience of the viewers.

4.1 Introduction

Virtual Reality (VR) can be used to create experiences. One of such experiences is the visit of a museum. A lot of these VR applications recreate the existing museum, making it possible to visit the museum without physically having to go there. However, VR applications are not limited to recreating the existing experience, they can also be used to enhance the experience. The physical laws do not apply in the virtual world, making it possible to create experiences that are not possible or very hard to achieve in the real world. An example of an enhancement are illusions that complement paintings in a VR museum (e.g. snow falling near a winter themed painting). This creates a new way in how the paintings are represented and allow people to enjoy them from another perspective. In this study, we explore the possibilities of these illusions and see if they can be used to influence the emotion and style awareness of the person when viewing a painting.

4.2 Related Work

In a previous pilot study [1], the researchers created illusions to complement a painting in a VR museum setting. There were three types of illusions:

- **Extending the painting:** using painting extending software [2], the wall behind the painting is filled with textures extrapolated from the painting.
- **Stylized background:** a picture on the wall behind the painting gets stylized in the same style of the painting by using the method of Gatys et al. [3]
- **Weather illusions with sound:** particles related to the painting fill the room. For example, snowflakes falling near a winter painting. At the same time, music, museum ambient sound or ambient sound related to the depicted scene in the painting was being played.

The research was mainly focused on the enjoyment level of the participants. The illusions were generally positively accepted by those who do not have high interest in art and even created a little bit of interest in art to few. Even though the study was not focused on the emotional level of the participants, a few of them mentioned that they were emotionally affected by the weather illusions with the sounds. This gave us the incentive to look further upon these types of illusions and in how they can affect a person's view on paintings. In a study by Locher [4], the ability of participants to distinct reproductions of paintings from their originals was investigated. Each set of paintings contained the original painting and two modified reproductions of the original. The participants had to give characteristics and properties of the painting why they thought a certain painting was the original. These comments were then classified in the five stages of Parsons' aesthetic

development [5]. Each stage focuses on certain aspects of an art piece. This way the researcher could see on what kind of aspects the participants focused on when picking the original painting. This method inspired us to use Parsons' theory on the paintings with illusions as a way to find out about what people are focusing on while viewing the painting.

4.3 Research Goal

In this study, we will continue with the research of the various illusions applied in a VR museum with only paintings. We are interested in what ways these types of illusions can be used to let people view art differently. This gives us the research question:

- *RQ: Can the way people view paintings be changed using complementary illusions in a virtual museum?*

To be more specific, based on the results of the previous pilot study, we want to know if these illusions can let people pay more attention to the painting style and influence their emotional state. This will divide the main research question in two new research questions:

- *SQ1: Does the viewer focus more or less on the style when commenting on the painting with the illusions?*
- *SQ2: Does the viewer focus more or less on the their emotion when commenting on the painting with the illusions?*

We expect that the illusions will increase the focus on the style and emotion. Looking at the three types of illusions, we expect that the stylized background illusion has the highest potential of influencing the style awareness of a viewer. This is because the illusion itself makes use of the style of the painting. The picture behind the painting slowly morphs into the style of the painting and we are assuming this might let the viewer notice differences between a picture and the style of the painting and thus pay more attention to the style of the painting. As for the emotional thoughts, based on the comments from the previous pilot study we expect that the the weather illusions with sounds are best suited to increase the emotional thoughts.

4.4 Experiment Setup

An user study was conducted to find out the possible influences of the illusions. The study was based on the methods of Locher [4] which asked the participants to comment on the paintings. The comments were then classified in the stages of Parsons [5]:

- **Stage 1:** reactions are primarily characterized by freewheeling associative responses to subject matter; pictorial contents are stimuli to pleasant experience and often reflect favoritism.
- **Stage 2:** the dominant reactions are to a painting's realism and beauty. At this stage, the basic purpose of painting is believed to be representing something.
- **Stage 3:** reactions reflect the expressiveness of the contents of a composition, that is, the experiences they produce.
- **Stage 4:** individuals respond to the style and form of compositions; they place emphasis on the way the medium itself is handled by the artist.
- **Stage 5:** an observer is autonomous in his/her reaction to art. The viewer's own experience with art is the basis for his or her reaction to an artwork

We adapted this classification method to not only classify the comments into the stages, but also on the topics based on Parsons' theory (Tab. 4.1). This is because we were interested in the types of comments in general, including their topics, about the style of the painting and the emotion of the viewer. The topics are the ideas one may consider when thinking about the painting. How the topics are described can be corresponded to a stage of psychological development. For the style comments, we focused on comments that are classified in the topic Medium, Style Form and in Stage 4: Style and Form (Tab. 4.2). As for the emotion comments, we focused on the the topic Expression and Stage 3: Expressiveness (Tab. 4.3).

	Topic			
	Subject Matter	**Expression**	**Medium, Style Form**	**Judgment**
Stage 1: Favoritism				
Stage 2: Beauty and Realism	XX	x	x	x
Stage 3: Expressiveness	x	XX	x	x
Stage 4: Style and Form		x	XX	x
Stage 5: Autonomy				XX

Table 4.1: Every comment made on the paintings can be categorized using these stages and topics. The large crosses represent the cell where a topic is most important in each stage.

	Topic			
	Subject Matter	**Expression**	**Medium, Style Form**	**Judgment**
Stage 1: Favoritism				
Stage 2: Beauty and Realism				
Stage 3: Expressiveness				
Stage 4: Style and Form				
Stage 5: Autonomy				

Table 4.2: Relative Stage and Topic when focusing on style comments.

	Topic			
	Subject Matter	**Expression**	**Medium, Style Form**	**Judgment**
Stage 1: Favoritism				
Stage 2: Beauty and Realism				
Stage 3: Expressiveness				
Stage 4: Style and Form				
Stage 5: Autonomy				

Table 4.3: Relative Stage and Topic when focusing on emotion comments.

4.4.1 Database

To limit the duration of the test sessions and keep the user study executable without too many variables, we limited the theme of the paintings to a forest/trees theme. By choosing this theme, the falling leaves illusion from the previous user study [1] can be reused.

(a) Training

(b) Standard 1

(c) Standard 2

(d) Stylized

(e) Leaves

(f) Leaves + Stylized

Figure 4.1: The used paintings for the experiment.

Six different paintings were used in the experiment (Fig. 4.1). The "Training" painting was used to introduce the participant of its task to make comments about the painting.

"Standard 1" and "Standard 2" were paintings of the same painter with the same theme. One was shown before the painting with the illusions and one was shown after the paintings with the

illusions. Which one was shown first depended on the setup of the test. The same painter was chosen to see if the illusions would have any effect on the types (style or emotion) of comments made when a similar kind of painting was shown. From this point onwards, we will refer the first "Standard" painting the participant has seen as "Plain 1", and the second "Standard" painting as "Plain 2".

The "Stylized" painting was accompanied with the stylized illusion. When choosing the painting, we payed attention to the style of the painting. It had to be a style that if it was applied to a picture, the original picture and the stylized picture would be noticeably different from each other. The "Leaves painting was chosen based on its content. The falling leaves of the illusion had to fit the scene of the painting.

The "Leaves+Stylized" painting was accompanied by two illusions, the stylized background and the leaves illusion, at the same time. When choosing the painting, it had to fulfill both requirements of the "Stylized" and "Leaves" painting.

4.4.2 Application

A mobile VR application was implemented for the user studies. The application was made in Unity with the Google Cardboard package. The application ran with a resolution of 1080p on a 5.5-inch Sony Xperia Z5 premium in Hema VR goggles. In the application there was a museum comparable to the museum of the previous pilot study [1]. The user could look around by moving his head and enter rooms by looking at the corresponding doors. The museum consisted of five floors, with each a hallway and doors leading to other rooms with paintings in it:

- Floor 0
  - "Training" painting
- Floor 1
  - "Plain 1" painting
- Floor 2
  - "Leaves" painting
  - "Stylized" painting
  - "Leaves + Stylized" painting
- Floor 3
  - "Plain 2" painting
- Floor 4
  - "Plain 1" painting

"Standard 1" and "Standard 2" (used for the " Plain" paintings), and "Leaves" and "Stylized" paintings were ordered in Latin square to create 4 setups. With this we could neglect the effect a certain painting or illusions could create by seeing it first. The setups were then equally distributed over the participants.

4.4.3 Experiment Procedure

1. The participant started with filling in a consent form. The participant was informed by the risks of VR applications that may cause cybersickness.
2. The experiment started with the Initial Questionnaire. This questionnaire contained general information about the participant. It also included questions about their interest in art and paintings and their experience with VR and VR museums.

3. The participant was asked to take seat in a rotating office chair. This makes turning and looking around in VR easier. The VR device was then put on and navigation instructions were given. The participant was given the assignment to visit every room of the museum. In the rooms were paintings and they had to note as many characteristics and properties of the painting, and what kind of emotions they evoked. They were also told to think thoroughly before they comment and state those comments as clear as possible.

4. The participant visits every room and makes the comment. The comments were noted down. Whenever the participant would comment too fast, the experimenter would interrupt and ask the participant to slow down.

5. After the visit, the participant had to fill out the Final Questionnaire. This questionnaire contained questions about what they think of the illusions. It also contained questions if this VR experience changed the way they look at paintings.

4.5 Results

4.5.1 Pre-Questionnaire

There were twelve participants who participated in the experiment. All participants were male students, two of them were digital arts students. The participants aged between 19 and 25, with an average of 20 years old. Nine of the participants had experience with VR, two of them had previous experience with VR museums. Half of the participants indicated that they have no interest in paintings. Four of them said their interest depend on the actual art, while two of them expressed they show interest in art.

4.5.2 Comments on the Paintings

The comments made by the participants were classified in Parsons' topics and stages. Whenever there was a disagreement on the classification, the classification was discussed until a mutual agreement was found by the experimenters. The amount of comments per type was compared to each other with the "Plain 1" painting serving as the ground truth.

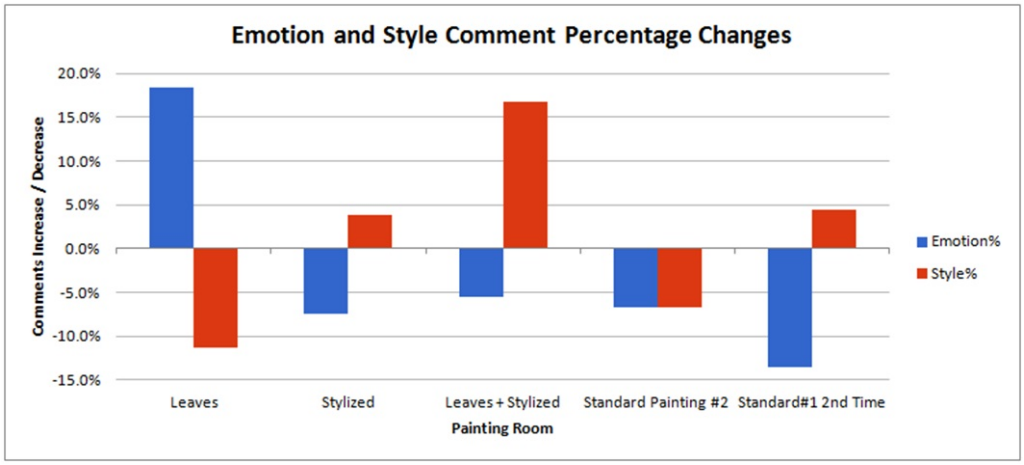

Figure 4.2: Relative change in emotion and style types of comments compared to "Plain 1".

As expected, compared to "Plain 1", the participants made more emotion-typed comments and less style-typed comments with the Leaves illusion (Fig. 4.2). The results with the Stylized illusions were also expected. The difference was not as huge as with the Leaves illusion, but there was still a decrease in emotion-typed comments and an increase in style-typed comments. When comparing these two illusions with each other (Fig 4.3), the difference in the relative amount of the types of comments can be clearly seen.

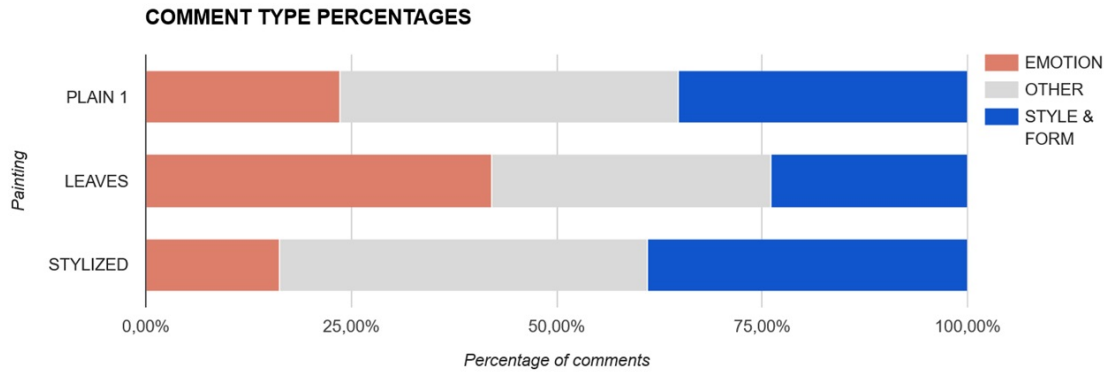

Figure 4.3: Relative amount of comments made per illusion.

As for the painting with both illusions there was an increase in style-typed comments and a decrease in emotion-typed comments (Fig. 4.2). A painting was chosen with a different style than that of the "Stylized" painting. However, the style might have been too different compared to previously shown paintings and caused the increase in style-typed comments and decrease in emotion-typed comments.

Comparing the amount of emotion and style related comments of "Plain 1" and "Plain 2", there is a small decrease in both types of comments. The decrease is minimal, indicating that the effect of the illusions are temporary. We had hoped that the illusions would change the way a person would view a painting, but this was not the case. However, the time the participants were exposed to the illusions was very short. The illusions might have more effect in a longer term of exposure making it a possible area to explore in future research.

The second time the participants saw "Plain 1", the relative amount of emotion-typed comments decreased and the style-typed comments increased slightly. A possible reason for this is that the participants were not motivated enough to make the same comments twice. They made more comments about the things they did not see the first time and focus less on what they feel about the painting.

The two arts students did not react remarkably different from the others. It must be stated that a test sample of two is too small to draw any conclusions from it and it might prove otherwise with a larger test sample. There was, however, a slight increase of emotional comments by those who stated that they were interested or very interested in art (rated 3 or higher in "interest in art") and might be an area worth looking into in future research.

4.5.3 Post-Questionnaire

The illusions were generally positively received. One participant preferred the Stylized illusion. Seven participants explicitly mentioned that they liked the Leaves illusion of which three of them said that they did not like the Stylized illusion. Another participant liked both types of illusions, and mentioned that watching the paintings without illusions was less exciting. There was also a participant who encouraged us to make more 3D effects like the Leaves illusion or perhaps make the stylized illusions 3D by applying it on all the walls. Two participants, however, did not like the illusions at all and called them distracting. When asking the participants if this experience in the VR museum changed their view on paintings, most of them stated that this was not the case. Still, one participant did say that he should look longer at a painting to discover more details.

4.6 Conclusion

This experiment was the first step investigating the effects of the illusions. The results seem to indicate that the illusions can have an impact on how a person perceives a painting. Especially the Leaves illusion seems to have an effect on the emotional state of the person viewing the painting. However, the test samples of this experiment was small and not very diverse, only giving an indication on the impact of the illusions. In future research, a more diverse test sample is needed to make any conclusions and to see if these illusions can also have a long-term effect on the participants' view on paintings. Furthermore, in this experiment only two illusions were tested.

Many more illusions exist and it has yet to been found out what their effects are on the person's view on a painting.

Another subject that one must keep in mind in this area, is the vague border of enhancing existing art or creating new art itself. Some might complain that the illusions are not complementing the paintings, or do not convey what the painter has wanted. Further research is needed to investigate what kind of illusions fit with which kind of paintings and how the illusions should be applied to them.

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Chapter 5

ACE Poster

This paper is written by Dr. Wolfgang Hürst based on Pilot Study 1. It was accepted by ACE2016.

Complementing Artworks to Create Immersive VR Museum Experiences

Abstract
Virtual and augmented reality offer various ways to enhance art exhibitions and create virtual museum experiences. In this work, we investigate the impact of digital additions to paintings in a VR museum setting. In particular, we evaluate if adding visuals in the same style of a painting or small 3D animations related to its content can have a positive impact on the experience and how the art is perceived. Using Parsons' theory of how we understand art, our results demonstrate an effect on the experience and thus confirm the potential of such digital additions for VR museums.

Author Keywords
Virtual reality; VR museum; VR experiences.

ACM Classification Keywords
H.5.1. Information interfaces and presentation (e.g., HCI): Multimedia Information Systems; Artificial, augmented, and virtual realities.

Introduction
Virtual reality (VR) museum implementations often try to recreated existing museum experiences in VR (cf. [5], for example). At the same time, people are experimenting with new ways how art can be digitally extended, modified, or enhanced in order to be explored in different ways. Examples include 3D

Figure 1: Inpainting applied to Van Gogh's *Starry Night*. The surrounding extension is automatically created using an algorithm that analyses the painting's content.

Figure 2: Automatically modifying a photo (cityscape at top) to represent it in the style of a painting (from [1]).

representations based on paintings [4], extensions to a painting automatically created with a technique called inpainting [6] (Fig. 1), or automatic application of a painting's style to, for example, a photographic image [1] (Fig. 2). In our research, we are investigating if and how such digital enhancements or modifications can be used to create new VR museum experiences and what kind of benefits such an installation may provide.

In a first pilot study, we applied the two effects shown in Fig. 1 & 2 to a VR museum implementation. Here, when people looked at some of the paintings, they started to "grow" by applying the inpainting technique. For others, we placed a related photo on the back wall of a painting. This picture slowly morphed into the painting's style using the "stylization algorithm" from [1] when people looked at it. In a second pilot study, we added 3D animations related to the paintings to the environment, such as falling leaves or snowflakes for paintings of autumn and winter landscapes, respectively. In all cases, people reacted very positively to the experience. Subjects usually not affiliated with art often stated that effects like this might increase one's interest in paintings, whereas art enthusiasts appreciated the increased experience, although some also expressed that it might be considered distracting.

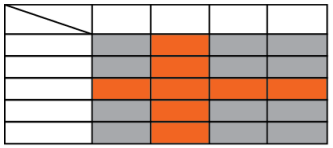
In this paper, we present a more in-depth study of the potential benefits of such complementing effects. In particular, we are interested in a possible impact on the observers' emotional connection to the art and their awareness of the artistic style. For this, we make use of Parsons' Stages of Aesthetic Development [3]. While originally being introduced for art education, this theory has been applied in various other contexts where people make judgments or express their interpretation and experience of artworks. For example, Locher [2] used it to investigate how people distinguish real from fake paintings. In the remainder, we start by describing this methodology, the tested extensions, and the experiment design, followed by a discussion of the results, and conclusions about the outcome.

Experiment Design and Setup

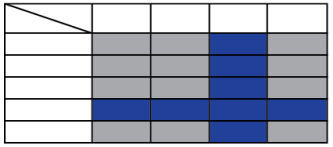
Methodology

In Parsons' theory [3], subjects are asked to review or comment on a particular piece of artwork. These comments are recorded or written down by a neutral observer and afterwards categorized according to the five stages and four topics illustrated in Fig. 3. Topics, represented by the table's columns, address the ideas an observer might consider when thinking about an art piece. Stages, i.e., the rows in Parsons' table, focus on different aspects of an art piece and relate to the psychological development an observer might have when experiencing it. Each stage correlates to a certain way in which individual topics are described, as illustrated by the crosses and their size in the table (Fig. 3); a larger cross represents a higher importance of that topic for the particular stage. For example, pictorial contents of people reaching stage 1 (favoritism) are generally stimuli to, for instance, pleasant personal experiences. People at stage 2 are commenting more on beauty and realism of the art and are thus assumed to experience a basic purpose to the art that is believed to represent something. Therefore, comments related to the topic "Subject matter" have a higher impact, whereas remarks related to other topics are also contributing, but have a lesser relevance for people at that stage.

Comments related to emotion



Comments related to style



Parsons' stages table

STAGES \ TOPICS	Subject matter	Expression	Medium, style form	Judgement
(1) Favoritism				
(2) Beauty & realism	**XX**	**x**	**x**	**x**
(3) Expressiveness	**x**	**XX**	**x**	**x**
(4) Style & form		**x**	**XX**	**x**
(5) Autonomy				**XX**

Figure 3: Parsons' Stages of Aesthetic Development.

By counting the amount of comments made by an individual for each stage-topic combination, we can therefore draw conclusions about the experience and level of people, or, by grouping related stage-topic pairs about the their reactions to certain pieces of art. For our experiment, we are mostly interested in the emotional response, which is related to the orange stage-topic pairs illustrated in Fig. 3 (top left), and the subjects' awareness of a painting's style, which correlates to the blue cells (bottom left). A larger amount of comments related to these cells suggest a related impact of the used digital extension.

Paintings and used extensions

Encouraged by the positive results from our pilot studies, we decided to further investigate the approach of putting content-related photos on the back wall of a painting that morph into the painting's style (cf. Fig. 2) and the small seasons-related 3D effects (falling leaves). Fig. 4 illustrates the first effect along with one of the paintings used in the test. Intuitively, we would expect that representing the related content from the photo in the style of the painting will make observers more aware of its style, and thus increase their understanding of the art to stage 4 (cf. Fig. 3).

Figure 4: Stylization effect (painting in center, back wall with original photo at the top, stylized after morphing below).

The 3D effects added to one of the autumn landscape paintings used in the tests are illustrated in Fig. 5. Here, the complementing effect is not related to the painting's style, but its content. Thus, intuitively, we would not expect an increase in the style-related

Figure 5: Falling leaves 3D effect (front view at the top, examples for the room experience below, including view of opposite side with exit door).

comments associated with stage 4, but instead, an increase of comments related to stage 3 (Expressiveness), which in turn reflect a higher emotional connection to the art.

In addition to these two extensions, we tested another case where both effects (stylized background wall and falling leaves in the room) were combined. As ground truth and for comparison, two other paintings were used in plain rooms without any additions. Another plain room was used for training at the start of the test.

Experiment design

To evaluate the aforementioned extensions using Parsons' theory, we created a virtual museum using a VR case for smartphones and a Sony Xperiz Z5 premium device as head-mounted VR display (5.5-inch screen, 2160x3840 pixels resolution, although the actual VR application ran at 1080 pixels).

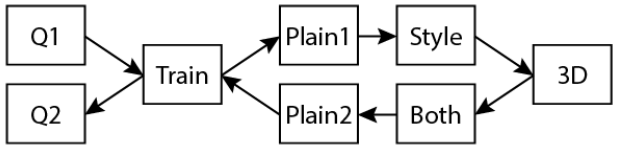


Figure 6: One possible walk through the experiment (orders of the rooms Plain1 & Plain2 and the effects Style & 3D were counterbalanced across subjects using a Latin square design).

As illustrated in Fig. 6, subjects of the study had to fill out a questionnaire at the beginning (*Q1*) before visiting six rooms with paintings in a given order, followed by a final questionnaire (*Q2*) and an informal closing interview. Each room featured a painting that was hanging on the opposite side of the entrance in an otherwise neutral environment. To add a transition phase before entering a room with another experience, subjects had to pass neutral rooms with plants and benches but no paintings. The first two rooms with art featured a standard representation of a painting on a plain wall. When entering room one (*Train*), people were explained the procedure and how to navigate rooms. Room two (*Plain1*) served as a ground truth. In this and each following room, subjects were expected to comment on the art and express their thoughts and emotions about it. Rooms three to five each had another extension associated to the respective paintings; first either the stylized effect (*Style*, cf. Fig. 4) or the 3D effect (*3D*, cf. Fig 5), then the respective other effect, followed by a combination of both in the fifth room (*Both*). The sixth room (*Plain2*) featured a standard representation again with a painting of similar style and type as the one in room two (*Plain1*). The goal of including another and comparable standard case was to evaluate if there might be a change in people's experience due to the effects (e.g., if people make more comments on style because the stylized effects made them more aware of style-related issues). Thus, both paintings were from the same painter and featured comparable contents and styles. Finally, subjects had to visit to the first room again. This step was supposed to identify if the subjects' comments differe majorly from their initial ones, which could indicate a longer lasting effect. Unfortunately, most subjects remembered having seen this exact painting before and thus did not add any further comments to it.

In the initial questionnaire, subjects had to provide some general information including their general interest in art and VR. During the test, a participant's comments were written down by two neutral observers in order to guarantee that nothing is missed and

annotations are made accurately. These observers also afterwards discussed and decided together on the assignment of comments to cells in Parsons' table to eliminate personal biases, especially for borderline cases. The closing questionnaire asked about their experience and additional comments on the test.

Results & Discussion

Twelve subjects participated in the experiment. All were university students, male, at ages between 19 and 25. Two of them were digital arts students, and thus more familiar with the domain, although not with VR. Ten of them were students from local computer science programs. We purposely chose such a younger and more technology-focused target group, because our pilot study suggested that one major benefit of our approach could be to make people with less affiliation to art more interested in it. About half of the computer science students did indeed characterize paintings as less interesting or even boring, some expressed a varying interest depending on the actual art, and two characterized themselves as strongly interested in it.

Results (quantitative)

In the following, we compare the amounts of comments made with respect to the stages introduced by Parsons, especially with respect to emotion and style (cf. Fig. 3). The first room visited after the training (*Plain1*) serves as a ground truth in order to evaluate a possible increase or decrease. Fig. 7 compares the relative amount of emotion- and style-related comments made by all participants. As expected, for the 3D effect, we see a clear increase in emotion-related statements, whereas style-related comments decrease compared to both the first plain room with a painting and the room with the stylized back wall. Yet, the latter does not show a major increase for style-related comments compared to the plain room, but only the expected change in both style- and emotion-related statements compared to the room with the 3D effects.

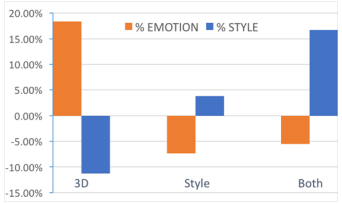


Figure 7: Changes in relative number of comments related to emotion & style between plain room (Plain1) and each of the three effects (3D, Style, Both).

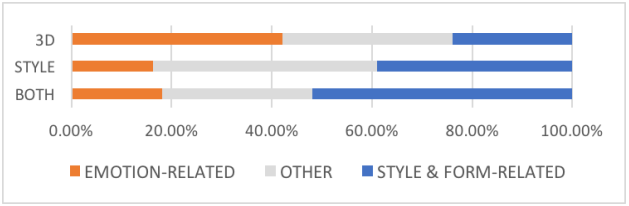


Figure 8: Relative amount of comments made for the respective categories (cf. color-coded cells in Fig. 3).

This impression is confirmed by when comparing the changes of each room with added effects to the initial plain room illustrated in Fig. 8; the strong increase in emotion-related comments for 3D effects ndicates that people did indeed feel more connected to the painting, while being less interested in the painting's style. The latter increased slightly with the stylized photo on the back wall, where, as expected, people also made less emotion-related comments. The strong increase in style-related aspects might be due to the fact that the painting strongly differed in style from the preceding one. We purposely chose it to avoid similarity effects between the *Style* room and the one with the combined effects, but unfortunately this motivated subjects to focus more on style than, for example, the painting's content. When looking at the statements made in rooms *Plain1* and *Plain2*, which both had different but comparable paintings, we see a slight decrease of 6.7% and 6.8% for emotion and style-related comments. This suggests that the observable difference for the rooms with the effects might not have a long-term effect but

seems limited to the actual experience. We were hoping that, for example, the stylization effect would have a stronger impact, making people more aware of a painting's style in general. This is either not the case, or an impact that can only be achieved over a longer period of time. Such long-term studies were beyond the scope of this test, but will be explored in future work.

Comments & questionnaires (qualitative)
In general, overall feedback was very positive, although we did find it a bit disappointing that the changes observed in the quantitative data were only slightly reflected in the subjects' comments. Almost all subjects stated that their opinion of paintings did not really change because of the experience, but one noted that it might encourage him to focus more on details. A little more than half of the participants expressed a preference over the 3D effect compared to the stylized experience. Some even asked for additional and more elaborate ones, or to make the stylized effect in 3D as well (e.g., extending over the room, not just the back wall). Only one explicitly stated a preference for the stylization effect. Two did not like any of them, mostly because they were considered distracting. Others made also comments about possible extensions and improvements, mostly related to additional effects and added interactivity. There was no noteworthy difference between the types of comments made by the two art students and the computer science students. Yet, there was a slight increase in emotional comments made by the subjects who characterized themselves as interested or very interested in art before the experiment compared to the ones who did not. Neither the difference nor the sample size are large enough though to draw final conclusions, but it suggests an interesting area for future work.

Conclusion

Generally, our results and the feedback by most participants is very encouraging and confirms the potential of adding such digital enhancements to VR museum environments. It is particularly important that the quantitative data also suggests an impact. This indicates that the positive user comments are not just due to an affection to technology and the addition of something new to a domain otherwise considered to be boring or of minor interest. Yet, it is also clear that this study can only be a first step, but further research is needed to, for example, investigate different kinds of effects and also their long-term impact.

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Chapter 6

Study 2: Painting Complementing Illusions in a VR Museum Environment

This study was done in collaboration with Ferdinand de Coninck as part of his small project for the master Game and Media Technology at Utrecht University.

Painting Complementing Illusions in a VR Museum Environment

X.J. Tan

September 11, 2016

Abstract

In previous studies, virtual Reality (VR) enabled us to create new ways to experience paintings by adding illusions that complement the paintings. This study is focused around a demo based on our earlier findings. The demo showcases the illusions and introduces a new 3D type of illusion in a VR museum environment. The demo was well received and gave us a view on the potentials of these illusions, such as creating a sense of presence in the world of the painting or teaching them about the artworks.

6.1 Introduction

One area where Virtual Reality (VR) is being applied to, but one might not initially think about, is the cultural heritage sector. VR can not only be used to recreate existing museums, but also has the potential to create new content for the user.

In previous studies [1], illusions that complement the paintings in the museum were added to create a new and better experience. For example, leaves falling near an autumn-themed painting while the sound of rustling leaves is being played to create a sense of presence in the world of the painting. The pilot study mainly focused on the enjoyment level of the users when illusions were being applied to the paintings. This gave us an indication of the potential of these kinds of illusions. The second study [3] showed that 3D leaves illusions had an effect on the emotional status of a viewer. The style based stylized background illusion, an illusion where the background photo on the wall of where the painting was located transforms into the style of the painting, also gave an indication that people payed more attention to the style of a painting.

In this pilot study, a demo of the VR museum with paintings was created while taking account of the results and comments from the previous studies [1, 3]. The paintings were also accompanied by illusions based on the previous studies and new types of illusions were tested.

6.2 VR Museum Setup

The previous studies had a controlled environment for testing purposes. The museums consisted of several floors, each floor had rooms with one painting in them. The participants often complained that it did not look like a museum. After the first part of the pilot study, decorations were added. The decorations did help to make it less hospital like, but the environment still couldn't be called a museum. For this study a new application was created in Unity with Google Cardboard. Models were created in Blender and Autodesk Maya. In this application, the museum was an octagonal room with several paintings in it (Fig 6.1). This recreates the feeling of a museum that there is more than one artwork in the same room. Also, the color of the walls were adjusted and given a warmer yellow tone. In the middle of the room was a fountain as decoration and in every corner of the room was a pillar. The pillar also had the function to separate the walls from each other.

Figure 6.1: VR museum layout.

In the previous studies, some participants also complained that they wanted to get closer to the painting, but that they couldn't. A reason why there was no free movement in the application was to avoid cybersickness. This time, however, we included the option to walk freely in the room as we wanted to give the users the freedom they would also have in a real museum.

6.3 Paintings and Illusions

There were seven different paintings in this museum (Fig 6.2). Each paintings was accompanied by an illusion. The illusion were only active when the user was standing near the painting.

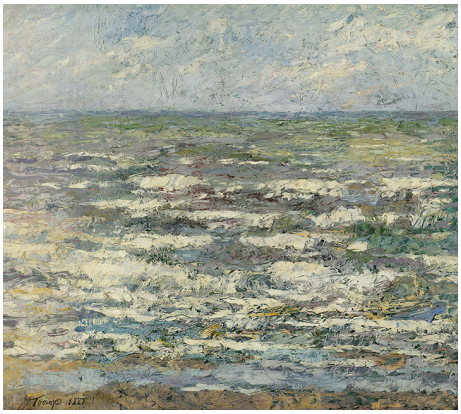
6.3.1 Stylized Background Illusion

For this illusion, a photo was displayed on the wall behind the painting (Fig 6.2a). The content of the photo was related to the content of the painting. When the user was near the painting, the photo slowly transformed into the style of the painting (Fig. 6.3) using the algorithm of Gatys et al. [4]. Another painting (Fig6.2b) already had a stylized background, but this background became blurred when the user was getting closer to the painting (Fig 6.4).

(a)

(b)

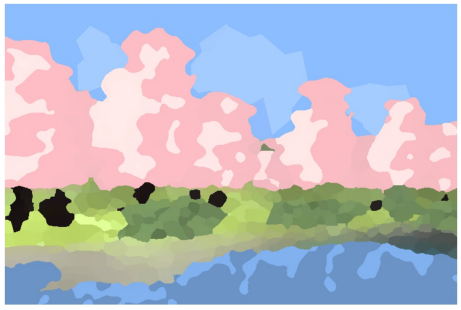
(c)



(d)

(e)

(f)



(g)

Figure 6.2: Paintings in the VR museum.

6.3.2 Inpainting and Extension Illusion

This illusion uses the inpainting algorithm 6.5) using an inpainting algorithm [2]. The transition of the extension animation was shown through a swirl texture instead of a circle in the previous studies. A swirl texture was chosen because the shape could be related to Van Gogh's Starry Night (Fig. 6.2c) painting style. The other painting of Toorop (Fig. 6.2d) used the same swirl as well but the shape had no relation to the painting itself.

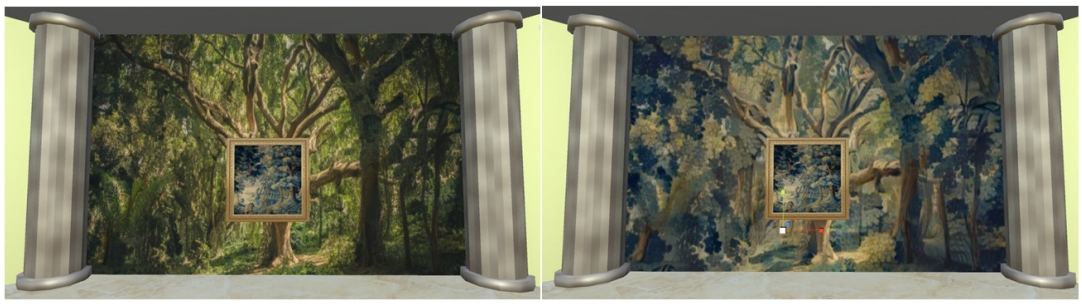


Figure 6.3: Background transforms into the style of the painting when the user approaches.

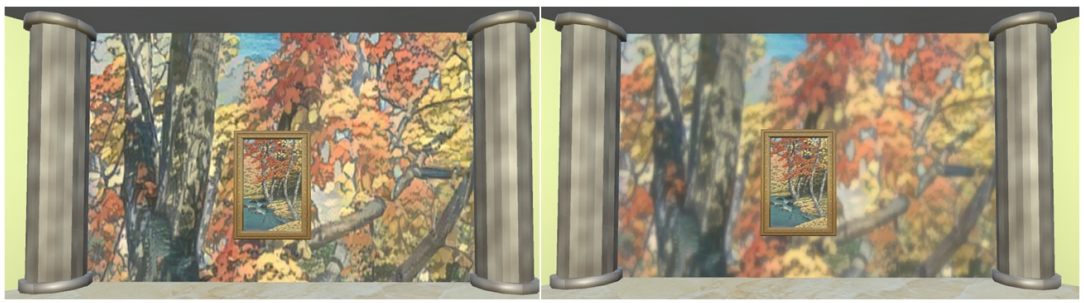


Figure 6.4: The stylized background becomes blurred when the user approaches the painting.

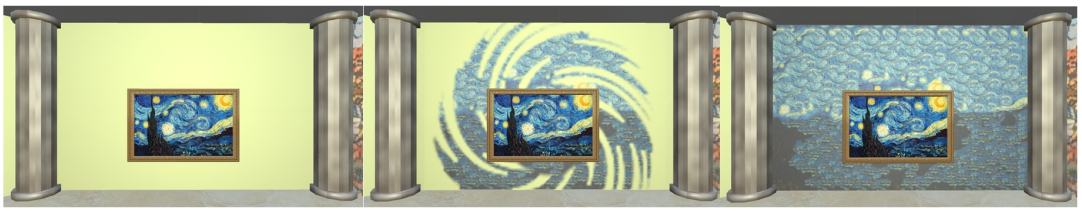


Figure 6.5: Extending illusion, the extension becomes visible through a swirl.

6.3.3 3D Weather Illusions

Two paintings were accompanied by an illusions of 3D objects which related to the content of the painting. Near the painting of Chikanobu (Fig. 6.2e), 3D snowflakes were falling down with some mist to create the a snow storm effect (Fig. 6.6). Near the other painting (Fig. 6.2f) leaves were falling down (fig. 6.7). This painting was also accompanied by music, whereas the snowstorm illusion was a visual effect only.

Figure 6.6: Snow and mist create a snowstorm illusion in front of a snowstorm themed painting.

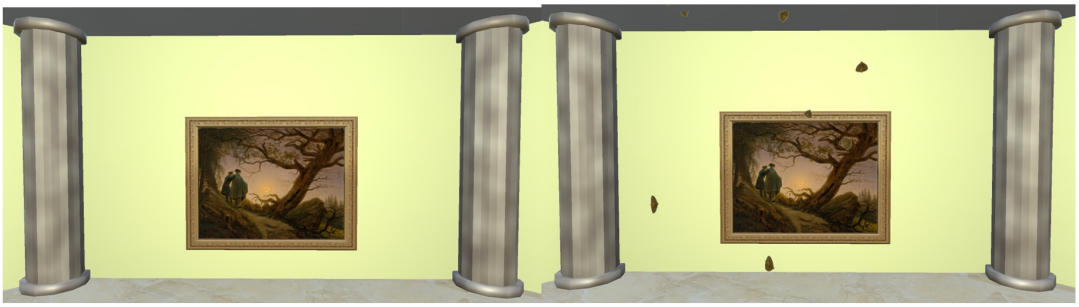


Figure 6.7: Leaves fall down while sad music is playing to create an autumn setting.

6.3.4 3D Scene Illusion

The final type of illusions was an illusion where the user gets teleported to the world of the painting. If the user was near the painting (Fig. 6.2g), the museum scene was replaced by a new fictional scene of where the painting was painted. In this new scene, there was also content related music playing. The scene also contained animations like falling sakura petals and an animated river (Fig. 6.8).

Figure 6.8: 3D scene illusions swaps the museum scene to the world of the painting.

6.4 Experiment Setup

The demo ran on a Sony Xperia Z5 Premium on a 1080p resolution with Hema VR goggles. Wireless Sony DR-BTN200 headphones and a Sony Playstation 4 controller were used for sound and controls respectively. Participants were asked to visit the museum and give comments about the application or any other things that came into their mind. They could stay in the museum as long as they wanted and look at the paintings in any order they would like. Afterwards, there was a small interview. We asked what they liked and didn't like about the museum and illusions, but also if they see any potentials in these types of museums and illusions.

6.5 Results

Five participants tested this demo. All of them were students and had participated before in one or both previous studies.

This museum setting was better received than the museum setups of the previous experiments. The participants appreciated the freedom to walk around in whichever direction they wanted and could get closer to the paintings than before. One participant pointed out that he liked the possibility to walk around, but that it might not be the optimal solution for navigation in VR because of cybersickness. Research about navigation in VR are still ongoing and is an interesting field for not only VR museums, but VR in general. Other participants liked the freedom of movement because they had a certain amount of control over the illusions they see. They liked the interactivity which they miss in real museums and encourages us to make VR museums more interactive and dynamic.

Comments about stylized illusions were mixed. Some called them distracting, while another participant pointed out that it made him feel more connected to the environment of the painting instead of being in a museum. For others, the illusion didn't really add anything to the painting, saying that the change might be too subtle. For the inpainting and extending illusions, some pointed out that they like the swirl texture for the extension transition. One participant mentioned that it fit the van Gogh's painting nicely, but thought that another type of transition like a simple fade would have worked better for the sea painting. This means that the type of transition, or how the transition is being visualized, depends on the painting and is another area which must carefully be considered when creating the best experience. Slight differences in the implementation of the illusions can create a different impact on the experience of the users.

The comments about the 3D objects illusions were mixed. One participant had the feeling that nothing was happening during the snow illusion while another mentioned that the snow illusion hit him emotionally. Two other participants said that the illusions made him more immersed and connected to the people in the painting because the illusion contributed to the feeling of being cold. A participant did mention that he missed the sound of the storm. In the leaves illusion music was being played. The music seemed to affect the feeling people have towards a painting. A participant added that the music made the difference in immersion. Another participant mentioned that the music can bias the user to a certain feeling, which might upset people if they have their own vision already. This indeed happened with another participant who didn't like the chosen music because he had seen the painting before and had already his own vision on it.

The 3D scene illusion was noted as the most immersive illusion. One mentioned that he had the feeling that he was "in an entirely new world, as if you were standing in the painting". Another mentioned that this type of illusion "nails the potential of virtual museums" because replacing a scene is impossible in real museums. The scene switch however, could be distracting from the painting. While some of them needed a moment before they focused back on the painting, others preferred to look around in the new scene. Asking if the illusion have potential to be used for educational purposes, two of them said that the illusion might be used to tell the backstory of the painting or where the painting was painted.

6.6 Conclusion

The 3D typed illusions was found to be the most positively received illusions. These types of illusions are also the types that are very hard or even impossible to create in real museums, but are very doable in VR. The music however, was differently accepted. Some thought it fit the painting well and contributed to the immersion, while others had the feeling that it influenced their feeling about the painting in the wrong way. Choosing the correct music is a delicate task and must be carefully considered.

The participants liked the freedom to walk around. Also, they liked the interactivity of the museum compared to real museums, and would like to have that even more. In future work, having the option to control the illusions might be a way to give the users more interactivity and also make the experience more personal.

Generally, the VR museum was positively accepted. There were some comments about some specific implementation choices which could be improved in the next demo. The sample size was very small but already showed that there are different opinions on certain illusions. However, there was always an illusions they could appreciate. This case is not one to be solved, however, illusions

can be developed to please as many people as possible. This demo showed that there is still a lot of research possible in this area. There are lot of possible illusions that may a benefit to the user. Especially the potentials in terms of education is worth looking into in future work.

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Chapter 7

ACE Demo

This paper is written by Dr. Wolfgang Hürst based on Pilot Study 2. It was accepted by ACE2016.

Using Digital Extensions to Create New VR Museum Experiences

Abstract
The digitization of paintings enables us to do various modifications with it and also to add digital content that complements such artworks. In our research we investigate how such digital extensions can be used in a VR museum setup. This Creative Showcase demo presents a first implementation of such an "enhanced VR museum" based on initial results and related user feedback from earlier experiments. Using techniques such as "inpainting", "stylization" of objects or other visuals in the style of a painting, and adding of content-related 3D animations we aim at creating VR museum techniques that create a better experience by, for example, being more immersive, creating a higher emotional connection, or having an educational value.

Author Keywords
Virtual reality; VR museum; VR experiences.

ACM Classification Keywords
H.5.1. Information interfaces and presentation (e.g., HCI): Multimedia Information Systems; Artificial, augmented, and virtual realities.

Introduction

Virtual reality (VR) offers us various possibilities to not just recreate existing museums, but to modify and add content in a way that has the potential to create

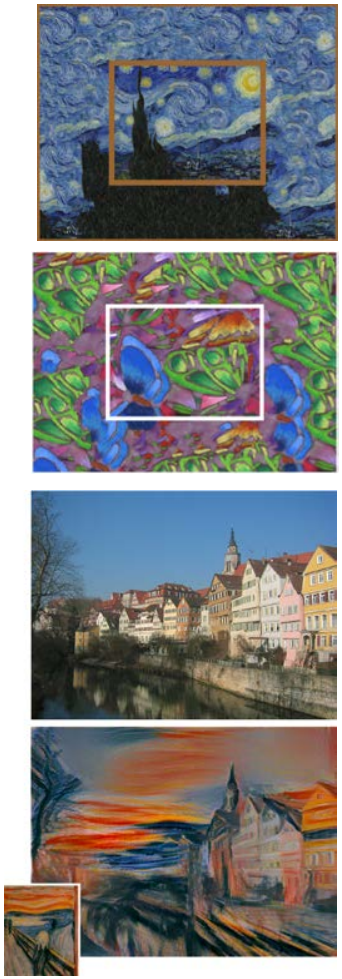

Figure 1: Examples for the inpainting (top, from [3]) and stylization algorithms (bottom, from [1]).

different, new, and engaging experiences. Currently, we see a growing interest in digital manipulation or modification of art pieces and the creation of new art based on existing ones. Examples range from 3D landscapes based on Van Gogh's paintings [2] to applications of a certain painting's style to photographs [1], or automatic "extensions" of paintings via a technique called inpainting [3] (cf. Fig. 1). In our research, we are investigating if and how such digital enhancements, modifications, or new creations of art can be used together with the originating art pieces in order to create different and more immersive VR museum experiences. Interesting questions in this context include: What effects work and how should they be implemented in such a context? Is there an actual benefit or are they just considered "gimmicks" and technical gadgets? For example, can we increase immersion or connectedness to the paintings? Can we use them to teach observers, for example, about the particular style of a painting or its artist?

In a series of experiments, we started to investigate these and other questions. Two pilot studies gave initial indication of the potential of such digital extensions, but also highlighted possible issues and pitfalls. A more formal experiment showed that adding 3D effects to the environment that are related to a painting's content (e.g., falling leaves to a painting of an autumn landscape) have the potential to create a stronger emotional connection to the art, whereas displaying related photographs that morph into a painting's style using the stylization algorithm of [1] could increase one's awareness of style and from. In this Creative Showcase contribution, we present a first demo that takes into account the results from these studies and general comments made by the test subjects. In particular, we show the implementation of a VR museum featuring standard paintings, each with an extension of one of three types of effects: inpainting, stylization, and content-related 3D objects or scenes. We presented our demo implementation to five people who also participated in the aforementioned tests and gathered informal feedback. In the following, we describe the concrete implementation, the different types of effects accompanied by the comments of those five test subjects, and conclude with more general observations and possible future directions to explore.

VR Museum Implementation & Effects

VR museum & implementation

Our VR museum is based on the Unity 3D game engine and implemented for the usage with standard VR headsets such as the Oculus Rift as well as mobile solutions such as Samsung Gear VR or Google Cardboard-style headsets. Fig. 2 illustrates a typical room layout with paintings on the wall. Visitors can freely roam the VR space using a standard controller. Related effects, described below, are active if and only if the user is standing closely to the painting (i.e., within the gray spaces indicated in the illustration).

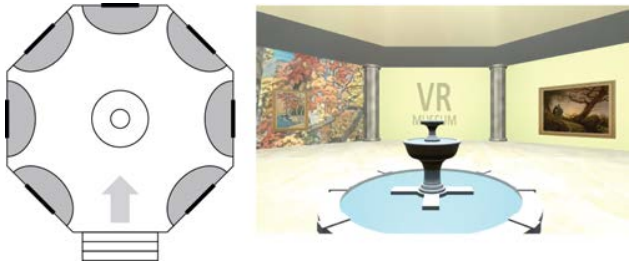

Figure 2: Typical museum room layout.

Figure 3: Example for stylization effect (full wall on top, morphing steps from original photo to stylized version below).

Stylization effects
Fig. 3 shows an example for the stylization effect. For paintings featuring this addition, a real photo of a content-related scene (e.g., trees for a forest painting) is placed on the back wall behind the painting. When approaching the space around the painting, it slowly morphs into the style that matches the one of the original artwork.

Feedback for this kind of representation was mixed. While most liked the idea of creating stylized versions of photos, most were skeptical about representing them behind the actual artwork and some even considered it too distracting or annoying. Although the effect is only activated when being close to the painting, the original photo is also visible at a distance, what some people did not like, but one participant actually noted this as positive, since it can be used to again people's attention.

Inpainting & extended painting effects
Several other paintings were selected that are suitable to apply the inpainting approach for extending their content across the original painting's borders. Fig. 4 shows two examples used in the implementation. Fig. 5 illustrates the transition phase when approaching the painting; the effect was activated using a spiral-style animation. One test user explicitly stated this as positive for the Van Gogh painting, because it nicely matched the painting's structure, but likewise argued negatively about this type of transition for the ocean painting, since it did not relate to the actual content. A blinds-like animation might have been more suited. This nicely illustrates the obvious problem that slight changes in the implementation might have a significant impact on the experience. Yet, overall this effect was well received, with one test person even stating that when being close, "*you get immersed in the painting*" because of the effect.

Figure 4: Examples for inpainting effect.

Figure 5: Transition phase when inpainting gets activated.

Content-related 3D animations added to the room
The third category of effects differed from the above insofar as they featured 3D objects or animations that

Figure 6: Paintings used to be enrich with animated 3D effects.

were related to the content of a painting but placed inside of the VR museum room. Fig. 6 shows to paintings enriched with "season-/weather-related" effects; falling leaves in relation to an autumn painting and snowflakes for a painting featuring people in a snowstorm. Fig. 7 illustrates the actual animations in the area around the painting once an observer gets close enough. Here, we also experimented with sound effects; adding storm noises to the snow storm and fitting music to the autumn painting.

Figure 7: Examples for the 3D effects featuring falling leaves and snowflakes, respectively.

Reactions to both 3D animations as well as sounds were mixed. While, for example, one subject said that "*there was not much happening at the snow effect*", another one stated that "*the effects in the snow painting really affected me emotionally*", made him feel more immersed, illustrating "*the feeling of being cold*" experienced by the warriors depicted in the painting. Likewise, people expressed similarly strong connections due to the music played for the autumn painting, stating, for example, that "*the music added a lot more to the feeling of the painting*". On the other hand, others noted the music as distracting and unfitting and did not appreciate it.

Content-related 3D animations replacing the room

The final effect is the most radical modification because it does not enrich the VR museum room with 3D objects and animations but completely replaces it. Related options include, for example, a virtual landscape that matches the one in a painting, or the painter's studio where it was created. In this concrete implementation, we opted for the first option. Fig. 8 shows the painting without effect, Fig. illustrates the 3D landscape, which also featured some small petals floating through the air and a slightly animated river in the background, and some subtle, fitting background music.

Figure 8: Painting used together with the 3D landscape before the effect is activated.

Not surprisingly, many subjects described this effect as being the most immersive, and characterized it as, for example, "*as if you were standing in the painting*" and one noted that "*the whole 3D scene nails the potential of a virtual museum*" meaning that it embraces the full

potential of VR. While one described the painting as being "*the most important thing*", another subject noted that he was more looking into the landscape before addressing the painting.

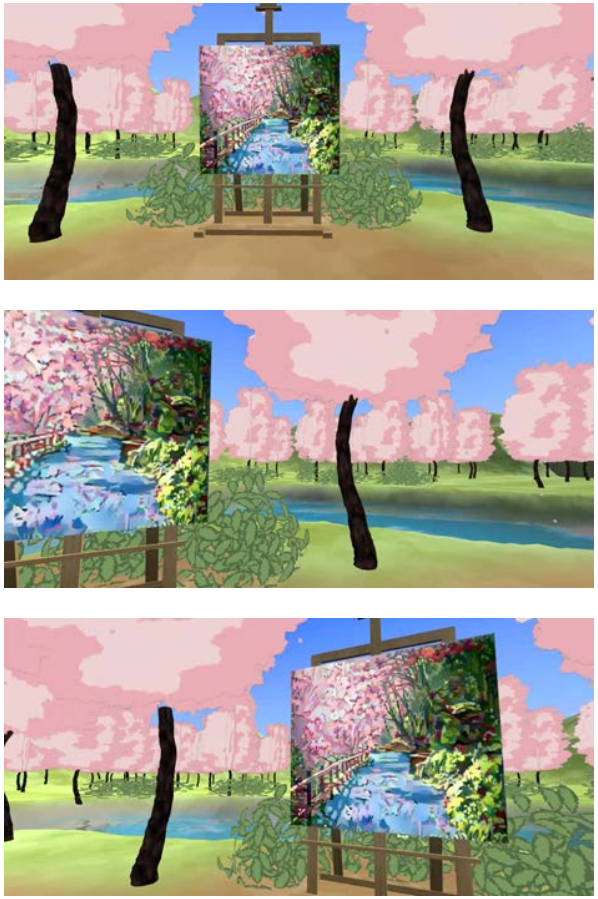

Figure 9: 3D landscape matching the painting and replacing the museum room once people get close enough.

General Comments & Concluding Remarks

As noted in the introduction, this demo implementation is based on results from two pilot studies and a formal experiment, all of which have been taken place in a more controlled environment and not featuring the option to walk around. The subjects who provided initial comments on this implementation all participated in at least one of the previous evaluations. All of them strongly appreciated the option to being able to walk around, to freely explore the museum, and to get close up to the paintings. Not surprisingly therefore, adding more interactivity was mentioned by some as possible good enhancement for future work. Being able to actively control some of the effects might also be a good option considering that appreciation and enjoyment is a very personal experience. Despite the small sample size of just five initial test users, it is obvious that people have very differing opinions about certain effects. The most contrary comments we got were related to the music added to some paintings with some highlighting them as the essential feature for immersion and others totally objecting them. Similar, although less extreme contrary statements were made about almost all effects. Yet, the trend for the 3D effects was overall very positive across participants with minor negative comments more related to concrete implementations. In addition, although preferences differed, none of the five test persons was totally opposed to the effects and each had at least one or more that they truly appreciated and enjoyed. In conclusion, our demo implementation illustrates that there are plenty open and interesting research questions to address in this context, but it also shows that they are well worth exploring by highlighting the huge potential such extensions can have for the visualization and exploration of artworks in VR.

References

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