Tampere University

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USER EXPERIENCE OF INTERACTIVE OMNIDIRECTIONAL VIDEO

Case Hugo Simberg VR

Faculty of Information Technology and Communication Sciences
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ABSTRACT

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Virtual reality technology is gaining popularity and market saturation with new types of head-mounted display devices reaching the market in the recent years. With more conventional uses, such as industrial simulators for flight lessons, the newer technologies have found their way on the consumer market, being used at home for entertainment and gaming. An emerging way to create these types of applications is using omnidirectional video as the basis. These Interactive omnidirectional video applications can be developed comparatively quickly, while still offering some challenges in the development process.

User Experience Design in the field of virtual reality has been gaining more foothold in the field of virtual reality application development. User experience offers a multitude of design frameworks and approaches to find the user needs and to ensure for the best user experience. While this design process is suitable for development on this field, the user experience and design implications regarding virtual reality and interactive omnidirectional remain quite limited.

User Experience design methods were used in a development process for an interactive omnidirectional video application, Hugo Simberg VR, which allows the user to explore a museum and a cathedral virtually. This thesis discusses this undertaken design process, from the initial exploratory design phases to the iterative refining design phases, and the evaluation of the finished application.

The results of the evaluation identified nine experiential dimensions in interactive omnidirectional video, of which six were perceived with positive valence, and three with negative valence. These findings show that these dimensions should be considered in the design of interactive omnidirectional videos.

Key words and terms: Virtual reality, Interactive omnidirectional video, User Experience Design
The originality of this thesis has been checked using the Turnitin Originality Check service

Contents

1 Introduction

In the recent years Virtual reality technology has reached a point, where consumer market devices are increasingly more available and affordable, specifically the head-mounted displays, that have made it possible for everyday users to gain virtual reality equipment in their homes. This increase in popularity in the last few years has made a whole development community that is creating a wide range of experiences in the fields of entertainment, gaming, industrial usage and even in the field of medicine.

The video capturing technology for omnidirectional video, capturing the whole environment around the camera, has also evolved in leaps and bounds. This is shown in an increase in portable and affordable cameras coming to the market and webservices, such as Youtube, offering omnidirectional videos. A development in the area is using these omnidirectional videos to create interactive applications, as they do not require designing computer generated environments, thus allowing for a faster development of the application. This type of application has shown potential in creating immersive experiences with head-mounted display devices (Kallioniemi et al. 2017).

User Experience Design is a process of defining user needs, idea and concept generation and user testing, that has been conducted as a part of digital development for decades, starting with early computer software development. The importance of including user experience design in the development has been understood since the end of 1980s with design industry landmark work, such as Donald Norman's Design of Everyday things (Norman, 2013), pinpointing the necessity of understanding the user. Nowadays user experience design methods are employed in almost ubiquitously in digital product development, with modern frameworks focusing on agile development becoming popular (Gothelf, 2017).

1.1 Research question

While there have been studies into the virtual reality experiences, most of these studies have concentrated on the technical features of the virtual reality systems or singular experiential dimensions, such as presence (Witmer and Singer, 1998). The development of virtual reality applications has previously also concentrated on the fidelity of the technical elements, instead of developing these experiences by concentrating on the users' needs. This thesis looks at how the user experience design process could be used to aid the development of these applications, and what experiential dimensions affect the user in an interactive omnidirectional video application.

1.2 Research Contribution

Interactive omnidirectional video applications have a potential of offering a rich immersive experience. This experience can further be deepened and made very interesting

with the addition of a storytelling aspect. As the development of these applications offers a quite robust and fast way of implementing an application, the process of user experience design should be used in order to avoid any possible pitfalls. Some of these pitfalls can be related to usability, but the necessity of understanding the users' needs is highlighted with the virtual reality technology's capability of causing nausea that is comparable to actual motion sickness (Gavgani et al., 2018).

This thesis identified experiential dimensions that users reported after using an interactive omnidirectional video application. The implication of these findings should be considered when designing a similar application, in conjunction with other guidelines and standards (Saarinen et al., 2017), to make sure the users are being delivered the best possible experience.

1.3 Research context

The development and the evaluation of the interactive omnidirectional video application discussed in this thesis, Hugo Simberg VR, was conducted as a part of the VIRJOX project. This project was a collaboration of the following research groups, with the co-operation of Sanoma foundation.:

- *Human-Centred Technologies* research group of Tampere University's Hervanta campus, -
- *Tampere Unit for Computer-human Interaction* (TAUCHI) and the faculty of Communication Sciences of Tampere University's city center campus,
- *The faculty of Journalism* of Jyväskylä University

The author of this thesis contributed to the project as as a research assistant in the Tampere Human-Centred Technologies research group, and took part in the design of two applications. The author also contributed in the following papers:

- *Assisting immersive virtual reality development with user experience design approach*. (Kauhanen et al., 2017)
- *Impact of device, context of use, and content on viewing experience of 360-degree tourism video (Kelling et al., 2017)*
- *Implications of Audio and Narration in the User Experience Design of Virtual Reality. (Kelling et al. 2018)*

1.4 Thesis outline

The second chapter of this thesis describes the central technologies of this thesis, virtual reality and interactive omnidirectional videos, and the technologies background and identified experiential dimensions that affect the use of these technologies. The third chapter discusses what user experience design is and what the frameworks used in the design process are. In the fourth chapter the implementation process of the application, Hugo Simberg VR, is outlined, while the user study of the application is discussed in the

fifth chapter. The sixth chapter provides the detailed findings of the user study. The seventh chapter discusses the limitations of the implementation and the user study, research findings, and the implications of them to the design of interactive omnidirectional video applications. The eighth and final chapter summarizes the thesis in a conclusion.

2 Interactive Omnidirectional Video

The description of interactive omnidirectional video (iODV) requires to first explain what Virtual Reality (VR) is. VR is sometime explained as a type of technology that can create Virtual Environments (VE), but in his work dating back to the early stages of commercial consumer VR devices, Steuer discusses how VR should further be defined with its capability of creating the feeling of presence in the experience (Steuer, 1992).

2.1 What is interactive omnidirectional video

iODV applications can be used in many types of environments and with types of VR technologies.In his paper of omnidirectional museum applications, Hakulinen discusses the testing of iODV applications on a Head-mounted display (HMD) device and a CAVE installation, and how they rely on creating the feeling of presence (Hakulinen et al,2018).

In contrast to many VR applications, which may have computer generated or are built around a specific interaction technique, iODV applications are based on using omnidirectional videos (ODV) as their basis. Saarinen describes iODV applications as "ODV applications with additional interaction in addition to looking around the scene" (Saarinen et al, 2017). This technology is becoming more widely accessible, since in the recent years cameras that can capture ODV have become more affordable for everyday users.

2.2 History of immersive virtual reality devices

2.2.1 Earlier VR devices

One of the earliest developed viewing devices that was considered device was Sensorama by Morton Heilig, a stationary device where the user would insert their head in an orifice and it gave the user a multimodal experience with screen, smell and sounds (Craig, 2012). While it is considered one of the first VR devices, the first device that was considered a HMD using VR device was developed by Ian Sutherland in 1968 (Craig, 2012). The device was nicknamed Sword of Damocles and required a rig to hold the heavy device up (Figure 1).

NASA's VIEW project (Sherman, 2003) made large leaps in 1980's progress, as the project produced multiple HMD devices. The project's contribution to the field was the creation of new interaction methods and improved viewing technologies (Sherman, 2003) As these HMD technologies were very expensive, they were not directed towards consumers.

Finally, during the late 1980s and the early 1990s gaming and entertainment VR systems also started to appear, including Nintendo's Virtual Boy. While Virtual Boy was not a commercial success (Boyer, 2009), it was one of the earlier VR HMDs marketed to a large consumer audience, showing the way for further development.

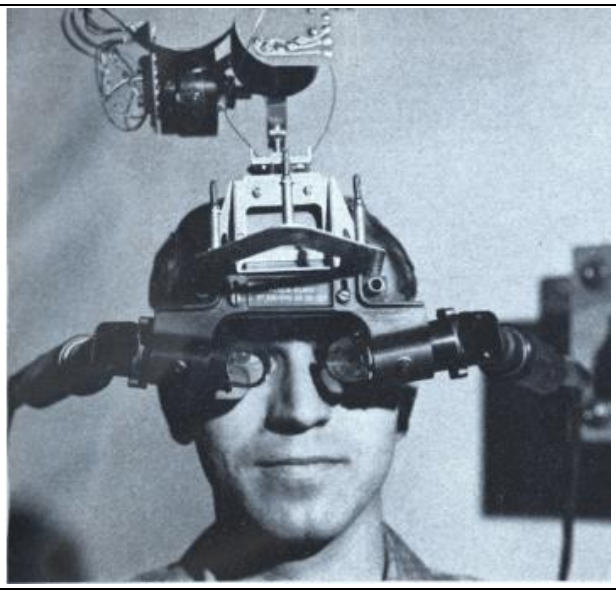

Figure 1. Sutherland's Sword of Damocles (Kostov, 2015)

2.2.2 Current technologies

During the 2010s a more recent wave of VR devices started to come to the market. One of the more known devices of this new wave of VR technology was Oculus Rift (Figure 2). This new wave of HMDs had noticeably two different types of HMD approaches. The first type is the computer attached dedicated HMD's, such as the just mentioned Oculus Rift.

The first type of devices acts as the screen in the VR experience, allowing for more computational power for the graphical performance. Most of these types of devices coming with wirelessly connected controllers for interaction in the VE. While the market does have some wireless solutions for these types of devices, most of them need to be attached to the computer via wire.

Figure 2. Oculus Rift DK1. (Maher, 2017)

The second type of HMD devices currently on the market, the smartphone based, is more related to this thesis. An example of this type of device is Samsung Gear VR (Figure 3), which was used in the study described in the evaluation chapter. This type of device uses a smartphone as a screen and to power the experience. Due to this, this type has limited performance on the visual quality, while they offer a wireless usage, allowing the user to move freely.

Figure 3. Samsung Galaxy X (Samsung, 2019)

2.3 Dimensions of experience

In earlier work on the same topic, based on earlier literature and initial user testing, a group of dimensions of iODV experience (Kauhanen et al., 2017). These experiential dimensions are: Presence, Immersion, Disorientation, Sense of Agency, Exploration and Simulator Sickness. This list of experiential dimensions is not exhaustive, as much of the research on the field has been concentrating on the pragmatical features of the technology

- A concise explanation of the **Presence** is "a state of consciousness, the (psychological) sense of being in the virtual environment" (Slater and Wilbur, 1997). This dimension is ubiquitous in the iODV experience, as on top of relating to the level of "being there" the user feels, it also is connected to the level of immersion, how engaged, and involved the user feels in the experience (Slater, 2003). As discussed earlier, presence has been described as the central experiential dimension of all VR technologies (Steuer, 1992).

- While presence is considered the subjective feeling of being in the VE, **Immersion** is described as the extent of feeling of reality the technology can provide (Slater and Wilbur, 1997). Bowman and McMahan broke down CAVE and HMD produced immersion down to Field of Regard, the size of the visual field, level of stereoscopy, and headtracking capability (Bowman and McMahan, 2007). While much research has concentrated on the visual aspects of the immersive technology, in earlier work on the same topic, it was noticed that audio also played an important role in the immersion (Kauhanen et al., 2017).

- As the user is immersed in the environment, it was identified in earlier work (Kauhanen et al. 2017) that test participants made mentions regarding results of their actions. **Sense of Agency** could be described as the feeling of being in control and understanding the consequences of their own actions (David et al., 2008). It was noticed that the participants' experience was affected negatively, if the application was not responding to their actions.

- Many VR experiences allow the users to explore. In previous user testing, it was identified the participants wanted to explore the VE naturally without having been given a direct task to explore the environment. Lepouras and Vassilakis had found, that on top of simple intrigue, the exploration in a VE even facilitated for the learning experience (Lepouras and Vassilakis, 2005). This showed that the inquisitive nature of humans makes VR technology great for facilitating for exploring new environments.

- One big concern with VR experiences is the user becoming nauseous while using VR devices. This nausea has been identified in research for decades, with Kennedy and colleagues devising a standardized test for level of simulator sickness (Kennedy et al., 1993). Causing nausea is highly destructive for an experience. For example, in user testing situations it would be a cause for stoppage. While caused by VR technology, the symptoms of this Simulator Sickness, or Cybersickness, has been proven to show the same symptoms as motion sickness (Gavgani et al., 2018).

3 User Experience Design

Modern digital development projects include many approaches and tasks. As the digital products are getting increasingly complex and computer, mobile and related technologies are becoming more ubiquitous, the User Experience (UX) design process is applied to make sure the user experience, as the name of the process implies, is optimized. UX design is employed in these the development process by using a broad set of methods and tools to make sure the developed products meets the user needs.

This chapter first describes what UX design is, before discussing what kind the processes are used in UX design work, and what type tools and methods used. Finally, the use of UX design process in the VR development is discussed.

3.1 What is UX Design?

While consisting of a recognized set of methods and tools, UX design is a process to make sure that the experience of a system or a product offers the best experience for the user. As a part of their standard for Human-Centred design (HCD) for interactive systems, the international organization for standardization states the user experience is “person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service” (The International Organization for Standardization, 2010). The definition shows that the design process’ moniker is very all-encompassing to how the user of a system or a product feels about their experience.

As stated in the standard, designing the experience is considered a part of human-centred design, which also consists of user interface (UI) design and different validation methods (The International Organization for Standardization, 2010). What this means, is that most, if not all, UX design processes consist of many tasks that are classically considered “Design”, such as the creating UI, with analytical approaches to make sure the elements and the users’ interaction with them offers the best experience.

As it is very rare to find two projects that have the exact same aims, tools and targeted user groups, the specific process frameworks and tools used in the UX design process differ by project.

3.1.1 Design processes

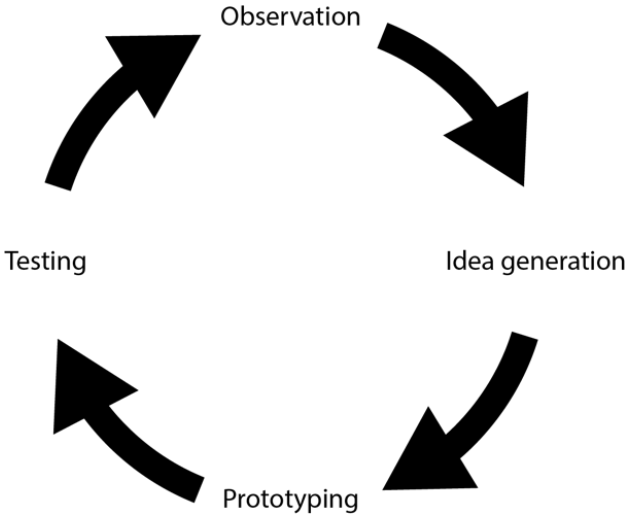

Figure 4. HCD process (Norman, 2013)

While UX design is described as a process, it does not have a set single process that it follows, whereas there is a history of different design processes that are used in the UX design work. UX design is considered a part of Human-Centred design, the cyclical HCD process (Figure 4) can be seen as a basis for many UX related processes, where iteration allows for confirming ideas with user testing. Design often takes part throughout the development of digital products. At the early stages it concentrates on the gathering information with different methods before generating ideas, after which the ideas are prototyped and tested (Norman, 2013). In the early 2000s the UK design council published a broad design process that shows the investigative nature of the design process (UK Design council, 2019). This double diamond (Figure 5) is also used as the basis for many later processes due to its convergence-divergence approach. Both of these more general design processes offer a highly flexible approach and simple structure that allows practitioners to use as a guideline to build new UX design frameworks.

One popular framework in UX design currently is Lean UX. This framework concentrates on responding to change over a structured plan, and collaboration with all stakeholders, including designers, developers and customers (Gothelf, 2017). The approach of concentrating on responsivity allows the development to modify methods, tools and ideas, if issues are identified during the development, and collaborating increases common understanding with all parties, while also allowing to avoid some possible communication issues (Gothelf, 2017). The main difference to the earlier presented processes that Lean UX offers, is the Minimum Viable Product (MVP) (Gothelf, 2017). The MVP concept allows the development team to create a ready viable product that only includes the needed features, instead of taking a longer time to create a product that includes all features. This allows the development team to take on issues and

implement the lower priority features in the next cycle phase, while it also facilitates for testing the most important features with end users in the market.

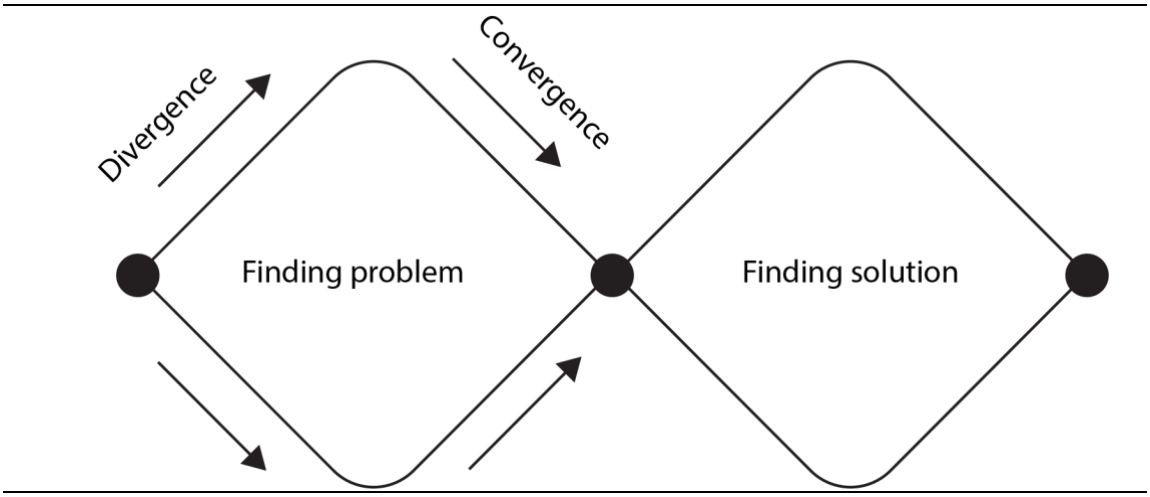

Figure 5. Double Diamond process (UK Design Council, 2019)

3.1.2 Methods and tools

When it comes to tools and methods, UX design has a vast amount of choices for different contexts and scenarios. As a concise description, these methods can roughly be divided into three areas: User research, Idea generation, and Concept & Visual design.

User research is a used in the UX Design process in two main areas, identifying user needs (Norman, 2013) and validating or testing ideas (Faranello, 2016). The research to map the user requirements, which can be conducted with different research methods, such as observation, but also needs to be visualized in different methods, such as Journey mapping (Szabo, 2017) or creating user personas (Faranello, 2016). The validation methods can often include questionnaires or interviews (Lang and Howell, 2017), to collect quantitative or qualitative information, to see if the users are satisfied with the different aspects of the experience, such as usability or other pragmatic features of the product (Thüring and Mahlke, 2007). The idea generation methods tend to involve stakeholders in the development process. These cocreation methods are often employed in workshops (Hamilton, 2016), and are used to gather as much ideas as possible in the initial stages of the process, as the divergent nature of finding solutions (Figure 5) benefits from quantity in finding the best solution. The tools for concept and visual design for digital products could be considered the more conventional, including a host of UI tools, from wireframe drawing to digital tools, such as Adobe Creative suite programs (Faranello, 2016), which are used for the visual execution of designs and communicating the designs to the development. While these tools can be collaborative on some levels, they’re generally more concentrated on a single person implementing the designs.

3.2 UX Design research in the field of Virtual Reality

As discussed in the previous chapter, much of the research in VR has been concentrating on the technical fidelity or specific dimensions of the VR experience. In recent years, research concentrating on more general experience, or context related experiences in VR usage have started to appear. One example of this is Kuo-Wei su and colleagues' work on the UI and UX of VR discusses different testing methods that were applied from mobile application development, and how UX design had a positive influence on UX (Su et al., 2019).

With the advent of HMDs that use smartphones to power the VR experience, UX research has also started to look on the environmental effect on using VR. Kelling and her colleagues conducted a study on how the context of use affected the user experience when viewing ODV (Kelling et al., 2017), and Schwind and his colleague researched the social acceptance of HMDs and how the user's peers perceived the user in different contexts (Schwind et al., 2018).

4 Design and Implementation

This chapter describes the iterative design and implementation process of the ODV application used for the study. The application called 'Hugo Simberg VR' was designed and developed in order to evaluate the resulting user experience. As the thesis concentrates on the user experience and studying what the experiential dimensions of iODV are, the chapter concentrates more on the design tasks undertaken.

The first section explains the design approach and the steps taken during the process, as the iterative process included two main iterative cycles to reach the final application. The second section discusses the design methods used to specify and create the content for the application, including the workshops, benchmarking, and the different stages of prototyping. The final section details the application itself, and the technical iterations it had during the process.

4.1 Design approach

As the application was experimental in nature, the design process needed to allow for as much exploration as possible in the initial phases and iterative improvement in the later phases. For the first parts of the design and development, where the application was ideated and the MVP was developed, the followed process (Figure 6) was similar to Liedtka's model, as it quantifies the process into smaller phases (Liedtka, 2011). This process follows the diverging and converging phases, of the double-diamond design process (Figure 5) discussed in previous chapter. The latter parts, where the application was refined to suit earlier user research findings (Kauhanen et al., 2017), followed process more similar to Lean UX Startup process (Klein, 2013). The latter process was suitable for the refinement, as it follows a cyclical approach that improves the application attributes and features on findings (Figure 7), which has a similarity to the HCD process discussed in chapter 3 (Figure4).

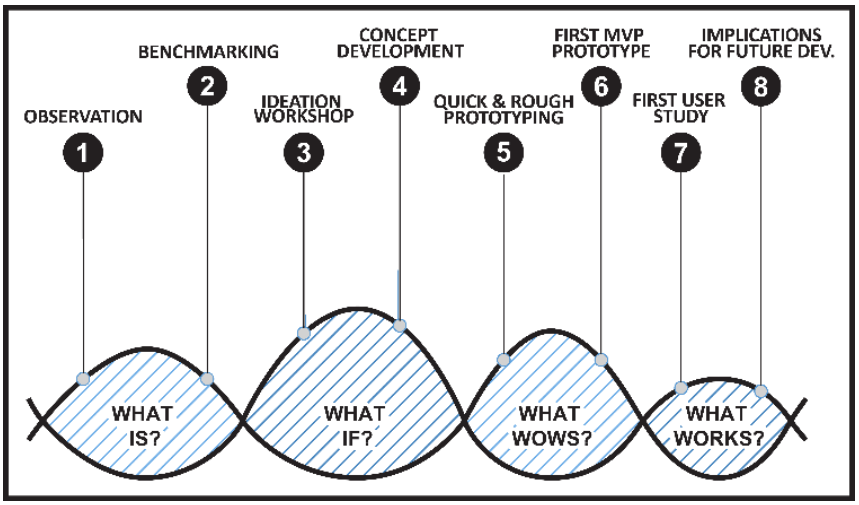

Figure 6. Initial design process

The initial design process was divided into four main phases (Liedtka, 2011): What is, What if, What wows, and What works. The first phase “What is?” concentrated on getting to know the field of topic at hand and benchmarking other applications and experiences that are in a similar topic or similar elements. The next phase, called “What if?” included more ideation and concept development tasks, to create an abundance of viable ideas and prioritizing them. Penultimately, in the “What wows?” the priority ideas are tested in quick prototyping methods to test the best idea in a way that shows the idea in a concrete way, and then produce the initial MVP for the application. Finally, the MVP was tested and evaluated in the “What works?”-phase to find required changes to improve application further.

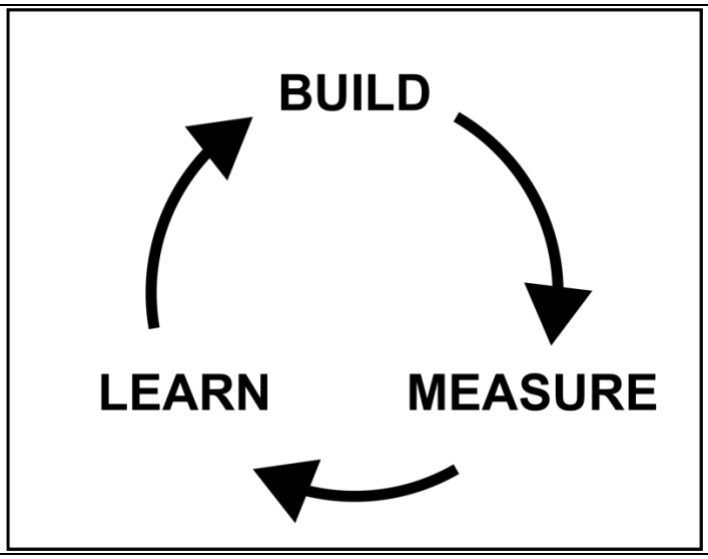

Figure 7. Lean UX process

The process that was followed in the latter stage was the Lean UX startup cycle, that focuses on fast iterations and improving in each cycle (Klein, 2013). The cyclical design process was included in the implementation of the application, as the initial findings (Kauhanen et al., 2017) showed that the application needed additional features and the functionality needed to be refined. This refinement was done in two main cycles after the initial user research (Kauhanen et al., 2017).

4.2 Concept creation and development

The topic and the museum setting was decided at the beginning of the project in a workshop. Six participants were briefed of the chosen setting, art museum Ateneum, and of the possible topics. The workshop followed the Ideas Cascade method (Hamilton, 2016), where the participants wrote down ideas on post-it notes in rounds, before passing them to the person to their right. After five rounds, the ideas were discussed and voted to

prioritize the most viable ideas. The result of the workshop concluded with the topic being artist Hugo Simberg, and his life.

4.2.1 Initial design process

To get familiar with the artist and the museum, short observation was conducted at the museum. The observation was to see how the public interacted with artworks in the museum. The findings of the observations were that people watch a single artwork piece separately, while moving only after viewing the artwork.

To see what other similar applications and experiences there were, the first step of the project was benchmarking said applications to find shared attributes and elements. The benchmarking was conducted to find guidelines for designing the application.

The chosen applications were: Boulevard (Boulevard, 2017), Night Café (Borrowed light Studios, 2015), and We Wait (BBC, 2017). The benchmarking was conducted in group by five members of the project and the findings were concurred in group discussion.

Boulevard is a virtual art museum visiting experience that allows the user to see well known art pieces and gain information about them (Boulevard, 2017). It was chosen due to the art viewing experience it showed, as it concentrated on imitating an art museum visit as integrally as possible. Night Café (Borrowed light Studios, 2015), on the other hand, showed a more experiential approach to the showing art in VR. It shows the world of its moniker art piece "Night Café", by Vincent Van Gogh. The VE replicates the texture of the art piece's strokes, and allowing the user to explore the café, while it didn't explain any information related to the art or the artist. The Final experience, We Wait (BBC, 2017), immersed the user in the experience of a Syrian refugee. While the experience's graphics were done in a low-polygon animation technique, it concentrated on journalistic storytelling, creating much of the immersion with the audio.

The main findings of benchmarking these applications were:

- The application should allow a level of free roaming. In Night Café, the user was allowed to roam the space freely, and all of the group members mentioned how finding the café's basement caused feelings of achievement.
- Audio is important in creating the immersion. While the graphics in We Wait were made in a low detail animation, the group members still mentioned feeling immersed in the story and the environment. The experience's audio used environmental sounds and the narrator to deepen the immersion.
- The experience should include as little text as possible. The textual information elements in the VE of Boulevard were considered hard to read and the group members mentioned eyes feeling tired after reading in the experience. This could have been caused by the resolution limitation of the technology.

An ideation workshop with the same six participants was conducted after the benchmarking had been finished. In this workshop, the same workshop method, ideas cascade (Hamilton, 2016) was used. The goal of the workshop was to create starter concept ideas that concentrate on the life of Hugo Simberg. The ideas were then gathered and refined into a selection grid, shown in earlier publication of the project (Kauhanen et al., 2017) that allowed the group to select one idea to go forward with. In the process of refining, the ideas were prototyped in a method of drawing the room with 360-degree sketching templates (Kurbatov, 2017), that allowed to see how an interactive element or a transition within a space could look in a VE (Figure 8)

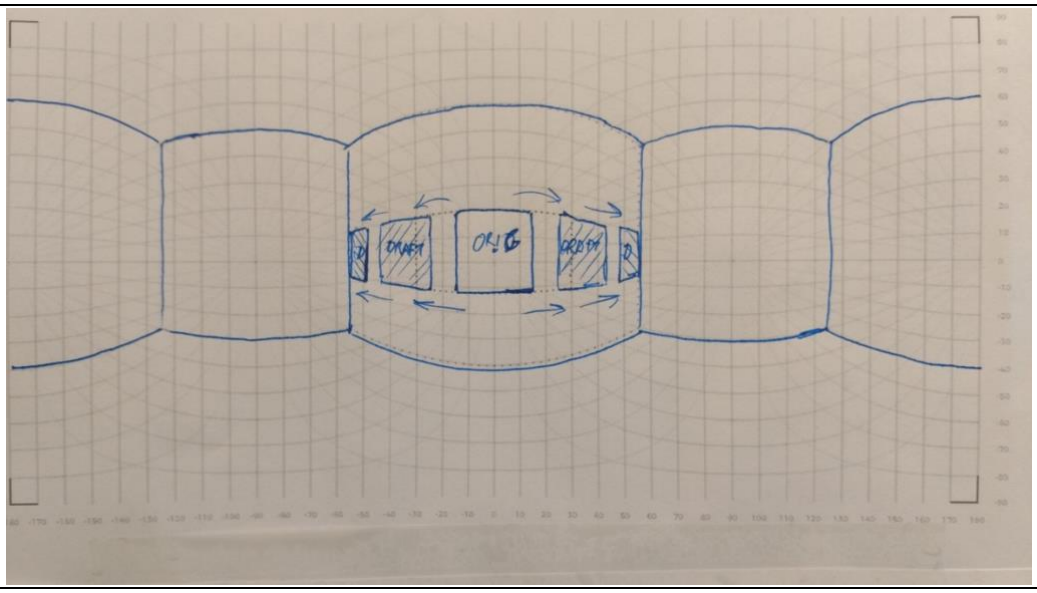

Figure 8. 360-degree sketching template

The concept was to allow the user to roam the museum freely and seeing works by Hugo Simberg, while a narrator would tell how these works related to the artist's life. Also, the idea included a transition to the Tampere Cathedral, as the artist had made murals in the space. The selected idea would use interactive omnidirectional video technology (Saarinen et al., 2017), that had been developed at the research unit TAUCHI of Tampere university.

4.2.2 Further design and implementation

During the initial design and implementation phase the application's basis functionality and concept were created and tested, while later phases concentrated on refining the quality of the experience. The iterative correction of flaws and addition of needed features that were identified earlier (Kauhanen et al. 2017) was a part of this refinement. Some of these changes included addition of background music, improved image quality, more consistent VE scene viewing locations, camera height, and a better produced narration.

The final experience consisted of 10 scenes, 7 of which were in the museum and 3 in the cathedral. The initial viewing area was the entrance of the museum and included an explanation of the application's content and how it was operated, while also encouraging the user to explore the area. The museum main hall and the cathedral had narration regarding the artist's works on display in the environment, while in the scene of the mural Garden of Death in the cathedral the narrator explained to the user that they had reached the final scene, and could continue looking around, but could also end using the application. The background in the museum was Beethoven's No. 8 in C-minor Pathetique, and Cantata BVW 127 by Bach played in the cathedral.

4.3 Application

The iODV application was Android based and was implemented with a development toolset that was developed at the TAUCHI research unit of Tampere University (Saarinen et al., 2017). It utilizes Unity's VR development tools and a NodeJS backend. The application type was chosen, as it allowed the easy use of 360-degree video and picture footage, that could be used to create the scenes. The unity base allowed the addition of interactive elements in the environment, that trigger movement to another viewing point. The chosen visual materials were recorded with a 360-degree camera with the resolution of 7744x3872, for the best possible image quality. The works of art by Hugo Simberg were also enhanced by editing high resolution images into the 360-degree images, for an optimized viewing quality for points of interest.

Figure 9. Application view with centre of the view of view marked

4.3.1 Interaction Technique

The interactive elements in the application activated with the user's gaze. The application did not include or utilize eye-tracking technology, so the gaze interaction worked by tracking the center of the field of view (FOV). The figure in previous page (Figure 9) shows the size of the interactive area in the center of the FOV. Upon overlapping the interactive area at the center of the FOV with an icon (Figure 9) the viewing point would move to the position of the pointed icon. To give the user feedforward of the icon being activated, the icon would enlarge by 30% slowly for one second, before activating.

5 Evaluation

This chapter first describes the approach and the aim of the study undertaken in this thesis. Then it discusses the methods and metrics that were used. Penultimately, the design of the evaluation is detailed, including information regarding participant demographics, the study apparatus, test conditions and environment, the task of the evaluation and the procedure of the study. Finally, the statistical tests and the interview data analysis methods used to evaluate the significance of the collected data are described.

5.1 Research Question

The study was iteratively based on an earlier study using an earlier version of the VR application (Kauhanen et al., 2017), where a group of affecting experiential dimensions where identified. Though many of these experiential dimensions, such as Immersion (Slater, 2003) and Presence (Steuer, 1992) have been investigated, a lack of broader understanding to the experiential dimensions of immersive reality was noticed in our earlier research, and thus the study's main goal was to identify these dimensions and their general effect on the experience.

The study had a two-fold approach to evaluating findings:

1. Interview: What is the subjective experience of an interactive iODV? As each participant will have subjective differences to their experience, their experiences were chosen to be via more qualitative methods, where the participants comments would lead towards the findings.
2. Questionnaire: Are there objective experiential differences between user groups? Some of the experiential dimensions had been well researched by the research community and had been further confirmed in an earlier study (Kauhanen et al. 2017). These dimensions could be used for an objective inquiry via questionnaire to see possible differences between participant groupings, such as their History of VR usage and Attitude to Technology.

5.2 Research Approach

Many VR related user studies are experimental in nature, concentrating in a limited number of experiential dimensions or interaction methods. Experimental methods investigate causal relationships in pre-set variables, via identifying how a change in one variable can affect another. Studies conducted in the experimental research approach tend to study the effect of a single dimension, such as Witmer and Singer's study into Presence in VE (Witmer and Singer, 1998).

As the user study was an inquiry into the overall user experience in VR, descriptive methods were found more suitable for this thesis. Descriptive methods, such as interviews with open ended questions, were chosen, as they allow using grounded theory (Strauss

and Corbin, 1994) to make findings based on the user comments, instead of pre-set questions. An example of a descriptive study for this type of approach is “Effects of Viewing Condition on User Experience of Panoramic Video“ by PJ Passmore and colleagues (Passmore et al., 2016), where the researchers combined asking the participants verbal questions and a written questionnaire to find themes surrounding the user experience of panoramic video.

5.3 Research Methods

The chosen two evaluation methods of the experience are described in this section. It explains the reasoning behind the chosen questions for both the subjective (interview) and objective (questionnaire) methods.

5.3.1 Interview

After viewing virtual reality experience, the participants were interviewed with a semi-structured set of questions. The first question was to ask the participant was feeling nauseous, after which the participants were asked about their experience. The first question allowed the conductors gauged of the participants’ wellbeing, and if they could continue the interview and questionnaire part of the study.

The second question was a starter question “What feelings, thoughts and ideas arose when using the application?” (Jumisko-Pyykkö and Utriainen, 2011). The question was used to start a conversation about the participant’s experience, during which the conductor questions arose from the participants answers.

5.3.2 Questionnaire

The questionnaire asked the participants’ opinion on 21 statements on a Likert scale of 1-5 (1=Disagree completely, 3=Neither Agree or Disagree, 5=Agree completely).

Due to the nature of the study, many of the statements were found from multiple sources. As studies in the field of VR tend to concentrate on a more specific experiential dimension and there is a lack of a holistic experience questionnaire. Some of the questions were also included to support the project’s cross-functional team and were more useful for Journalistic use. The statements were directed towards responses within different experiential dimensions.

The statements regarding emotional response were chosen to see the participants response to see if the experience is enjoyable and positive. The included statements regarding general user experience, such as Pleasantness (Q2) and Ease of Use and (Q4) (Thüring and Mahlke, 2007). The participants were also asked if they would recommend the experience (Q3), if they would like to see more similar content (Q17), and if they would use similar VR applications in spaces, such as museums (Q18-21) (Jumisko-Pyykkö & Vainio, 2012). The participants were also asked if they felt a sense of Agency (Q8) (David et al., 2008).

Statement #	Statement	Experiential Dimension
Q1	I'm interested in Art	n/a
Q2	The experience was pleasant	Pleasantness
Q3	I would recommend the experience to my friends or loved ones	General emotional response
Q4	Using the application was easy	Ease of use
Q5	Moving from one view to another felt logical	Disorientation
Q6	I felt I was there in the spaces represented in the experience	Presence
Q7	I was aware of my surroundings while I was exploring the virtual environment	Presence
Q8	The consequences of my actions had expectable outcomes	Sense of Agency
Q9	The environment I visited left an impression	n/a
Q10	The transition from the museum to the cathedral felt natural	Disorientation
Q11	I felt myself nauseous during or after the use of the application	Simulator sickness / Nausousness
Q12	The music was pleasant	n/a
Q13	The narration was interesting	n/a
Q14	I felt I was immersed in the story	Presence
Q15	I would like to get to know the story in more depth	Presence
Q16	The image quality was good	n/a
Q17	I would like to get to know other works of art and their makers in similar fashion	General emotional response
Q18	I would use a similar VR application at home	General emotional response
Q19	I would use a similar VR application at a museum	General emotional response
Q20	I would use a similar VR application at a cafe	General emotional response
Q21	I would use a similar VR application in education facilities such as classroom or library	General emotional response

Table 1. Questionnaire statements

The questionnaire also included statements that were more pinpointed towards the VR specific experiential factors identified from the literature or previous study (Kauhanen et al., 2017). The statements about presence were concentrated on two different types of presence. Witmer and Singer's study (Witmer and Singer, 1998) discussed on Sense of Presence in VE (Q6 and Q7), while Schubert and colleagues' study (Schubert et al., 2011) concentrated on the Sense of Presence in the story.
The participants were also asked of the more negative aspects of the experience, such as feeling disorientated (Q5) (Ahuja & Webster, 2001), and Nausea or Simulator Sickness (Q11) (Kennedy et al., 2009). These statements represent experiential dimensions that can ruin the experience for a user. For example, nausea can halt the experience completely as it can cause harsh negative physical reaction.

5.4 Experiment Design

5.4.1 Test environment

As the two preliminary studies were done in a public place, which lead the participants to be distracted by noise and other external factors, it was decided that the study should be conducted in controlled environment. The laboratory used in the study is called "SimLab", a studio isolated space of approximately 5-by-5 meters and is dedicated for virtual reality use. A swiveling chair was placed in the middle of the room for the participant to sit in during the test. The space also had a table and a chair for the participant to answer to a informed consent form, and a pre-test and a post-test questionnaire.

5.4.2 Participants

The study was conducted with a convenience sampling of 21 participants. The participant recruitment was conducted via Social media and Email lists, such as student guilds, faculty mailing lists and local Facebook groups. Participants were offered a Cinema ticket (worth 10€) incentive for participation. Participant demographics are shown in the table below (Table 2).

5.4.3 Test apparatus – Hardware and Software

The testing apparatus was a Samsung Galaxy S7 smartphone, running on Android Nougat 7.1 operating system, that was inserted in a Samsung Gear VR SM-R323 Virtual reality headset (Figure 3). Connected to the phone were a pair of On-Ear headphones, connected to the smartphone via Bluetooth. For wearing comfort, the device had adjustable straps on the horizontal radius and on the top of the head. The participants could also adjust the lens focus via a scroll on top of the device and the sound volume with volume up and down buttons on the side of the device.

#	Gender	Age (Years)	Attitude to technology	History of VR usage
1	Female	26	Early majority	No previous usage
2	Female	22	Early adopters	Used 3-5 times during the last 30 days
3	Female	40	Early majority	No previous usage
4	Female	24	Late majority	Has tried once or twice
5	Female	40	Early majority	Has tried once or twice
6	Male	23	Early adopters	Has tried once or twice
7	Male	28	Early adopters	Used 3-5 times during the last 30 days
8	Female	24	Late majority	Has tried once or twice
9	Female	26	Late majority	Has tried once or twice
10	Other	27	Early majority	Has tried once or twice
11	Male	57	Late majority	No previous usage
12	Female	21	Early majority	No previous usage
13	Male	26	Early adopters	Has tried once or twice
14	Female	24	Early majority	Has tried once or twice
15	Female	41	Early adopters	Used 3-5 times a week last month
16	Female	26	Early majority	No previous usage
17	Female	26	Late majority	Has tried once or twice
18	Male	28	Late majority	Has tried once or twice
19	Male	20	Early majority	Has tried once or twice
20	Male	33	Early majority	No previous usage
21	Male	27	Early majority	Has tried once or twice

Table 2. Participants

The application, which is discussed in detail in previous chapter, was a unity based Android software for Samsung Gear VR, which included two spaces that had been converted into virtual environments: Ateneum, Finland's museum of Art history, and Tampere Cathedral. Both of the environments had scenes the participants could go to and view their surrounds. The locomotion within the scenes was achieved by pointing the center of the HMD field of view at marked areas on the floor (Figure 10). The participant could choose the scenes they moved to freely.

Figure 10. Orange interaction element in VR scene

The environments had background music and narration in some of the scenes describing the phases of Hugo Simberg's life and art. The background music for Ateneum was Beethoven's no.8 C-minor Pathetique, while the music in the cathedral was Bach's Cantata BW 127.

5.4.4 Tasks

As the experiment was conducted as an inquiry to the experiential components of the UX of IODV, the experiment did not have a strict task for the participants to actively complete, so that it would allow the participants to use the testing HMD and application as naturally as it is possible.

The participants were instructed to explore the VE freely and could stop using the application and remove the HMD when they felt they had seen everything, due to wanting the participants use the application at their own pace. While the application had a final scene, which informed the participant of having seen everything, the participant could still keep exploring the environments further.

After the participants felt that they had seen everything, they would remove the HMD.

5.4.5 Study Procedure

The study procedure was estimated at a maximum of 30 minutes for each participant. After welcoming in, the participants were informed of the project and the research's aims, and of the study's aims and any risks involved, and their rights. The participants were then asked to verbalize their thoughts, following the think aloud protocol, during the study situation. After the verbal explanation, the participants were given an informed consent form, that explained same details, and also asked for permission to video and record the study (Appendix 1).

The participants were then demonstrated how the testing apparatus is worn and operated. After the demonstration, and before giving the equipment to the participant, the participants were informed of the symptoms of simulator sickness (Kennedy et al., 1993), and how they should inform the conductor immediately upon experiencing any of the symptoms, so the test could be stopped. The participants were then given the apparatus to use.

The VR experience started with simple instruction on how the application is operated, such as locomotion. The conductor's task during the use of the application was to write down any remarks made by the participant, and assist the participant, if need arose. After reaching the scene furthest from the starting point, the application told the participant they had seen everything they needed to, and they could stop using the application or they could keep exploring the experience further. The estimated time of use for the application was 5 minutes, but it was expected that some participants could take less or more time.

After the participant decided they were finished, they were told to remove the HMD, and were assisted in removing the device if they needed help. The conductor then inquired if the participant felt nauseous, and in a case of nausea, the participant would be asked if they feel capable of continuing with interviews.

The interview was semi-structured and started with the question "what thoughts, ideas and emotions came to your mind?", and the rest of the interview questions were formed as a response to the participant's statements. The conductor also could ask questions regarding the experience if they noticed the participant had been struggling with using the application or asked for help.

The penultimate part of the procedure was the post-test questionnaire (Table 1), in which the participants were asked for responses to statements regarding their VR experience.

Finally, the participants were asked if they had questions regarding the study or the project and were offered the promised participation reward of cinema ticket.

5.5 Analysis methods

This section details the methods undertaken to analyse the study's results. As discussed earlier in this chapter, the study included both objective (questionnaire) and subjective (interview) gathering methods for the findings. The datasets were analysed separately, as their results were not dependent on each other.

5.5.1 Questionnaire

The objective results were initially looked at general result to see the general response to the statements from all the participants was of a positive or negative scoring. Secondarily the questionnaire results were analysed in a non-parametric method to find if there is correlation with the responses of different groups (History of VR usage, Attitude to

Technology, and Gender). The non-parametric method of Kruskal Wallis H-test (Fletcher and Weiss, 2005) was chosen instead of parametric, as the sample size was small (21) and the results came from the same testing method.

5.5.2 Interview

The participant comments were transcribed and made into individual statements. The process of creating statements also included first having all the digital transcripts' sentences being put to individual items, and then reading though and separating the viable statements. The criteria for a statement to be included was that it was related to the participant's experience or described a feeling or thought.

As the interview was semi-structured, with only a leading question at the start, the statements were analyzed with grounded theory (Strauss and Corbin, 1994) approach, where the findings arise from the comments. The comments were then sorted with two analysis methods, the Structural (Saldaña, 2009) and In Vivo (Saldaña, 2009). The initial method was the Structural, where the comments were sorted into larger categories that had joining themes, such as talking about the application's usability. Then, using the In Vivo method, the comments were coded with words that they included, such as "responsive", to group the comments into subgroups that had more detailed descriptions and give more insights into the interview results.

The sorting was done in three stages, where they were initially grouped by the conductor of the study, after which they were reviewed by a group of 3 people, including the study conductor, and finally they were sorted by the study conductor and another person.

6 Results and Findings

This chapter describes the results of the study discussed in the previous chapter. As there were two sets of data collected during the study, the chapter entails the analysis of both the questionnaire and the interview results. The first results and findings to be described is the questionnaire data, which concentrates on the general negative and positive scorings and the non-parametric test findings. The latter section of this chapter describes the analysed results from the interviews.

6.1 Questionnaire results

The questionnaire results are divided into four sections for an ease of describing the findings. The first three sections discuss the general positive-to-negative scoring of different statement areas: Emotional responses and User experience (Figure 11), VR specific responses (Figure 12), and Negative and Physical responses (Figure 13). The last section discusses the results of non-parametric tests that were conducted.

6.1.1 Emotional responses and User experience

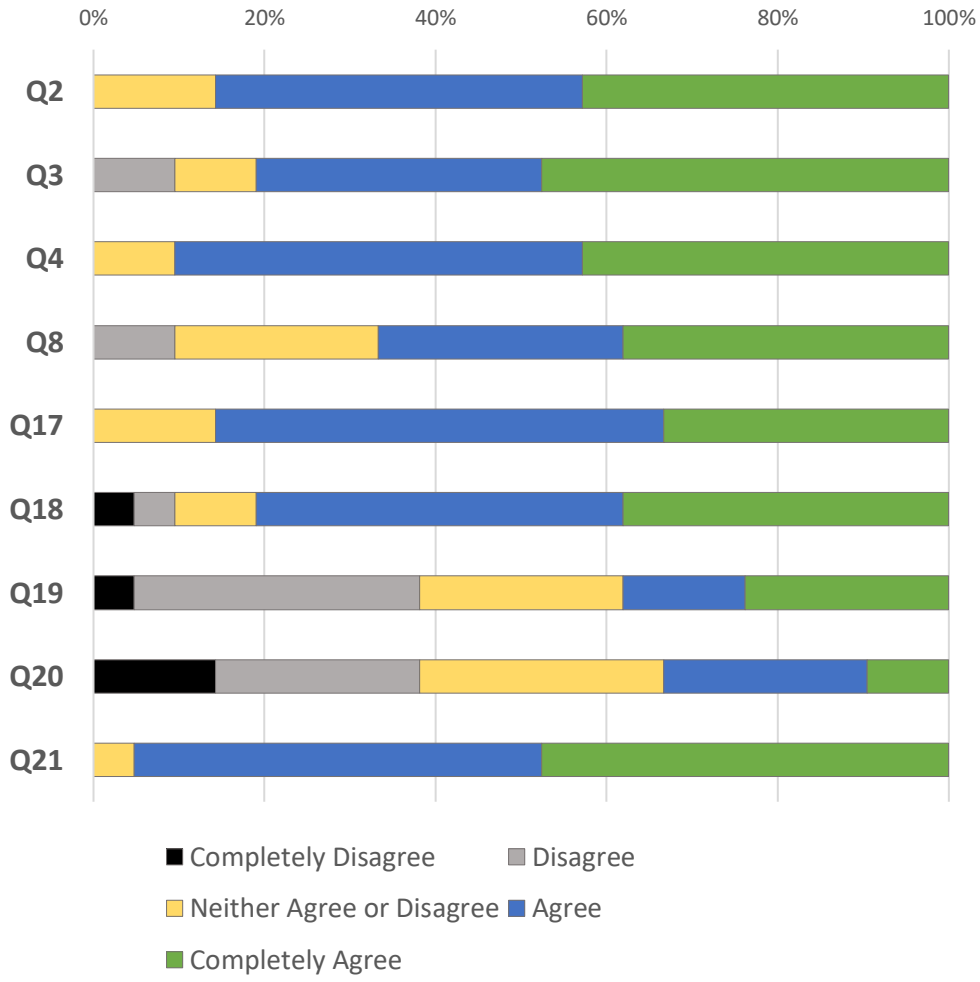

Figure 11. Emotional responses and User experience

The results regarding the user experience (Thüring and Mahlke, 2007) indicate that the participants found the experience pleasant (Q2, avg.=4.3, mdn.=4) and easy to use (Q4, avg.=4.3, mdn.=4), as both of the statements had more than 40% response on completely agreeing (43%) and agreeing (43%), while some participants neither agreed or disagreed (14%) to these two statements, none disagreed at either degree.

The statement asking if the participants felt a Sense of Agency (Q8, avg.=4.0, mdn.=4) received a slightly mixed response. While the responses were more positive than negative, getting a combined response of Completely agreeing and Agreeing (38% and 29%, respectively), it also received 24% response to Neither disagreeing or agreeing, and 9% of disagreeing.

When asked if the participants would recommend the experience to friends or family (Q3, avg.=4.2, mdn.= 4), or if they would like to get to know other artists works with a similar experience (Q17, avg.=4.2, mdn.=4), a majority responded positively, with both statements receiving >80% Agreeing or Completely agreeing.

6.1.2 VR Specific responses

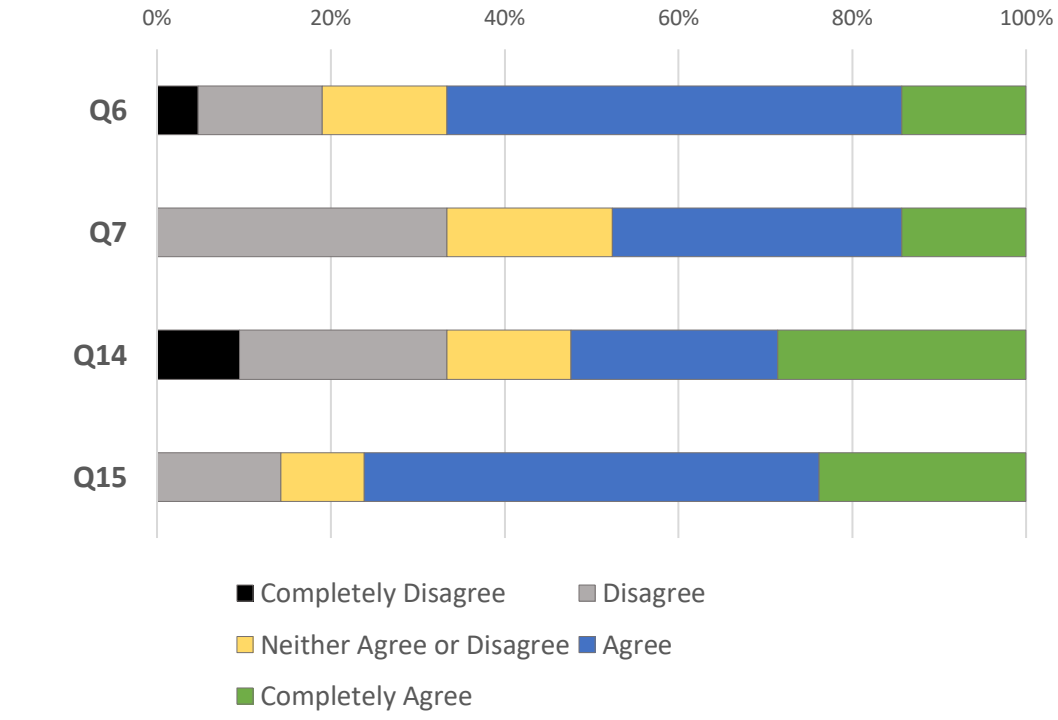

Figure 12. VR Specific responses

The statements that asked if the participants would use similar experiences at Home (Q18, avg.=4.0, mdn.=4) or School (Q21, avg.=4.4, mdn.=4) they responded with more than 80% positively with Agree or Completely agree, while usage at home (Q18) did also receive 1 Disagree and 1 Completely disagree. The two similar statements regarding use at Museum (Q19, avg.=3.2, mdn.=3) or at a Café (Q20, avg.=2.9, mdn.=3) received very

spread out responses, with both having either as much or less positive responses, than negative responses.

There were two statements regarding feeling of presence in the VE, that received slightly contradicting results. Feeling present in the represented areas (Q6, avg.=3.6, mdn.=4) received 67% positive responses, while there were only 19% negative responses. The statement of having felt aware of their surroundings while in the VR (Q7, avg.=3.3, mdn.=3) received 48% positive responses with only 33% negative responses. While the first discussed statement indicates a sense of presence with positive result, the latter instead proves a lack of the same with a more positive result.

The questionnaire also had two statements towards feeling present in the story, I felt I was immersed in the story (Q14, avg.=3.4, mdn.=4) and I would like to get to know the story in more depth (Q15, avg.=3.9, mdn.=4). The first statement had 52% positive and 33% negative response, while the latter received 76% positive responses. This would indicate that the story presence elements showed mostly positive results.

6.1.3 Negative or Physical responses

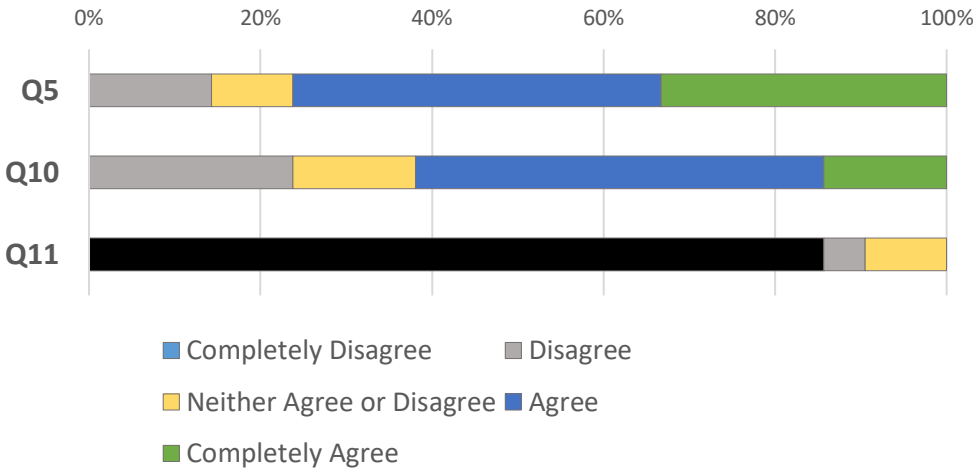

Figure 13. Negative or Physical responses

Two statements were asked from the participants to indicate disorientation during the experience. The first asked if the movement in the experience felt natural (Q5, avg.=4.0, mdn.=4), while the latter asked if the transition between the environments felt natural (Q10, avg.=3.5, mdn.=4). Both of these statements more than 60% positive responses (Q5=76% ,Q10=76%), indicating to the experience not causing disorientation.

The participants were also asked if they felt nauseous during the experience (Q11, avg.=1.2, mdn.=1). Though the results show that most (91%) of the participants responded to not having felt nauseous, two participants responded with “Neither agree or disagree”.

6.1.4 Non-parametric testing

As a part of the analysis process for the questionnaire data, non-parametric testing was conducted to see if there are significance between four groupings:

- Gender: Female (12) and Male (8)
- Attitude to technology: Early adopters (5), Early majority (10), and Late majority (6)
- History of VR usage: No previous experiences (6) and Has tried once or twice (12)

The results of the tests showed that one statement had significance with the Kruskal-Wallis H test. This was statement Q11 - I felt myself nauseous during or after the use of the application. The significance ($p=0.025$) for the statement was shown for the Gender grouping (Females and Men), where the men had stated fewer negative responses (Disagree or Completely Disagree) to the test.

6.2 Interview results

There was a total of 434 comments from the participants that were divided into 12 larger categories and 40 groups, where the smallest group contained 4 comments and the largest group contained 38 comments. Many of these groups have similarities to the experiential dimensions of virtual reality discussed in the first chapter.

As the interview did not have set questions, the comments were analyzed with Structural and In Vivo analysis methods (Saldaña, 2009), where the results were respectively divided into thematically cohesive groups, with more detailed subgroups (Tables 3 to 5). The groups showed the different aspects or dimensions the participants experienced while using the application. Some of the groups showed experiential dimensions that are not specifically related to VR, such as **Usability** and **Enjoyability**, while many of the groups discussed dimensions that were very specific to VR or the attributes of the application. Such specific groups were **Exploration**, **Storytelling**, **Physical Comfort**, **Immersion**, **Moving in VR**, **and Presence**.

The largest comment group was regarding Usability (75/434), where most of the participants (19/21) discussed their thoughts on the experience's functional components, their interactivity, or how they felt to use. The group consisted of three subgroups, Icon Activation, Ease of Use, and Icon Affordance (Table 3). The subgroup Ease of Use contained comments, such as "Easy, somehow intuitive", from ten participants (10/21) that talked about using the application being easy to use. Sixteen participants (16/21) commented on the Icon Activation with comments relating to the icons in the application not activating, the icons taking a long time to react, and being hard to locate the activating area. An example of the subgroup comment is "The icon didn't activate. I tried looking at it and it didn't work". The final subgroup was related to the Icon Affordance, where

nine (9/21) of the participants expressed their thoughts on the different type of icons used in the application, such as “What purposes were the different icons used for”.

USABILITY (Degree if functionality and interactivity of application elements)	75	Icon Activation	(38)	(Icon responsiveness)
		Ease of Use	(20)	(Level of ease perceived by participants)
		Icon Affordances	(17)	(Ability to recognize and understand icons)
EXPLORATION (Desire to, and facilitation of, exploration)	56	Interest in Exploration	(23)	(Desire to look around further)
		Interest in Textual information	(7)	(Wishing to read more about artworks)
		Ease of Virtual Visit	(7)	(Facilitation of virtual tours)
		Free Exploration	(6)	(Independence in examining the Virtual Environment)
		Desire to Learn More	(8)	(Wanting to obtain addition or re-hear information)
		Lack of Fine Details	(5)	(Wanting to see closer details of artworks)
VISUAL QUALITY (Level of Acceptance of Visual Elements)	53	Visual Execution	(15)	(Technical aspects of the 360 photography)
		Image Accuracy	(10)	(Lack of Visual Precision)
		Expectation of Graphical Representation	(10)	(Visual quality of Artwork did not meet expectations)
		Image Quality	(9)	(Elements of general image quality)
		Resolution	(9)	(Pixilation and Blurriness)

Table 3. Groups containing more than 50 comments

The group showed, that the application’s Usability had some issues relating to the responsiveness, response speed, icon affordance, and accuracy. Many of the participants still expressed their thought that the application was easy to use, which contradicts the other two subgroups. The group as a whole, shows that while some parts of the application caused some negative comments, the experience as a whole could still be felt positively.

Eighteen (18/21) made comments regarding the Visual Quality (53/434) of the application. Most of these comments revolved around the negative aspects of their perceived visual quality while in the experience, such as the groups Image Accuracy, Image quality, and their expectations for the visuals. Comments, such as “It was surprisingly blurry” and “That looked really cool”, showed that while the participants did make comments regarding the image quality, other aspects of the experience could still affect the experience to have a visual impact.

The second largest group of interview comments discussed aspects of Exploration (56/434). The comments mainly consisted of subgroups (Table 3) where a majority of participants (19/21) discussed their interest to explore the VE further, or read the texts in the spaces, and how the application facilitates Exploration. The subgroup Interest in Exploration consisting of comments, such as “Exploring the space further would have been interesting”, showed that the participants wanted to explore the spaces and find out more information about the items and text in the space, when given an experience of being able to explore a new environment in a virtual format.

The three groups with the most comments showed that while some of the aspects of the application caused negative responses with icon interaction and the image quality, the experience still engaged the participants in a way that caused them to want to explore the content and environments further.

When mentioning the experience’s Storytelling (43/434), the participants (16/21) gave slightly mixed responses. The larger two subgroups, Interest in Narration and Supplementing the Museum Atmosphere, consisted of the participants talking how they were interested in the storytelling of the narrator, or how the narrator added to the museum atmosphere. For example, one such comment was “It enriched the things in the museum, like a virtual guide”. The comments regarding the topic being unclear mostly discussed how the participants were unsure the painting that was being discussed when the narrator started describing information regarding a painting in the scene the participant was in. In general, the participant comments regarding the narration seemed positive, while the topic of the narration was not clear.

The Audio (37/434) group contained comments regarding how the music and narration, and how their voice levels and audio quality impacted their experience. The subgroup Narrator and Music Imbalance mostly had comments regarding the music in the application being too loud compared to the narrator, which affected the participant’s experience negatively. The other two groups, Impact of music and Voice of Narrator, concentrated on how the audio side of the experience impacted the experience positively with comments, such as “The organ music suited the church well. It brought out the environment differently”. The comments regarding Audio showed that while there were

negatively affecting aspects of the audio, the music and narrator impacted the experience positively.

STORYTELLING (Influence of Story and narration on overall experience)	43	Interest in Narration	(17)	(Degree of which narration appealed to participants)
		Supplementing the Museum Atmosphere	(15)	(The impact of narration on museum atmosphere)
		Unclear Topic	(11)	(Inability to discern narration subject)
AUDIO (Significance of Music and Narrator on virtual experience)	37	Narrator and Music Imbalance	(14)	(Inability to hear Narrator over Music)
		Impact of Music	(14)	(Effect of music on general atmosphere)
		Voice of Narrator	(9)	(Perceived quality of Narrator's voice)
PHYSICAL COMFORT (Bodily response to Virtual Environment and Device)	37	Body Disassociation	(14)	(Adverse reactions to lack of body in Virtual Environment)
		Nausea	(10)	(Feelings of being nauseous)
		Nausea Susceptibility	(7)	(Reflections on sensitivity to VR induced nausea)
		Vertigo	(4)	(Reactions to perceived height in Virtual Environment)
		Physical Symptoms	(2)	(Discomfort caused by Head-Mounted Display)
ENJOYABILITY (Emotional Valence and degree of interest towards the experience)	36	Pleasantness	(12)	(Feeling pleased, or calm)
		Fun	(7)	(Having fun in the experience)
		Cool	(6)	(Feeling amazed and intrigued)
		Impressive	(6)	(Feeling impressed)
		Interesting	(5)	(Showing general interest)

Table 4. Group containing less than 50 and more than 30 comments

The participants (17/21) made multiple comments regarding their Physical Comfort (37/434) or lack of it. Subgroup Nausea consists of ten (10/21) participants stating how they did not feel nauseous, and in the subgroup Nausea Susceptibility the participants discussed their expectations or previous experiences of being nauseous while using VR devices, while not stating feelings of current nausea. The participants also made comments regarding physical symptons, caused by the worn device's weight.

Seven of the participants (7/21) made statements, such as "It's weird when you can't see your hands", as the experience limited them from seeing their body. This subgroup was labeled as Body Disassociation, and showed the participant having mildly negative reactions to lack of seeing their body. Two (2/21) of the participants also made statements like "The seats looked really high when you looked down", noting feelings of Vertigo, while transitioning from the museum two the cathedral". Both of these groups showed that the participants were prone to negative physical reactions due to environmental or the limitations of the application.

The participants (11/21) also mentioned feelings of Enjoyability (36/434) they had while using the application. The comments were divided into five subgroups that described the experience positively: Pleasantness, Fun, Cool, Impressive and Interesting (Table 4). While these comments were generally short, for example, "It was really nice" or "Really cool", they showed a very high valence in the response. These comments showed that while many of these participants also made statements in other groups that contained more negative experiential dimensions, the experience could be enjoyable on a general level.

Confusion (28/434) was mentioned in the interviews by ten (10/21) participants. The group included the subgroups Disorientation and Uncertainty. The first subgroup received comments from participants in situations where they felt confused about having transitioned to another spot, or not being sure of where in the virtual environment they were compared to the last spot. The other subgroup consists of comments where the participants were unsure of what they should do in the application, such as "Should I have gone somewhere now?". While the participants had stated of wanting to further explore the spaces, the latter subgroup showed that too much freedom of roaming/actions can cause some negative emotions to rise.

Ten of the participants made statements regarding Immersion (26/434). The group describes feelings of VE Realism, Detachment from Real World, and how the VE felt Captivating (Table 5). The group showed how ten participants (10/21) made statements of feeling immersed into the experience, with comments such as "I forgot completely that I was in this test situation. It was somehow lovely".

CONFUSION (Feeling disoriented and uncertain)	28	Disorientation	(14)	(Loss of sense of location in the Virtual Environment)
		Uncertainty	(14)	(Obscure purpose and questioning of expected actions)
IMMERSION (Loss of reality and degree of absorption in Virtual Environment)	26	Realism	(17)	(Extent to which the experience felt realistic)
		Detachment from Real World	(6)	(Loss of Presence in Reality)
		Captivation	(3)	(Becoming engrossed in the Virtual Environment)
MOVING IN VR (Movement within and between an environment)	22	Transition	(16)	(Attitudes towards transitions *within* the environments)
		Transition Between Environments	(6)	(Attitudes towards transitions *between* environments)
PRESENCE (The extent of presence in virtual environment)	16	Feeling Present	(16)	(The sense of "being there")
RECOGNITION AND RECOLLECTION (Reactions based on Personal memories and knowledge)	15	Familiarity	(11)	(Relating virtual environments/elements to their real counterparts)
		Similarity to Guided Tours	(4)	(Associating experience with real world museum behaviours)

Table 5. Groups containing less than 30 comments

Fifteen (15/21) of the participants discussed Moving in the VR (22/434) during the interview. There were two main locomotion types in the experience, within an environment and between the environments. The comments regarding the movement within one environment mainly concentrated on the transition being easy and logical, such as “The movement was pleasant, and clear”, where the comments on the between environment transition mostly mentioned it being surprising. The movement method only had two (2/22) negative comments, showing the general reception was positive. Furthermore, while some participants had stated feelings of Confusion (Disorientation) after moving, the locomotion method mainly seemed rational enough for the participants.

During the interview there were mentions of feelings of Presence (16/434) during the experience. The significance of the group was, that twelve (12/21) of the participants mentioned feeling present in the VE with comments, such as “Just like I was there”.

The group with smallest amount of comments, Recognition and Recollection (15/434), mainly consisted of the participants recognizing elements in the experience, or how they associated the experience with a museum tour.

7 Discussion

7.1 Design and Implementation

At the beginning of the designing it was identified that there were not no fully tested or verified processes and guidelines for the specific design of VR and iODV application. Due to a lack of guidelines, the process undertaken during the creation of the application needed to be very flexible in order to allow experimental approach. The initial design phase (Liedtka, 20111) allowed for a lot of trial and error by breaking down the initial design tasks by thematical stages. The latter cyclical approach (Klein, 2013) was a broader process approach, where specific stages had not been set, but it allowed to refine the application to reach for the final outcome.

While the undertaken approach was very suitable to such an experimental design and the end result of the process was a fully functional and defined iODV application, having some ready tested guidelines for the design and implementation could have allowed for less testing features and design ideas. Being able to avoid possible pitfalls would in turn have allowed for some time saving and allowing for even more refinement of the experience quality.

7.2 Evaluation methods

As discussed in chapter five, at the time of the studies there had been very few broader UX studies into the area of iODV or VR. Many of the identified studies had concentrated on the interaction techniques or the specific experiential dimensions, such as presence in VE (Witmer and Singer, 1998). This caused constraints on the designing of the evaluation, mainly the questionnaire.

While the experience was a fairly specific experience, as it was a museum and storytelling concentrated iODV application, the main challenge with the questionnaire came from the lack of existing questionnaire sets. As no existing questionnaire sets were identified, many of the questionnaire statements needed to be picked from separate sources, and a couple had to be created specifically for the evaluation. As user testing VR devices is becoming more common in the research community, comprehensive UX questionnaire sets are hopefully bound to start forming.

As the application was Android based, the technology did not allow to show the participant's VR view on a separate screen or projector. This would have allowed for the study conductor to also write down observation notes of the participant behavior in the VE, for further study findings or to make specific questions to the participants about their experience. In further testing it would be recommended to facilitate to see what the participant is seeing in the VE. For example, VR glasses that are connected to a computer, could make this possible.

7.3 Results and Findings

Statement 11 in the questionnaire received more responses from male participants saying they felt nauseous during the experience than the female participants. The literature on the matter have shown opposite findings. One example of such findings is Nichols and Patel's study into the health implications of VR, where their findings indicated that females are likelier to feel nauseous while using VR technology (Nichols and Patel, 2002). The contradictory results are interesting, but two things should be considered.

1. Discrepancies in the results could be caused due the number of participants being only 21 (12 females, 8 males) and the participants represented a convenience sample.
2. None of the participant stated having felt nauseous in the questionnaire, but the results showed that one male participant answered Disagree and another male participant answered Neither Agree or Disagree. This result poses the question, if the phenomenon of nausea should be tested again, since newer and more precise viewing devices, aside other innovations in the field of VR, have come to the market.

The participants showed that they agreed to using VR devices at Home or Educational environments, but also said they wouldn't like to use the devices at public spaces, such as Café and Museum. An interesting thought on the matter is, what causes participants to prefer using VR in private (home) or limited public spaces (school), instead of public spaces, such as Museum.

The group *Enjoyability* included the subgroup *Pleasantness*, while also consisting of the subgroup *Interesting* amongst other subgroups. This shows that while the earlier work identified pleasantness as a dimension (Kauhanen et al., 2017), Enjoyability could be a more appropriate naming for the dimension, as it allows for a broader and more understandable description of the experience.

The earlier work showed how Simulator Sickness could be very destructive to the experience (Kauhanen et al. 2017), and the group Physical Comfort shows concurrence. While Simulator Sickness (Kennedy et al., 1993) is a more concentrated on the nausea caused by simulations, the group Physical Comfort consisted of Nausea (Simulator Sickness), Body disassociation, Vertigo and Physical Symptoms. The results, combined with the earlier work, shows that Nausea and Body Disassociation have a very negative impact on the experience, and should be avoided.

In the evaluation, the group Usability and Moving in VR showed similar themes to Sense of Agency, which was identified in our earlier work (Kauhanen et al., 2017). As mentioned (Kauhanen et al., 2017), when the user feels they are not in control of the interaction and the space, the quality of experience deteriorates. Thus, the usability and

the method of locomotion should be designed, to give the user a feeling that they are in control of their actions.

The group Recognition and Recollection was more specific to the environments included in the experience, such as recognizing the artworks or the spaces. While the participants' mentions on the spaces were in positive tone, the specificity of the statements does not relate to the experiential dimensions as much as the other statement groups.

7.4 Implications for designing iODV applications

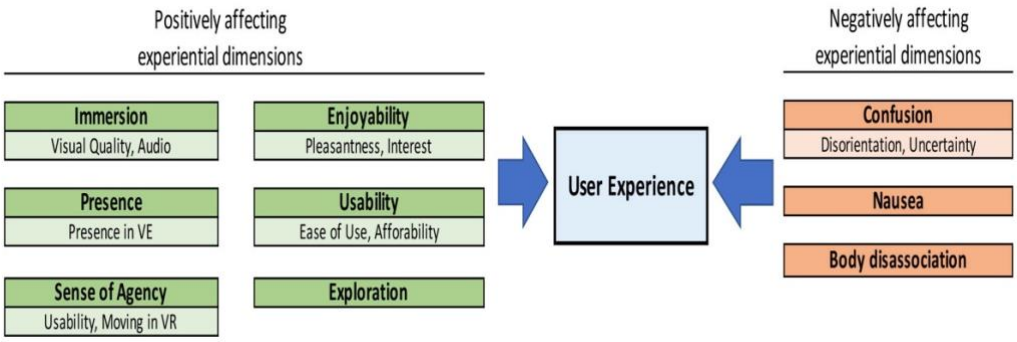

Figure 14. Groups of positively and negatively affective experiential dimensions

The findings show that experiential dimensions can affect the experience in a positive or negative way. Figure 14 shows which dimensions can have a deteriorating or improving effect on the experience. Six dimensions were identified to improve the experience and should be emphasized on in the design and implementation of iODV applications. These dimensions are Immersion, Presence, Sense of Agency, Enjoyability, Usability and Exploration. As these dimensions are what the user experiences, there are many factors that effect on their level. For example, Immersion can be affected by the visual quality and environmental audio for example.

The negatively affective dimensions, on the other hand, can be very destructive to the experience. During the design and implementation of an experience, making sure that avoiding these dimensions should be of an utmost importance.

As discussed in fourth chapter, design and implementation, approaches that can help with making sure to avoid pitfalls and using the correct elements in the experience were identified.

Firstly, a explorative method should be used, as the interaction of different elements and environments can cause unexpected effects on the experience. Such an approach, for example, is the initial design process used (Liedtka, 2011).

Secondly, iterative development process, such as the cyclical approach that was used in the design and implementation of the application (Klein, 2013), should be used. An iterative approach allowed testing and refining the application, as each iteration caused new challenges with added features, such as adding the background music.

Finally, with the field of Virtual Reality becoming more established, possible golden standards and guidelines should be used as much as possible, along existing development frameworks. With tested solutions some negative experiential dimensions, such as Nausea, can be easier to avoid. Some guidelines have started to appear (Saarinen et al., 2017). While there is still a heavy concentration on a more technical approach, it shows that the UX considerations are starting to be get more attention in the development.

8 Conclusion

In this thesis, the development and evaluation of the iODV application Hugo Simberg VR was presented. This application offers the users a virtual tour of the Ateneum museum and Tampere Cathedral, with a narration telling the user about the works of Hugo Simberg. The developed application shows how UX design approach was employed to boost the development process. The application was evaluated as an inquiry to identify and confirm experiential dimensions of the iODV applications. This chapter summarizes the thesis by describing the design approach and the findings of the evaluation.

The fourth chapter discussed design and the implementation. In the initial process, using UX design tools and methods helped defining the concept for the the application and allowed for iterative content creation. The main benefit in the initial process that the UX design brought, was a structured approach in the discovery and creation phase to make a minimum-viable product, that could be tested. In the latter phases the cyclical iterative approach of the Lean UX design (Gothelf, 2017) allowed to refine the product flaws, such as improving the visual quality, and to add further needed features.

After the development of the iODV application was finished, it was evaluated in a user study with 21 participants. The evaluation itself had an experimental approach due to user testing with the specific equipment and study aims being quite new in the field, so using a questionnaire and interviewing the participants regarding their experience were used. The findings of this study are:

- The male participants agreed more to the statement “I felt myself nauseous during or after the use of the application”. As earlier findings in the field indicate that females tend to report more nausea (Nichols and Patel, 2002), this is an interesting finding, which could be cause by study settings, but should be further investigated.
- During the interviews conducted at the end of the study, six experiential dimensions were regarded positively in their valence during the interviews: *Immersion, Presence, Enjoyability, Usability, Sense of Agency,* and *Exploration*. Three dimensions were noticed to carry a negative valence: *Confusion, Nausea,* and *Body disassociation*. Designers should look to offer the first group of dimensions, for example, an increase in Presence makes the user feel more present in the experience’s VE. The latter group should be avoided as much as possible as dimensions, such as nausea, can be disruptive, if not destructive, to the experience as a whole.

As the design process was experimental, as the literature regarding UX design in the field of VR or iODV was quite limited, the findings of the process were combined with the evaluation results to find implications for the UX design of iODV applications. Firstly, an explorative approach should be used throughout the process, this allows generating a

higher amount of ideas to narrow down to. Secondly, the experiential dimensions should be considered in the design from the beginning. Finally, the iterative approach was found suitable, as the process of implementing and testing showed that additions and changes in the experience may affect some of the experiential dimensions negatively.

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Appendix 1

HugoVR Käyttäjäkokeilu - Osallistumissuostumus

Olemme kokeilemassa virtuaalitodellisuuden kokemuksellisuutta ja HugoVR prototyyppimme tarinankerrontaa, ja haluisimme kutsua sinut mukaan kokeiluumme.

Tutkimus liittyy VIRJOX-tutkimushankkeeseen, jossa tutkitaan virtuaalitodellisuuden sovellusten suunnittelua ja kokemuksellisuutta. Hankkeessa on mukana Jyväskylän Yliopisto, Tampereen Yliopisto ja Tampereen Teknillinen Yliopisto.

Kokeilu suoritetaan Tampereen Yliopistolla SimLab virtuaalitodellisuus tilassa. Ennen kokeilua näytämme sinulle, kuinka prototyyppi toimii ja kuinka virtuaalitodellisuuslasit asetetaan päähän, jonka jälkeen haluisimme sinun kokeilevan prototyyppiä noin 5 minuuttia, tai kunnes tunnet olevasti valmis kokemuksen kanssa. Kokeilun jälkeen haluisimme sinun täyttävän lyhyen kyselylomakkeen, ja keskustella hetken käyttökokemuksestasi.

Äänitämme kokeilua ja kokeilunjälkeistä keskustelua äänitse, ja haluisimme myös kysyä lupaasi nauhoittaa kokeilua ja keskustelua videoitse. Suostumuksesi videointiin on vapaaehtoista.

Äänitykset ja videot tullaan pelkästään käyttämään tieteellisiin tutkimuksiin ja tietosi säilytetään täysin anonyymisti. Tietojasi ei tulla luovuttamaan kolmansille osapuolille.

Säilytämme tutkimuksessa kerättyjä tietoja, kuten osallistujien nimet, kesäkuuhun 2018 asti.

Osanottosi kokeiluun pitäisi kaikkiaan kestää enintään noin 45 minuuttia.

Osanotto kokeiluun ei sisällä riskejä. Virtuaalitodellisuuden kokemukset saattavat aiheuttaa joillekkin käyttäjille lievää huonovointisuutta. Jos koet olevasi huonovointinen kokeilun aikana tai kokeilun jälkeen, ilmoita meille heti, ja voimme lopettaa virtuaalilasien käytön.

Kokeilun osanotto on täysin vapaaehtoista. Voit keskeyttää osanottosi kokeiluun milloin tahansa ilmoittamatta syytä keskeytykseen.

Jos haluat tietää lisää VIRJOX projektista, voit käydä sivustollamme:

http://virjox.hti-tampere.fi/ Tai ottaa yhteyttä ryhmän jäseniin:

Kokeilun suorittaja:
O. Kauhanen
Tutkimusapulainen
Tampereen Teknillinen Yliopisto
Ihmiskeskeinen Teknologia

Projektipäällikkö:
H. Väätäjä
Tutkijatohtori
Tampereen Teknillinen Yliopisto
Ihmiskeskeinen Teknologia

Jos sinulle tulee mieleen mitään kysyttävää, voit kysyä kokeilusta ja projektista ennen kuin aloitamme kokeilun, tai missä tahansa vaiheessa kokeilua.

Kiitos osallistumisestasi!
Ole hyvä ja käännä sivun toiselle puolelle.

Ole hyvä, ja täytä alla olevat tiedot, jonka jälkeen voit antaa paperin takaisin tutkijalle. Saat tästä lomakkeesta oman kopiosi.

Merkkaa alla mahdollinen suostumuksesi taltiointiin, ja että olet ymmärtänyt lukemasi tiedot:

☐ Annan suostumukseni taltioida osallistumiseni videona.

☐ Olen lukenut ja ymmärrän edellisen sivun informaation, ymmärrän että kokeilu äänitetään, ja olen saanut vastauksen esittämiini kysymyksiin. Suostun ottamaan osaa kokeiluun.

Osallistuja	**Tutkija**
_____	_____
Aika ja paikka	Aika ja paikka
_____	_____
Allekirjoitus	Allekirjoitus
_____	_____
Nimen selvennys	Nimen selvennys