Assisting Immersive Virtual Reality Development with User Experience Design Approach

Full Paper

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ABSTRACT

In our study we explored how to design a biography of a late Finnish artist as a VR experience. We conducted a development process assisted by user experience (UX) design methods, which increased the process efficiency, and resulted in a research prototype. Through previous research and our development process, we identified components affecting the user experience. These components are: Immersion, Presence, Disorientation, Sense of Control, Pleasantness, Exploration and Simulator Sickness. From our user study with 13 participants, we were able to draw implications that relate to these components. While the set of components could be incomplete or subject to change, shows that further research is necessary for a more comprehensive knowledge of user experience in the field of Virtual reality.

CCS CONCEPTS

• Human-centered computing → Human computer interaction; *HCI Design and evaluation methods*; User studies • *Interaction paradigms; Virtual reality.*

KEYWORDS

Virtual Reality, Immersion, User Experience Design, Omnidirectional Video, Interactive omnidirectional video.

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1 INTRODUCTION

Immersive storytelling in virtual reality is raising increasing interest in the field of journalism. News organizations around the world are experimenting with using VR (virtual reality), and especially 360-degree videos, i.e. omnidirectional videos, in news reporting. Different trials varying in production levels and formats are being created, and many are adopting storytelling as a means to engage viewers. However, design approaches in this field are still largely experimental, and research is greatly needed in investigating and evaluating novel approaches to content creation and engagement through storytelling. One of the few pioneers who have published academic research on immersive journalism are Nonny de la Pena et al. **[8]**.

Since very little academic research exists to create experiences for journalistic content and storytelling in VR **[26]**, we set out to explore jointly with a Finnish media company the types of storytelling best suited for VR as well as the kind of experiences that can be created with journalistic content. During the early stages of the process we identified "slow" journalism as one of the interesting possibilities in the field. However, we aimed to specifically explore the opportunities which lie in the creation of biographies in VR, as this is one of the key story types in journalism. Our design and development efforts concentrate on two areas – creation of immersive storytelling VR experiences, and how their creation can be achieved utilizing a UX design approach.

To aid in service facilitation, the Finnish National Gallery's Art History museum, Ateneum, participated as our project partner and exclaimed great interest in storytelling through their art and artists. We describe in this paper the phases from concept creation to initial research prototype implementation and the user evaluations throughout the iterative design and development process. Based on the prior research and findings from user testing we discuss a set of user experience components and implications for next stages of design and development.

2 BACKGROUND / RELATED WORK

2.1 Immersive Virtual reality

Immersive Virtual Reality is defined as virtual reality that “envelop the senses with computer-generated stimuli” and the head-mounted displays are a “distinctive feature” of Immersive Virtual Reality systems **[2]**. This definition applies to our work, however, the computer generated stimuli in our case is in the form of 360-degree video – omnidirectional video (ODV) – viewed with a head-mounted display. Head-Mounted Display (HMD) is a personal graphical display that can be worn on a user’s head. HMDs that project on both eyes are referred to as Stereoscopic Head-Mounted Displays **[ibid.]**. As a desire to concentrate on VR technology that is the most widely available for consumers, we focused on using the Google Cardboard **[10],** which is one of the simplest types of HMDs. The advantage of Cardboard **[ibid.]** is that it uses a smartphone as both the display and the processor. Thus users only need to invest a very moderate amount of money – at minimum a few euros – on top of already owning a smartphone to experience VR content with their own devices.

Yu et al. **[30]** discuss how 360-degree panoramic images and videos can be used to create spherical 3D environments that can be viewed in HDMs. This allows **omnidirectional video** to be used in an immersive way.

Kallioniemi et al. **[14]** used omnidirectional panoramic images for their CityCompass application that projected these images to a wall. Based on similar a similar idea, an application for viewing **interactive omnidirectional video** (**iODV**) content on HMDs was developed. The **iODV** application uses the direction of the user’s direction of view as interaction method (2.5 second dwell time), via head-tracking.

2.2 Existing VR experiences for journalism and museums

Because our focus for this work was to explore journalistic biography in the context of art, we began the design process by benchmarking the existing applications in both journalism and museum contexts. We briefly outline the three most important works that influenced our design decisions by highlighting both the positive and negative aspects that can affect the user’s experience. These three applications were: Night Café **[4]**, We Wait **[2]**, and Boulevard **[5]**. We examined these VR applications to understand the features they offered to the users, and what their strong suits were in terms of the overall experiences.

“Night Café” transports the user in the world of Vincent Van Gogh’s art **[4]**. It allows the user to explore the café depicted in Van Gogh’s Night Café. The graphics of the experience mimic Van Gogh’s art style, and the user can roam to see the scenery, explore items and find characters set all over the café. Van Gogh himself is set in the scene, a pianist plays music, and one can find a way to a cellar as well. The experience was a good representation of allowing user to explore the space freely, while the method of roaming the space seemed to cause simulator sickness within the team members.

“We Wait” gives the user the perspective of a group of Syrian refugees waiting for a boat to Europe **[2]**. The experience’s visualization is a low-poly video graphic, which removes most of the details of the visual representation. The story is narrated by the refugee characters, and the majority of the atmosphere is set by the audio rather than the visuals.

“Boulevard” **[5]** is a VR application that allows one to visit museum collections around the world in virtual environments. In addition to being able to see art pieces from famous collections, the application offers information about the artworks in audio and text format. However, we found that the texts were not easy to read and the quality of the artwork was very low in VR at the time of viewing. This influenced the feeling of “being there” negatively and hindered experiencing the museum and art as it is in real life.

Through the benchmarking, we found the following key findings: 1) Audio can, to some extent, help minimize the negative effects of poor visual quality, 2) Audio can be used to direct the attention of the user, and 3) Audio facilitates storytelling elements.

2.3 UX dimensions of Virtual Reality - Experiential Design and Evaluation Components

In this section we describe experiential components for VR based on prior research. Many of these concepts and their definitions are under constant discussion and some concepts, such as immersion, currently have many definitions.

Bowman and McMahan **[6]** refer to **immersion** as an objective quality by defining it as “the objective level of sensory fidelity that a VR system provides”. Alternatively, many refer to immersion as a subjective phenomenon. For instance, Witmer and Singer **[29]** define immersion as “a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment…” They also consider immersion, together with involvement, as a requirement for experiencing presence.

Presence is the user’s subjective response to the immersion produced by the technology, and can be defined, as “the psychological sense of ‘being there’ in the environment: it is an emergent property based on immersive base given by the technology” **[24]**. Presence is a complex phenomenon with multiple dimensions and subcategories, and perhaps thus, a wide range of definitions for it has been created. This is obviously confusing, and for example, Lombard and Jones **[21]** express their concern about this direction as it may hinder the development of understanding the phenomena itself.

As some of the virtual environments can be large and complex, users may feel disoriented or lost while experiencing them. **Disorientation** has been explained as the feeling of loss of the “sense of location,” which “can cause users to become frustrated, lose interest” **[1]**. While Ahuja and Webster **[ibid.]** concentrated on web-based technology, the same seems to apply in virtual reality, where disorientation can affect users even more negatively due to the deep immersion in which users can be entirely engrossed. Therefore, examining this feeling of being lost or confused is highly important when collecting user feedback, as was evident in our testing.

Another aspect paramount to a positive VR experience is having a **sense of control** or **sense of agency**, defined as being able to “distinguish actions that are self-generated from those generated by others giving rise to the experience of a self-other distinction” **[7]**. In other terms, sense of control could be explained as one feeling that their actions have the consequences that they expected **[ibid.]**. In VR, reduced sense of control has negative effects. For example, in our study, participants expressed frustration, when an interaction did not work as they expected.

As expected with any interactive system or media content, VR content should also be pleasant for the user. **Pleasantness** is a positive emotional valence, which can be linked with many positive experiential factors, such as satisfaction, joyfulness, relaxation and fascination **[9]**.

Exploration is another important aspect to consider in the design of VR content. This is especially true for content such as the museum and cathedral used in our prototype, as they are public places that are specifically meant to be explored. One of the greatest advantages of VR compared to more traditional media is the ability to become immersed in a new world or environment that users would not normally be able to experience. Furthermore, Lepouras and Vassilikis **[20]** argued that in VR experiences meant for museums, exploration can even facilitate an enhanced learning experience.

A further issue that should be taken into account considering virtual environments is **simulator sickness**. It is a set of physical symptoms of discomfort that can afflict users when using HMDs, and includes, but is not limited to, symptoms such as general discomfort, nausea, difficulty focusing and vertigo **[16]**. Kennedy et al. **[ibid.]** define simulator sickness as follows: “Simulator sickness in high fidelity visual simulators is a byproduct of modern simulation technology. Although it involves symptoms similar to those of motion-induced sickness (MS), SS tends to be less severe, to be of lower incidence, and to originate from elements of visual display and visuo-vestibular interaction atypical of the conditions that induce MS.”

3 THE FIRST PHASES OF DESIGN AND DEVELOPMENT PROCESS FOR A RESEARCH PROTOTYPE

In this section we discuss the design and development process resulting in a research prototype to test the central idea of our concept. Our approach includes workshops for concept creation, further design development, early stage prototyping, and the process of capturing 360-degree photos used in the prototype. The developments lead to a minimal viable product prototype applying interactive omnidirectional video that was evaluated in practice within the fast design and development iterations.

3.1 Design Process for a concept

To design and implement a minimum viable product prototype, we applied co-creation methods at the first stage of the design in the form of a workshop. This allowed us to receive input from all stakeholders at an early stage. After the findings from the ideation workshop were analyzed, the concepts were consolidated into concept ideas. After the most desirable and viable concept idea was chosen, it was prototyped with a low-level proof-of-concept prototype, to find issues, examine experiential aspects and needs, and finally implemented into a further working prototype.

3.1.1 Concept development

The first phase of the development process was a concept creation workshop. There were six (6) participants in the workshop: one (1) representative from the collaborating company, two (2) researchers with Human-Technology Interaction (HTI) and computer science backgrounds, one (1) designer with HTI background, and two (2) researchers with media and journalism backgrounds. The workshop started with a one hour pre-prepared discussion agenda on the focus, goals, and the technological solution target, and constraints for implementation. These included concentrating on immersive virtual reality technology that can be used on smart phones with an Android operating system, with the content focus of a Finnish painter and graphical artist, Hugo Simberg and his biography through his art. The Finnish National Gallery’s Art History museum, Ateneum, was chosen as the virtual environment for the artist’s work, as it is a collaborator of the media company participating in the project.

Table 1: VR Concept idea selector

Large story construct (meta layer not required for stand-alone experience)	Experiences in Map/Area/Place	Experiences in a Timeline	Story is tied to Historic events	Story set in physical world (user travels/adventures)
Environment	Physical Space (staged/existing)	Inside Artwork	Landmarks	Recreated historic spaces/rooms
Visualisation type	Art/piece based Texture	Simple Polygon texture	Flat Graphics	360° Video or Picture
Technology type	Augmented Reality	Virtual Reality	Omnidirectional Video	
Point of View	Artist/Character	Stationary viewer	Roaming viewer	
Story Flow type	Continuing and story segments initiaged by user interaction	Scripted story. User only views and has control on timeflow		
Story teller type	Narrator (Not seen, only heard)	Characters in Environment speak		

The second part of the workshop was an ideation session aiming to create as many ideas as possible within a limited number of iterative ideations focusing on Hugo Simberg and the possibilities of VR. The chosen technique was similar to Hamilton's "Ideas Cascade," where everyone writes initial ideas down, and the ideas are passed to the next participant to receive comments, further iterations or new ideas **[12]**. Each participant was given post-it notes to write ideas on for three minutes, after which the post-its were handed forward to the next participant. Our workshop had two cycles of circulating the ideas, ending with three persons' ideas to be included in a more complete ideation cycle to further build on top of each other's ideas.

The post-its were then gathered and placed on the wall, and were examined together to group similar ideas or thoughts. In total, sixteen (16) ideas were produced during the workshop. They focused on, but were not limited to, concept ideas and thoughts on how timelines could be presented in virtual reality. The main theme that arose from these ideas was to concentrate on representing Hugo Simberg's life and thoughts through his artwork.

The findings were gathered into a simplified idea selector (see Table 1) that could be used to make new VR experience structures by selecting one option from each horizontal level. Some of the ideas, such as the visualization types, were inspired by VR applications we benchmarked, such as the imitation of visualizations in Night Café **[4]**.

Five (5) concept ideas were created with the selector. These ideas were: VR Experience in Simberg's workshop (see Figure 1), Augmented Reality Simberg tour at the museum, seeing Simberg's work through the eyes of his muse, seeing Simberg's artworks through artist's own eyes, and diving into Simberg's painting.

After the concept ideas were developed by the designer, they were presented in a meeting with four participants from the museum, two from the media company and the remaining (5) participants from the project team.

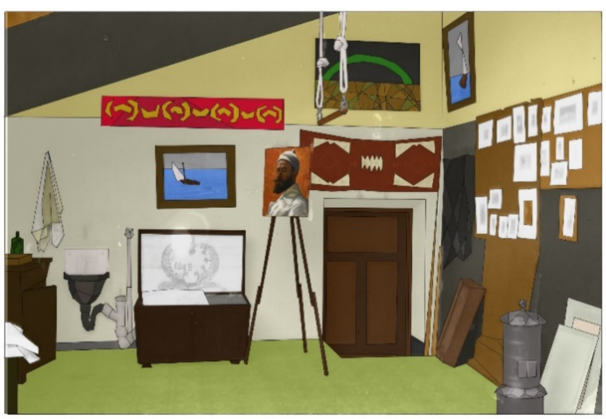

Figure 1: Visualization of the workshop concept idea

The participants from the collaborating museum and media company were interested in the idea of transitioning between spaces, and were even discussing the idea of an added VR room to present artwork as a virtual exhibition at the museum. After the meeting, when considering the options and interests, the designer and one of the researchers considered how to make a low-level Proof-of-Concept testing. They decided to test the experience of transitioning between spaces with an interactive omnidirectional video. At this point in the concept, 360-degree videos and images were deemed easier and faster to produce and test than computer generated graphics. The idea included the transition from one space to another through one of the famous paintings by the artist. The concept consisted of being able to explore the museum's gallery to view Simberg's artwork with a concentration on his "Wounded Angel" painting. A transition was created through the painting itself from this space to a Cathedral in Tampere, Finland where Simberg had created a fresco-version of the painting being displayed in the museum.

3.1.2 Early phase sketching and towards prototyping

360-degree sketching templates **[18]** were used to draw ideas, as demonstrated in Figure 2. The 360-degree sketches could be scanned or photographed and tested with various 360-degree photo viewing software. This method allowed those involved to explore and communicate ideas within the team in a way that allowed seeing the idea in the intended three dimensional manner. Another low fidelity prototyping approach was to take 360-degree still images that had been taken in the museum and cathedral. This allowed the testing of how graphical elements, premises during a test shoot, and use a photo editing software to add visual elements, such as simple navigational icons, worked in the intended environment. While this was a faster way of testing the graphical elements, the method could not be used to produce interactivity within and between the elements.

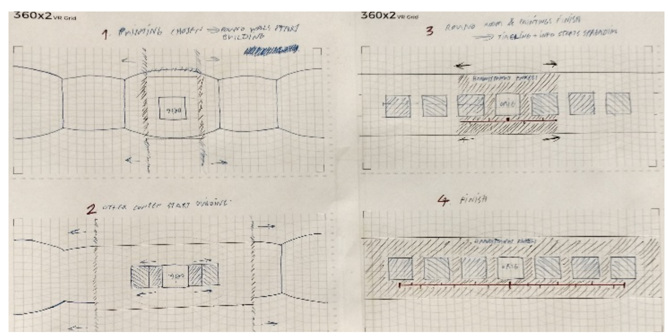

Figure 2: 360 Sketch template examples

3.1.3 360-degree video capturing

The prototype's images were captured for the first phase prototype that tests the concept of exploring the space and the transition between the museum and cathedral, with a Ricoh Theta S camera **[22]** that uses two cameras to capture the full surrounding environment. The photoshoots were arranged for one location per day, so both the museum and cathedral were shot on separate days during the same week in the end of January 2017.

Because the 360-degree camera captures the whole surrounding environment, it produces some limitations when the photographer should not be visible in the image. Two ways to mitigate this were produced: taking timed images or editing the photographer out of the images. When possible, the former was a more effective method, as the editing process for 360-degree images proved time costly.

3.2 Prototype

The final result of the initial development phase that this paper discusses was the creation of a research prototype. This prototype was developed to test the idea of transitioning between two spaces through the "Wounded angel" painting. The research prototype was implemented to be used on Android phones, using Google Cardboard **[10]** VR viewers. In the museum, the main exhibition hall and one conjoined side room with works by Hugo Simberg, was included into the VR experience. In the Cathedral, the VR experience includes the right side balcony on which the Wounded Angel fresco is displayed on the wall, the middle of the ground floor aisle, and the front left corner of the cathedral that is next to another famous fresco by Simberg.

The navigation was conducted via looking at orange colored icons, with 2.5 second dwell time. The icons that were used to move within a space had a symbol similar to the Cardboard **[ibid.]** logo, and the icon for the transition between the museum and cathedral had an upwards pointing arrow. The transition icons between the two spaces, museum main exhibition wall, and the Cathedral, were placed under the Wounded Angel artwork. The symbols for the icons were chosen by the design team. The prototype starts with the user situated by the main entrance of the museum's main hall, across the room from the wounded angel painting.

Figure 3: User's perspective in the research prototype

4 USER STUDY OF THE FIRST PROTOTYPE

After the development of the first phase research prototype, a user study was conducted. The goal of the study was to find out what changes and additions were required to be implemented to holistically improve the experience of the users.

To support the fast iterative testing approach in the our design and development process, the testing method we chose was "Guerrilla Testing" **[17]**, where the testing is done in a public, semi-public, or in other field settings, and thus does not use a laboratory testing space. Guerrilla testing also is conducted in a way where the participants are recruited on the testing location, usually passers-by. Informed consent of the participants was asked for.

The testing procedure was pilot tested with two participants. The pilot testing was conducted with the same procedure as the testing. Neither of the pilot test participants had no previous knowledge of the "Wounded Angel"-prototype, and thus the results from the pilot phase were included in the analysis.

4.1 Test set-up

The testing was conducted on 23rd Feb. 2017 from 11am to 1pm and on 24th Feb. 2017 from 9am to 11am at two separate universities. The testing locations were public lobbies as the testing participants were recruited on site. Participants were recruited one at a time, as the testing device only allows one user at a time

4.2 Participants

Participants were randomly recruited from the passers-by at the testing locations. All-in-all, thirteen (13) participants attended the testing (5 Female, 8 Male), aged between 19 and 52 (average = 28), one participant omitted their age. Participation for the testing was not compensated, while the participants were offered refreshments at the testing location.

The participants consisted of university students and staff. They had no experience or knowledge of the prototype before being tested. One of the participants reported having used Head-mounted VR devices 1-3 times during month before testing, four participants reported having tried Head-mounted VR devices once or twice, and eight participants reported no previous experience with Head-mounted VR devices.

If the participant stated that they did not feel healthy their results regarding simulator sickness were omitted, as Kennedy et Al stated that a lowered state of health could affect results regarding symptoms of simulator sickness **[16]**.

The participants were asked of how much they had used VR technology. Most had little-to-no experience with VR Technologies (8/13), and had limited experience with 360-degree videos (6/13) that can already be viewed on many social media sites. Five of the participants reported having at least tried 360-degree videos or images, while only one participant had captured 360-degree still images or videos.

4.3 Testing apparatus

The device used in the testing was an LG G3, which used the Android 6.0 operating system and has inbuilt gyroscopic sensors. It was inserted into Homido VR viewer **[28]**, which allows the smartphone to be used as part of the Head-mounted Display, as can be seen in Figure 4. The device tracks the participant's point of view in the virtual environment via head tracking. We also considered Samsung Gear VR **[23]** for the testing, as it is similar to the Cardboard **[10]** that was wished by the participating company to reach "masses", as it uses a Samsung smartphone as the display and processor. The decision to prefer technology similar to the Cardboard **[ibid.]** was due to it being less limited in the choice of phone used in the set up for the prototype testing.

The interactive omnidirectional prototype allows the user to navigate the virtual environment, including the transition between the museum and church environments, with the use of round icons that either had VR-goggle graphic or an upwards arrow graphic on them (see Figure 3). The icons activated with a 2.5 second dwell time interaction upon being looked at.

Figure 4: Head-Mounted Display trial

4.4 Background questionnaire

The participants were first asked to fill a background questionnaire with thirteen (13) questions, such as age, and participants' familiarity with Virtual Reality technologies. The questions regarding possible previous use of Virtual Reality technology asked of usage frequency with range of: *No previous use, Tried once or twice, 1-3 times during last month, 1-2 times per week during last month, 3-5 times per week during last month, and Daily*.

4.5 Testing procedure

Before starting to use the Virtual Reality testing device the participants were informed of how the device was worn. The participants were also explained that the device operates via head tracking, and as they were standing, they should not walk while wearing the device. Due to the possibility of VR causing simulator sickness, the participants were explained that if they felt any discomfort, they should inform the researchers and could stop using the device at any time.

Participants were told to freely explore the virtual environment and were not given any task. Participants were asked to use the think aloud method and report their thoughts while using the device. The participants were allocated around 2-3 minutes to explore the virtual environment, after which they were told: "if you feel you've seen everything you can stop using the device". In some cases the participant refused and were given another minute before being asked to stop using the device.

4.6 Post-test interview

After using the device, the participants were asked if they felt any discomfort, and were offered a chair if they reported any signs of simulator sickness. Participants were then asked what kind of thoughts, feelings or ideas did the viewing raise, as an open ended interview question.

4.7 Post-test questionnaire

After the interview the participants were asked to fill a questionnaire that asked of their experience using the "Wounded Angel"-prototype. There were 15 questions, which were related to the Experiential Components of Virtual Reality discussed in section 2.3. The questions (see Table 2) were in forms of statements and asked the participants how strongly they agreed to said statements on a 5-point Likert scale (1 = Completely Disagree, 5 = Completely Agree.

5 RESULTS

5.1 Questionnaire results

Most of the post-test questionnaire's statements were related to the experiential components mentioned in section 2.3. The questions were asked on a 5-point Likert scale (1 = completely disagree, 5 = completely agree), where an answer of 1- 2 means a negative result and 4- 5 a positive perception. The results of the questionnaire, such as average, median, standard deviation, minimum and maximum of each question, can be seen in Table 2.

Most of the participants (9/13) responded positively results to having had fun (Q1) and 11/13 participants answered that they would use a similar product again (Q2). Neither Q1 nor Q2 received fully negative answers (1/5).

Most participants (10/13) agreed that they wanted to explore the environment more (Q3).

The participants were divided on understanding the meaning of the markers (Q4), as about half (6/13) of the participants agreed, and almost the same amount (5/13) disagreed. More than half of the participants (8/13) reported that they found the icons easily (Q5).

Nine participants (9/13) reported that they understood how they could activate the markers (Q6), while only one participant disagreed fully. Furthermore, when asked if the participants agreed that the icons indicated the place of movement clearly (Q7), the participants' response was mostly positive, as 7/13 agreed, 3/13 neutral and 3/13 disagreed.

A majority of the participants (9/13) agreed to understanding where they were inside the space (Q8). The participants'' opinions were divided on not having being confused after moving (Q9), as almost half (7/13) agreed and almost the same amount (6/13) disagreed.

A majority of the participants (9/13) agreed on having felt expected outcomes to their actions (Q10).

Almost all (12/13) participants disagreed on having felt nauseous (Q12), and a majority (10/13) disagreed having felt vertigo (Q13) during or after the use. The participants reported slightly more eyestrain compared to the other two simulator sickness symptoms with only nine (9/13) participants disagreeing to their eyes feel strained after the use.

We omitted one participant's results regarding simulator sickness (questions 12, 13 and 14) as the participant reported a stuffed nose **[16]**.

When asked if moving to the church felt strange (Q11), the participants responded neutrally, with 5/11 neutral responses, while there were both 2/11 positive and negative results. Four of the participants did not find the transition to the church by looking at the icon below the painting, and did not answer the question.

Table 2: Post-test questionnaire results

	Avg.	Mdn	Std	Min.	Max.
1. Using the prototype was fun.	3,85	4	1,07	2	5
2. I would use a similar product again.	3,92	4	0,95	2	5
3. I would have liked to explore the environment and the objects more.	3,92	4	1,26	1	5
4. I understood what the markers are for.	3,38	3	1,50	1	5
5. I found the markers easily.	3,85	4	1,28	2	5
6. I understood how to activate the markers.	3,62	4	0,96	1	5
7. The markers' placement pointed the movement spot clearly.	3,31	4	1,32	1	5
8. I understood where I was inside the space	3,62	4	1,45	1	5
9. Moving from one spot to the next did not feel confusing.	3,15	4	1,68	1	5
10. I felt that my actions had an expected outcome.	3,69	4	0,95	2	5
11. Moving to the church felt strange.	3,00	3	1,12	1	5
12. I felt nauseaus when I used the prototype.	1,25	1	0,45	1	2
13. I felt vertigo while using the prototype.	1,58	1	1,16	1	4
14. My eyes felt strained after using the prototype.	2,00	1	1,48	1	5
15. I felt that the "Fallen Angel"-painting was the central piece.	2,85	3	1,52	1	5

When asked if people understood that the "Wounded angel" painting by Hugo Simberg was the central piece of the experience (Q15), the participants' opinion was divided, as positive and negative were both reported by five (5/13) participants, and three (3/13) participants had a neutral response.

5.2 Interview results

The prototype testing and interviews were audio recorded, and the audio was transcribed after the testing. An "In Vivo" Coding method was used to go through the transcript **[25]**. The coding uses the comments verbatim to create codes. Some larger comments lead to creation of multiple codes, while some codes had multiple comments referring to them **[ibid.]**.

In total, 182 unique In Vivo comments were found from the transcript, which lead to 194 unique codes. Out of the comments, 103 relate to a single code, 55 to two, 18 to three, four (4) to four, and 1 comment relates to 5 codes.

These codes were then further categorized into groups, which can be seen in **[15]**. Some codes lead to their own groups, some had multiple codes per group. The grouping was based on the Grounded theory methodology, in which the code categorization comes from the data, in a bottom-to-top manner **[27]**. Some of the codes were then clustered into one, or even further 'main' categories to group the codes more cohesively. The coding resulted in 13 main categories, of which three (3) categories had 50 or more mentions, two (2) categories had comments between thirty and forty comments, four (4) categories had between 5 and 15 mentions, and four (4) had less than five mentions.

The main groupings are: **Usability** (59 mentions, 30%), **Disorientation** (58 mentions, 30%), **Emotional Reactions** (50 mentions, 26%), **Visual issues** (38 mentions, 20%) and **Presence** (33, 15%). Many groups were regarding their perceptions on the quality of the experience with the prototype, such as **Usability**, **Visual Issues** and **Head Tracking Issues**, while many others were regarding participants' subjective descriptions of the experience using the prototype, such as **Emotional Reactions**, **Exploration** and **Loneliness**.

Usability (59/182, 30%) related mentions was the largest category. It includes codes, such as 'I am using icons to navigate', where a participant described "*Yeah, I'm moving around with these orange things*". Many (42) comments were of users having issues using the prototype, such as code's 'Hard to interact with icons' was described by one user as "*I think I would explore more, but since it's hard to interact with those icons, I'll stop*". The negative comments ranged from not being sure of how the interaction works "*Is this working? Because, sometimes these Icons come and sometimes they don't*", to comments on the interaction's difficulty, such as "It's not working all the time". Fourteen (14/59) comments describing the usability of the system were positive or stated how the participant had understood how the system worked, such as "*Yeah I think some of the pictures were blurry, but I mean it was cool to interact with the icons*".

Disorientation (58/182, 30%) was the second largest grouping. Over-all 58 comments regarding disorientation were mostly negative, and showed the participants feeling disoriented. They ranged from regarding 'Generally confused about navigation' such as *"I'm all already mixed, so…uhh… how to go back?*" to more specified, such as category 'Feels like they are stuck / going in circles' comment "*OK I'm going in circles, so is there a way…?*".

Emotional reactions (50/182, 26%) of the participants were categorized into their own groupings before being categorized in the larger Positive (26), Negative (16) and Neutral (8) groupings. The Positive categories groupings, such as 'Fun' and 'Excited', with respective comments, such as "*I thought it was fun looking at the paintings, and it felt like I was in a virtual game*" (Translated from Finnish) and "*Well the experience was exciting*" (Translated from Finnish). The negative groupings consisted of 'Frustration', 'Scary' and 'Self-blame', with respective comments of "*I think I would explore more, but since it's hard to interact with these icons I'll stop*", "*This is scary*!" and "*Ah… Now it's happening! I was being impatient*".

Visual Issues (38/182, 20%) were mentioned by ten out of the thirteen participants. The most mentioned visual issues were regarding 'low image quality' (17), such as "*The image is a bit blurry*" (translated) or "*I think visually it was kind of not accurate enough*". Furthermore, the participants mentioned a low "*Image's text quality*" (5), as the walls of the museum had texts on them. For example, one participant mentioned "*The texts are not very clear in this. I want to read those*". Another mentioned visual issue was the 'Camera / Image position' (12) that noted how the position where the camera had been set was not pleasing to the participants, such as "*This is scary. It feels like I'm higher*" (translated).

Presence (33/182, 15%) was mainly mentioned positively, with 27/33 comments, as they mentioned relating to the room's size and having a recollection of the space, such as the comments "*This is a big room*" and "*I'm wondering if this is some museum. Some museum in Helsinki, that comes in my mind first, something really traditional*" (translated).

Exploration (14/182, 7%) grouping contained comments of the participants wanting to walk "*Can I walk whole I'm wearing these?"* (Translated), wanting to explore the virtual environment "*And I can also, like, move around the cathedral?*", and wanting to read the texts in the environment "*The texts are not very clear in this. I want to read those*".

While groupings, such as **Usability**, **Visual Issues** and **Disorientation** showed the negative responses for any flaws the participants had, the participants reported having enjoyed the experience in general and reported feeling present in the museum and cathedral.

6 DISCUSSION

In this section we will discuss about the UX Dimensions, design approach, experiment method and results, and further work that are planned regarding the prototype development.

6.1 Design Approach

The design approach of the development process was considerably efficient, as all stakeholders were included into the process early on, which helped reduce time spent on communicating ideas after the concept creation was conducted. The benchmarking conducted during the concept creation stage also helped finding usable features and possible pitfalls in VR experiences before going further with making early stage prototypes or implementation.

As we chose to implement the prototype using interactive omnidirectional video, computer generated VR graphics were not required to be designed and developed, which shortened the timespan from concept to prototype.

The early stage prototyping before implementing the actual research prototype helped with finding many errors early on, which also reduced the workload that would have been added by extensive evaluation of implemented final prototype.

6.2 UX Dimensions of Virtual Reality – Experiential Design and Evaluation Components

Many of the UX dimensions were mentioned in the interview results, including: Immersion, Presence, Disorientation, Pleasantness, Sense of Control, Exploration and Simulator Sickness.

The prototype succeeded with the regards of **Presence, Pleasantness, Exploration** and **Simulator sickness**, as the first three had positive mentions and questionnaire answers. Simulator sickness had a low mentions and negative questionnaire answers, which was a desirable result.

Immersion had few mentions and the question relating to **Sense of Control** had slightly neutral answers, and thus it is indeterminate if our prototype succeeded with these dimensions.

Disorientation had many mentions on the participants feeling lost, which would lead to argue to this dimension had unwanted results.

6.3 Testing approach in the wild

The chosen testing method, "Guerrilla testing" **[17]**, allowed for testing the prototype with participants in a faster manner. The strength of the method is that it supports the prototype process, as it can be conducted at a fast pace. No laboratory space is required and the recruitment of participants is done on site, in the wild, and it can be used to find usability issues, amongst other findings such as the flaws in the central concept idea, in the early part of the development process. The method's main weakness is that there can be ambient noise and other distractions in the environment.

6.4 Questionnaire results

While the sampling size was only 13 participants, the background questionnaires showed that Virtual Reality is still an emerging technology in Finland even among university students and faculty. Not many participants were familiar with it, as eight (8) of our 13 participants had no previous experience, while four (4) had tried once or twice and one (1) had use one to three times during the last month. The size of participants with experience with VR technology in our study sample could even be higher than the general population, as five (5) of our participants had a background in Information Technology.

The participants' perceptions in the post-test questionnaire had a fairly neutral-to-positive over-all response, such as the questions regarding Usability of the interaction method and if the participants felt disoriented. Results seem to indicate that the participants had a more pleasant than unpleasant experience, and that the participants were not greatly affected by simulator sickness.

6.5 Interview results

Due to immersion being linked to the level of sensory quality produced by the technology **[6]**, the immersiveness of the system may have been affected by the low level of the image quality.

The analysis of the interviews indicate that the participants were affected by disorientation, as the participants got lost in the museum space while exploring. This could be caused by the prototype's low image quality or the large museum space. Some participants went into a museum's side-room that could be visited, and were not able to find a way out.

Another concern was technically derived negative issues raised by the participants, such as the visual issues, usability issues and head tracking issues. These issues may indicate that there could be an influence on the user's experience, even if a majority of the issues were not severe enough to force the participant to stop using the prototype.

The interview comments showed that the participants wanted to explore the space more than expected during the development phase, which could be shown by multiple comments about wanting to read a text that is too blurry. Furthermore, participants attempted to walk, even after being asked not to walk during the testing. It seems that even in this type of simple exploration of space, the physical movement is natural and important.

6.6 Implications for further development

The results and feedback received from the testing were used to find implications for further development and refinement of our prototype. While many of the implications concentrate on the issues found with the testing, the interview and questionnaire form also showed that the participants had fun during the experience.

Visual quality needs to be improved. As the low visual quality was mentioned, it shows that improvement in the omnidirectional still image quality was needed. This was highlighted even further as no audio was included, so the experience had to rely on visual material. Using a better quality camera, or further image error reduction, as the camera used for this prototype **[22]** uses only two lenses and provides a resolution of 5376x2688 pixels.

Users need to be able to relate to camera positioning. Some participants commented negatively that the perspectives were different from what they were used to. More meticulous planning of camera position, such as the height the camera is set to, and distances from walls, should be considered to relate more to someone visiting the museum. Helle et al have also discussed the importance of camera position being in a natural position for the user **[11]**.

Audio content is required. Audio were only mentioned five times, but guerilla tests in the wild showed that ambient sounds in the environment sounds could distract the users. Furthermore, some of the benchmarked VR experiences showed that audio could add and be in fact the central element to the virtual environment and storytelling, so further development should include audio elements as part of the design and implementation.

The ease of usability with the interactions and the icons is important. The icons need to be made easy to notice and clear with their feedback, to let the users know that the icon is activating when looked as in our case at or otherwise interacted with. Some of the usability issues in our early prototype testing, such as icons not activating when looked at, were caused by technical errors, and should be debugged.

Disorientation needs to be mitigated. Some participants seemed to get lost in the side room of the main hall of the museum that they could enter. This showed that a simpler virtual environment with less confusing layout could be more beneficial, in case this helps the users.

While these implications are concentrated on improving further iterations of our prototype, these implications could be of possible help in development of similar products.

6.7 Limitations and Further work

As all (X put number here somewhere to remind the reader) of the participants were either university students or staff, and five (5) of the participants had a background or currently worked in the IT field, it is possible that the participants do not represent general population clearly. However, for the very early testing of the initial idea for further development and to get an understanding of the interactions, exploration, experiential aspects, and major usability issues, we believe that for this purpose the convenience sample works out fine.

The testing was conducted "in the wild" in a non-controlled public space, and the ambient noise and other commotion could have effected immersion negatively. One participant mentioned the ambient noises with "*I kind of thought that what is happening here when I heard the noises and a group of people went past, and then I was back in the other reality*" (translated).

Results of the study are being used in further iterations of the design and testing. Semi-controlled experiment will be conducted to further evaluate the experience with participants when the prototype reaches a sufficient level of maturity required. Lighter form of testing with a few participants is done continuously with participants. The aim is to keep the prototype on level showing the concept is working with storytelling, and other audio and visual aspects more finalized but not a final product.

The aim of a further study would also be to examine the experiential components of the virtual reality experience that were discussed in this paper, which could aid any UX research and work being done in the field of VR.

7 CONCLUSION

In this paper, we completed a Virtual Reality development to an implemented prototype stage with the aid of UX Design methods. The UX design approach helped with the efficiency of the process and allowed mitigating potential pitfalls. During the process we identified experiential components of the VR experience based on prior literature, user testing, and subjective descriptions of experience in the test situations. These included: Immersion, Presence, Disorientation, Sense of Control, Pleasantness, Exploration and Simulator Sickness. Furthermore, the results of the evaluation testing were used as guidelines in the further development of the prototype.

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