Narrative Navigation in Virtual Reality

A study on the simplification of interactions in a virtual environment

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Abstract

Virtual Reality is a powerful, although still fairly new, medium; its immersion and involvement capability is particularly useful in the cultural heritage domain, where it can be used to visualize places or artifacts long gone.
However, its employment in museums has brought a problem to light: how to design an interface simple enough to be easily used even by someone who has never experienced Virtual Reality before, which is the case with a fair number of museum-goers.

This thesis examines the most common interfaces for heritage VR applications, paying particular attention to the navigation system, in relation to the Finnish Pavilion project (a virtual interactive reconstruction currently on show in the Design Museum of Helsinki). It also reflects on the possibility of introducing a narrative in the installation.

It is true that every navigation metaphor is strictly connected to the environment and the purpose of the VR application. For this particular installation, the teleportation was chosen. With the idea of intuitiveness and, when possible, the use of established designs, I developed three prototypes: an automatic one, a controlled one and a GUI-based one. To verify the efficacy of the prototypes, user tests were conducted at the Museum.

Acknowledgements

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"Imagination, rather than mere intelligence, is the truly human quality"

Terry Pratchett

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Introduction

The idea of Virtual Reality (VR), as a synonym of an alternate existence, has fascinated mankind for a long time. In 1968, Ivan Sutherland implemented one of the first head-mounted display (HMD), and using wire-framed graphics, made the first virtual immersive experience possible, making an idea, reality. Milgram, Takemura, Utsumi, and Kishino, in 1995, defined the VR environments as the pole of a reality-virtuality continuum, with, at the other end, the real world. The VR presents a “completely synthetic world, [...] which may also exceed the bounds of physical reality” (Milgram et al., 1995), as opposed to the real environment that is inevitably bound by the laws of physics. Everything in between is considered Mixed Reality, which also encapsulates Augmented Reality and Virtuality, where “real world and virtual world objects are presented together within a single display” (Milgram et al., 1995).

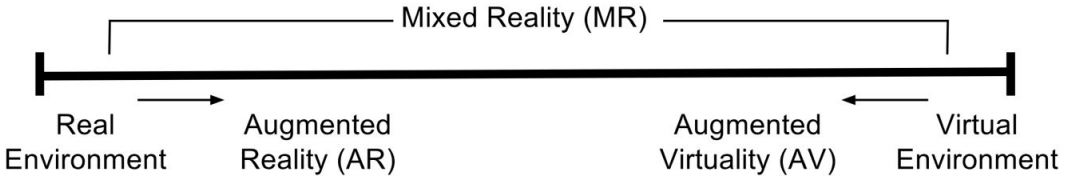

Figure 1.1: The “Reality-Virtuality Continuum”. Credit: Milgram et al., 1995.

From Sutherland’s first displays, the technology has significantly evolved and has found use in many different fields: for example, design and prototyping, psychiatric treatment, scientific visualization, and heritage. (Bowman et al., 2004). About the latest in particular, VR can really help bring back to life cultural and historical sites: where the passage of time has made it arduous to obtain information, having a virtual reconstruction allows to visualize the artifacts in their original contexts.

> “...simply watching an animation or real time simulation is a passive method of interaction, a more immersive user experience is obtained through the active exploration of the artefacts.”
> (Arnold et al., 2008).

Cultural Heritage (CH) encompasses all those artifacts that, for historical and artistic reasons, constitute the cultural richness of a place and a population; it is an “essential expression of the wealth and diversity of human cultures and therefore its

documentation, interpretation, restoration, and dissemination are considered to be crucial tasks" (Portales et al., 2018). The combination of the new technologies and the CH has brought significant novelty in the ways of fruition of the cultural structures: the interaction that VR and AR carry helps the user to be at the center of the application, enjoying art and culture from a broader perspective (Portales et al., 2018). It also brings back to life "architectural complexes that no longer exist or diachronic urban spaces that have characterized the history of specific urban places." (Casale et al., 2017).

Cultural heritage institutions (galleries, libraries, archives, and museums) are starting to embrace the integration of User Experiences (UX) into the conventional ways of presenting exhibits: the technology should be adapted and balanced to maximize the meaningfulness of the visits for museum goers (Konstantakis and Caridakis, 2020). The use of technologies in museums has already changed the means of communication between the institution and the visitors, and it is predicted that technologies will be used more extensively in the near future. (Parry, 2007).

The potentials of immersive encounters are several: increase an institution's visibility and contribute to the innovation of culture; offer more dynamic ways of connecting with visitors; encourage rich practice of participation; engage users with alternative viewpoints (sites, collections, themes); and provide a possible new revenue stream. (Kidd and McAvoy, 2019). As Konstantakis and Caridakis (2020) concluded in their article, "meeting visitors' needs and expectations within cultural spaces is crucial to stimulate learning, to engage visitors and, at the same time, to create meaningful experiences for visitors".

Therefore, many different examples of VR applications specially made for CH can be found. One is "TroiaVR": a virtual installation that includes the recreation of Troy in different time periods, as well as its past and present landscape setting, and context information. The aim of the project is to serve both as an archaeological presentation and a research tool. (Jablonka et al., 2002).

Another is "Virtual Veronese", a VR and AR project in the National Gallery of London, in 2019. To remedy the decontextualization of the painting "The Consecration of St Nicholas", the prototype allowed the participants to go back to its original setting, the church of San Benedetto al Po, near Mantova, Italy. Ian Baverstock, Chairman of Focal Point VR, the company that superintended the project, stated: "We wanted visitors to understand the political and religious significance of the art but in a short, intense experience."(Hinkin, 2019).

The "Rediscovering Vrouw Maria" project (Figure 1.2) is a gesture-based interactive simulation that allows the user to navigate around the wreck of a Dutch merchant

ship that sank near Finland. The relic was rediscovered in 1999, very well preserved. The experience consists of, among others, real-scale 3D graphics, based on the measurements and photographs of the site, immersive soundscapes, and info spots furthering more detailed information on the site. (Reunanen et al., 2015).

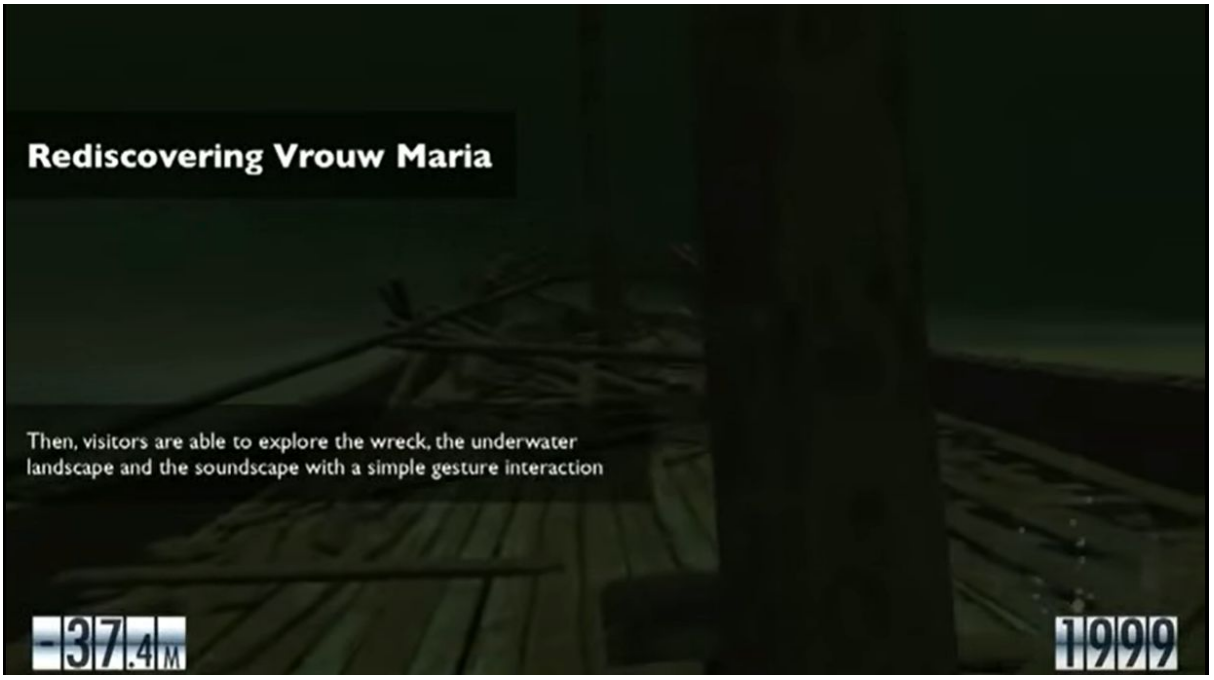

Figure 1.2: a still frame of “Rediscovering Vrouw Maria”. Credit: Aalto University Youtube video “Interactive Installation for shipwreck Vrouw Maria”, 2012.

The “Journey into the heart of Evolution”, exhibited in the National Museum of Natural History of Paris, is yet another example. The installation depicts the classification of the living species and how they are related to each other; it also focuses on the origin of life on earth and the impact of mankind on the environment. The wildlife can be thoroughly inspected thanks to animated 3D models and infographics.

And, of course, there’s “The Finnish Pavilion at the 1900 World Fair” (Figure 1.3), the case study of this thesis, displayed in the Design Museum of Helsinki. It’s a most faithful 3D reconstruction of the 1900 World Fair Pavilion of Finland, that the user can roam freely in all its parts; the project is a long-term, ever evolving one, which started in 2010 and grew in various ways since then. Right now, it’s a Unity project developed for HTC Vive, with the support of Steam VR. (Diaz-Kommonen et al., 2010).

Figure 1.3: Inside view from the west end of the Finnish Pavilion.
Credits: Mikko Hovi, http://paviljonki.mlog.taik.fi/gallery/ (2020)

Every interface in those different projects is deliberately designed to best fit the purpose of each application, with a special attention to the user and exhibit place; in particular, there are specific issues to take care of when a VR application is installed in a museum. As Wojciechowski et al. (2004) point out, the exhibition must be the result of the collaboration of the curators and the developers, and “the system must provide museum visitors with an intuitive human-computer interface based on well-known metaphors”.

The question at the heart of this work is the following: what is the best interface possible for a VR application meant to be shown in a museum? Of course, there is not an unambiguous answer to this inquiry. User experience (UX) designs are the results of tradeoffs, of choices that bring both benefits and disadvantages. (Bowman et al., 2017). Moreover, these decisions greatly vary with the application in hand, the input and output devices, the selected audience; these issues are particularly sensible when applied to museums, as few studies have been concerned with the complexity of the museum experience (Everett et al., 2009). For this research, I will take in consideration the Finnish Pavilion project.

One of the most notable problems with the Finnish Pavilion, and the spark that ignited this thesis, are the navigation mechanics, which can be easy enough for experienced users, but have been a real obstacle for the generic museum audience. Most of the visitors seem to find it complicated to press the pad to point and teleport, and some are confused about the color scheme of the pointers. Another issue, less

critical but notable nonetheless, is the absence of a narrative as guidance in the installation: the user is free to roam the Pavilion to their liking, but also to get lost in it, missing sometimes remarkable spots. In the original project there were information hotspots, accessible via UI (user interface) icons, with brief descriptions about the models: those panels are not deployed in the current interface.

My role in this project has been to find an alternative navigation system, that could prove to be simpler and more natural than the one in use. Furthermore, a narrative of sorts has to be added, with the establishment of a fixed tour and the restoration of the original idea of the info points along it.

Thesis Scope and Structure

In this thesis, I will address the problems of designing an intuitive navigation system for a particular museum VR application, and the integration of a narrative to guide the user through the experience.

In the second chapter, the most common navigation metaphors for VR will be examined, reflecting on the interaction design in a 3D virtual environment.

The third chapter will introduce the Finnish Pavilion: from the origins and meanings of the project, to the modes of operation of the current interface. Then it will outline the prototypes for the new navigation system in detail.

The user tests conducted in the Design Museum are the object of the fourth chapter: the chosen procedure, the preparations made before-hand, the questionnaire which was used are also displayed. It will then present the transcripts of the interviews my colleague and I conducted on the users, and our analysis on the tests results.

Interaction in a 3D application

For the past decades, user interfaces (UI) on desktop computers have used and reinforced the same designs and principles, so that now every modern user is acquainted with interaction techniques such as drag-and-drop, or UI metaphors such as WIMP (Windows, Icons, Menus, Pointer) (van Dam, 1997). With newer technologies, like VR and AR, however, developers are struggling to find UI designs as intuitive and functional. The task is not elementary. Many different problems have arisen: the unusual computing environments, applications, input/output devices are very often incompatible with the traditional interaction metaphors, and moreover users often find it difficult to move and act in a 3D space (Herndon et al., 1994).

To start designing a new interface for a computer technology, a basic knowledge of HCI (Human-Computer Interaction) is necessary. Like Bowman et al. (2017) report, HCI is a field that studies the relationships between human users and the digital technological world, with an emphasis on the “humans” and their needs. It also focuses on designing new ways and forms of interaction; in particular, there’s special attention on the UIs, through which the user actually interacts with the machine.

Another aspect to be considered when talking about VE and 3D spaces is presence. The concept of presence, or in case of VE, telepresence, is the subjective experience of really being in the virtual space (Oh et al., 2018). The conjunction of immersion and interactivity enhances the user’s presence: “To apprehend a world as real is to feel surrounded by it, to be able to interact physically with it, and to have the power to modify this environment” (Ryan, 1999). To maintain this unique state of experience, it is important not to break the illusion of presence: so the attention to the 3D space’s creation and the usability of VR hardware and software is paramount, (Marsh and Wright, 2000), as the design of a seamless interaction interface (Bekele et al., 2018).

Interaction techniques

The interaction techniques are particular elements of the UI: they consist in “methods used to accomplish a given task via the interface” (Bowman et al., 2017) and comprehend the inputs given by the users and the responses given back to them by the system. Generally, in a 3D virtual environment, the user will need means to move about in the virtual world, to grab and place objects, if there are any, to navigate eventual menus. According to LaValle, the Universal Simulation Principle is: “Any interaction mechanism from the real world can be simulated in VR” (LaValle, 2015). This does not translate into a necessary commitment to realism; on the contrary, “it is often preferable to make the interaction better than reality”.

In his book, LaValle indicates that when developing the interaction mechanisms for a VR application, the main issues to consider are:

1. Capability for the task to reach the necessary speed and accuracy.
2. Complexity of the mechanisms: the user should manage to use the application easily and naturally, without having to struggle for a long time.
3. Complexity in terms of cognitive load: the user, after having understood and mastered the mechanisms, should not have to put continuous attention to the task.
4. Global comfort after a prolonged period of use: the user should not be excessively fatigued, unless the goal of the application is physical exercise.

Almost every kind of interaction can be organised in three great families: travel, selection and manipulation, and system control (Bowman et al., 2017). The first one, travel, is tied to the navigation tasks, which include both moving and wayfinding in the environment. It concerns the translation and rotation of the viewpoint, the modification of certain conditions, such as speed, and the spatial understanding necessary to find our way in the world and to determine the paths that we are going to follow. The second one, selection and manipulation, covers all the techniques for selecting, positioning, rotating, scaling a virtual object. Those greatly depend on the input devices that are being used, in addition to the goals of the application. The last one, system control, is about the commands through which the user can modify the system or the interaction mode, in some ways; this comprehends physical controllers, graphical menus, voice or gestural commands, among others. I will primarily focus on the first one.

Navigation metaphors

Locomotion is the “most common and universal interaction task in 3D interfaces” (Bowman et al., 2017). In the physical world, moving is one of the simplest and immediate actions: our brain instinctively communicates with our muscles. In 3D UIs, physical motions can be effective when the space and the speed are limited; for most applications, however, the virtual environment covers a much wider area than the tracked one. In these cases, the movements must be mapped to navigation metaphors.

There are different travel tasks that might need to be carried out in a 3D application, each of them conditioning the practicality of the various techniques. Bowman et al. (2017) divide them into three categories: exploration, search and maneuvering. In an exploration task, the goal is to wander through the environment, inspecting and learning about it, getting the user accustomed to the world they’re in. The equilibrium between guiding the user along a predetermined path and giving them complete freedom to roam must be balanced, especially in those applications that include storytelling: composing a scene that draws the user’s attention in a particular direction, or having a character that points to or moves in line with what the storyteller wants in view are all techniques that can redirect the user without constraining the path (Pausch et al., 1996).

In a search task, the user has to travel to a specific location, previously known or unknown by them; in the first case, Darken and Sibert speak of “primed search”, in the second, of “naïve search”. In a primed search, the navigator knows the whereabouts of the target location, so “the search is nonexhaustive” (Darken & Sibert, 1996). In a naïve one, the navigator needs to exhaustively explore the world

to find the target: the task is similar to the exploration, but as opposed to it, the user has a specific goal. The two kinds of search are often found in sequence, when, for example, the navigator does not know the precise position of the target but has a general knowledge of the area.

The maneuvering tasks may be considered a special type of search task, but in a small, limited space, with the requirement of precise movements. It is most frequently used when there is the need to stir the viewpoint in an accurate way to perform a task, e.g., to read the text of an infopoint from the right point of view, to have it legible. The best metaphor for this task is considered to be tracking of the physical movement of the user, to achieve the precision and efficiency required.

Bowman et al. (2017) classify travel techniques by four common metaphors: walking, steering, route selection and travel-by-manipulation. When it is possible to track the physical motion of the body and the area is free of obstacles, the real walking technique is of course the most natural one. There are, however, many complications that make this option not always practical: other than the need of a large tracked space, the cables for the hardware must also be long enough and supervised by an operator or a machine, to prevent them from getting tangled in the user. Even if the requirements for the real walking cannot be entirely met, there is still the opportunity to let the user move in VE (Virtual Environment) by physical walking: through visual manipulations (i.e. the redirected walking [Razzaque et al., 2002] or the seven league boots technique [Interrante et al., 2007]) or with the aid of specialized hardware (such as treadmills, like the Virtusphere [Medina et al., 2008], or low-friction surfaces, like the Wizdish [Swapp et al., 2010]).

Another travel technique is steering, “the continuous control of the direction of motion by the user” (Bowman et al, 2017); that is accomplished by manipulating a tracking device, or maneuvering a physical steering prop. In the first case, the steering can be gaze-directed, when the point of view of the user determines the direction, or hand-directed, where is the position and direction of the hand that regulate the motion (Mine, 1995); the second case is especially viable when a vehicle or other means of transportation are simulated: as Mine reports, haptic feedback greatly enhances the sense of presence of the user.

The selection-based travel techniques are predicated on the pick of a target or a path by the user. They are best suited for those applications where the goal of the movement is to position the viewpoint to a specific place, for example when there is an object to inspect more closely. The travel can be accomplished using a continuous movement from the startpoint to the endpoint, which helps the user not to lose their bearings in the environment, or by a “blink”, a teleportation to the target directly, that is less likely to cause simulator sickness compared to the other, at the

expense of the better orientation. To choose the destination, various selection techniques are used, such as selecting or placing a target in the environment, selecting the location from a menu, or entering coordinates or the name of a place on a text entry widget.

Lastly, manipulation-based travel is deeply intersected with the object manipulation techniques, and particularly useful in application when both these tasks are frequent and interfused; it can be attained by manipulating the viewpoint of the world. When manipulating the viewpoint, usually a miniature version of the virtual world is held by the user, and either the absolute position of the camera, or an avatar, is shown at the user's position: moving them in the miniature results in the travel in the "bigger" world. The alternative is to manipulate the entire environment relatively to the viewpoint: an example is the "grab the air" technique, by Mapes and Moshell (1995). With a haptic glove as input hardware, the user can clutch either objects or move through the environment, the same hand gesture handling both the tasks: "grabbing" the world in the direction the user wants to travel makes it shift in that way, giving the impression to move through space, even if the viewpoint maintains its absolute position; the same motion oriented towards an object allows to manipulate it.

Virtual Reality is still a developing medium, so there are not fixed metaphors for given situations yet. A tool that is giving many developers room to experiment is the SteamVR plug-in for the cross-platform game engine Unity 3D: it has been largely employed in the Finnish Pavilion project because it is easily connected to the Vive HTC hardware in use in the museum.

Simulator Sickness

A common problem connected with the utilization of VE technology is the so-called simulator sickness, or cybersickness: Cobb and Brown (1997) noticed that although the symptoms and effects are similar to those usually caused by other simulators or transportation, the causes and symptoms patterns were unique enough to justify a specific name.

The symptoms include nausea, headaches, and disorientation (Kolasinski, 1995); the causes appear to be multifactorial. Various studies (Kolasinski, 1995; Howarth and Costello, 1996; Kennedy and Fowlkes, 1992) agree on pointing as primary source the conflictual information about body orientation and motion received by the eyes, the vestibular apparatus (that controls our equilibrium), and sense of self: this is called cue conflict theory.

The conflict can be generated by the time lag correlated to the recalculation of the scene of a VE when the user changes point of view (Howarth and Finch, 1997), by

the virtual motion while the physical body is staying still (visually induced motion sickness, as called by McCauley and Sharkey, 1992), or by a combination of the two. While motion sickness can be caused by vestibular stimulation alone, simulator sickness is “more likely a result of the compounding of the visual and motion cueing” (Kolasinski, 1995).

Many other elements can be associated to the cybersickness: Kolasinski found forty different factors that had shown or were believed to influence the manifestation or the intensification of the sickness, that range from the individual (age, gender, mental rotation ability…), to the simulator (binocular viewing, flicker, refresh rate…), to the task (duration, method of navigation, movement speed…).

Moreover, Howarth and Costello (1997) found that even ruling out the most accepted factors (tracker lag, accommodation-convergence conflict, visually induced motion sensation), users still report nausea and stomach awareness. They concluded that “certain symptoms may be more likely to occur in the presence of particular problems. Sensory conflict appears to be a powerful stimulus for the genesis of nausea and stomach awareness. Motion, including head movement, is likely to lead to feelings of disorientation, and inappropriate optical design will result in eyestrain and associated ocular symptoms.”

In conclusion, the complete avoidance of cybersickness is very unlikely, but a series of specific types of compliance can help reducing or avoiding the insurge of the phenomenon: Bowman et al. (2017) named, between others, directional compliance, nulling compliance and temporal compliance (lack of latency).

Visual Narrative

Images were among the first means of communication and storytelling in history: from the Altamira cave paintings, to the first pictograms, men started developing a visual language before a literary one. Today after centuries of textual words preeminence, we are again appreciating how much “what we see is as important, if not more so than what we hear or read” (Rose, 2001). We live in a world of images, and visual technologies are flourishing; pictures and texts interconnect in communication. As Thibault and Walbert, 2003, stated, “visual literacy allows the viewer to gather information and ideas contained in the image, place them in context and determine whether they are valid”.

Visual perception can be passive or active (Arnheim, 1969): we can just see things, or we may want more information and fully become involved. We do not just identify objects, but we give them meaning depending on the relations between each other

(Carrol et al., 2004). These relations are what forms the “bigger picture”, and can be used to tell a coherent story.

Over the past few years, interactive systems have been used in museums, exhibitions, archeological places, and in general CH sites, to enhance the experience of visitors: these systems consist of a plethora of contemporary and emerging technologies, from mobile apps, to multi-touch displays, to VR/AR systems (Koutsabasis, 2017). Immersive practices are an “important driver of creative innovation and creative economy” (Mateos-Garcia, Stathoulopoulos and Thomas, 2018, as cited in Kidd and McAvoy, 2019).

VR brings new challenges in actively engaging the user’s perception and sense of discovery, as a moderately new technology, with no fixed paradigms yet. While Shneiderman’s Visual Information-Seeking Mantra (1996) can be in general a useful start for any data visualization, the HCI in VR has to be treaded carefully. “(VR) needs to have a form and a content, which catches and holds the user’s attention and absorbs the user in the illusion of interacting in the three dimensional space […]” (Marsh & Peter, 2000). The user has to be free to explore and interact, while being guided through the flow of the experience (Galyean, 1995). Narrative, in this sense, has to be voted to the engagement of the user: Branigan, 1992, defined narrative as the “organization of experience, which draws together many aspects of our spatial, temporal and causal perception”.

Haywood and Cairns found engagement to be described in terms of participation, narration and co-presence of others. VR installations in museums are therefore bound to double standards: on one hand, “stories live in and are influenced by their container, the medium of their telling” (Barry, 2000); on the other, the museum audience, an increasingly diversified community, has to be accounted for.

In one of his papers, philosopher and writer Umberto Eco, analyzed the role of the museum in the third millennium; starting from a quote of Paul Valéry, (1923), he synthesized three problems these institutions faced: “(i) an unfriendly, quiet, dark environment, (ii) lack of context for the individual works, (iii) abundance of works and complexity in perceiving and memorizing them all.” (Eco, 2007). If the Pavillion is to be considered a sort of virtual extension of the museum it is placed in, it suffers from just one of the issues aforementioned, the lack of context.

The project

The Finnish Pavilion

The Finnish Pavilion was built on occasion of the 1900 World Fair in Paris; it represented the effort of the Finnish cultural elite, the most distinguished architects, artists and designers, to show the “soul” of Finland. Even if it was then part of Russia, (until 1917), the Finnish wanted their Pavilion to manifest the spirit of a “strong, independent and industrious region” (Diaz et al., 2010); it showcased the most modern pieces of art and industrial products of the time (Fredrikson, 2001). Nowadays it is considered as “the archetype of the emerging national image” (Diaz et al., 2010). After the fair, the building has been torn down, the exhibit redistributed, and the only reminders of its image have been old photos, documents and verbal stereotypes.

Figure 3.1: Outside view of “The Finnish Pavilion at the 1900 World Fair” VR project. Credits: Mikko Hovi, http://paviljonki.mlog.taik.fi/gallery/ (2020)

In 2010, the Media Lab of Aalto University and the Department of History of the University of Helsinki collaborated to create a VR installation of the Finnish Pavilion (as shown in Figure 3.1). The structure was 3D modeled after blueprints, photos and drawings, with the goal to be the most faithful possible to the original; details of the exhibition inside were also added. The UI presented two icons, one for the entrances/exits, one for the information spots. Moreover, there were 3D diegetic sounds for the doors opening, the steps, and the atmospheric ambience, as well as non-diegetic ones (music, narrative sounds). The chosen navigation metaphor was walking: the user would move the viewpoint and walk in the chosen direction using a

mouse input. The installation setup comprised a stereoscopic immersive display, a sound system, a computer and a table with a mouse and two buttons. (Diaz et al., 2010).

Figure 3.2: The HTC Vive headset and one of the two hand controllers. The controller provides a round trackpad (left side of controller), the grab trigger on the opposite side and three buttons. Credits: HTC™.

The current installation at the Design Museum in Helsinki is an updated and developed version of the 2010 original one: first of all, the hardware has been changed to the HTC Vive headgear and hand controllers (Figure 3.2); then, the project has been moved to the Unity game engine. The interface has been changed as well: the info points have been removed, as the UI icons. The navigation system has become an arc teleporter: pressing the Vive controller pad, a rod-like line appears from the controller's 3D model inside the VE and, on the floor, a grid shows the teleporting area; the rod arc ends on the selected part of the floor with a pad, which changes color if the selection is valid or invalid. Releasing the controller's pad teleports the user in the chosen area.

This navigation method, though easy enough for the experienced users, has proven to be difficult to master for the museum-goers who never had VR or gaming experiences before. With the objective of simplifying the interactions as much as possible, I designed three different prototypes of the navigation system.

The concept design

When designing the new navigation system for the Pavilion, I tried to recreate a museum-like guided tour. The user's main interaction is to visit the structure and take into consideration the architecture, the artifacts and the art pieces: in this case, the means of travel should not hinder the actual goal of the application. I pinpointed four different approaches, as illustrated in Figure 3.3.

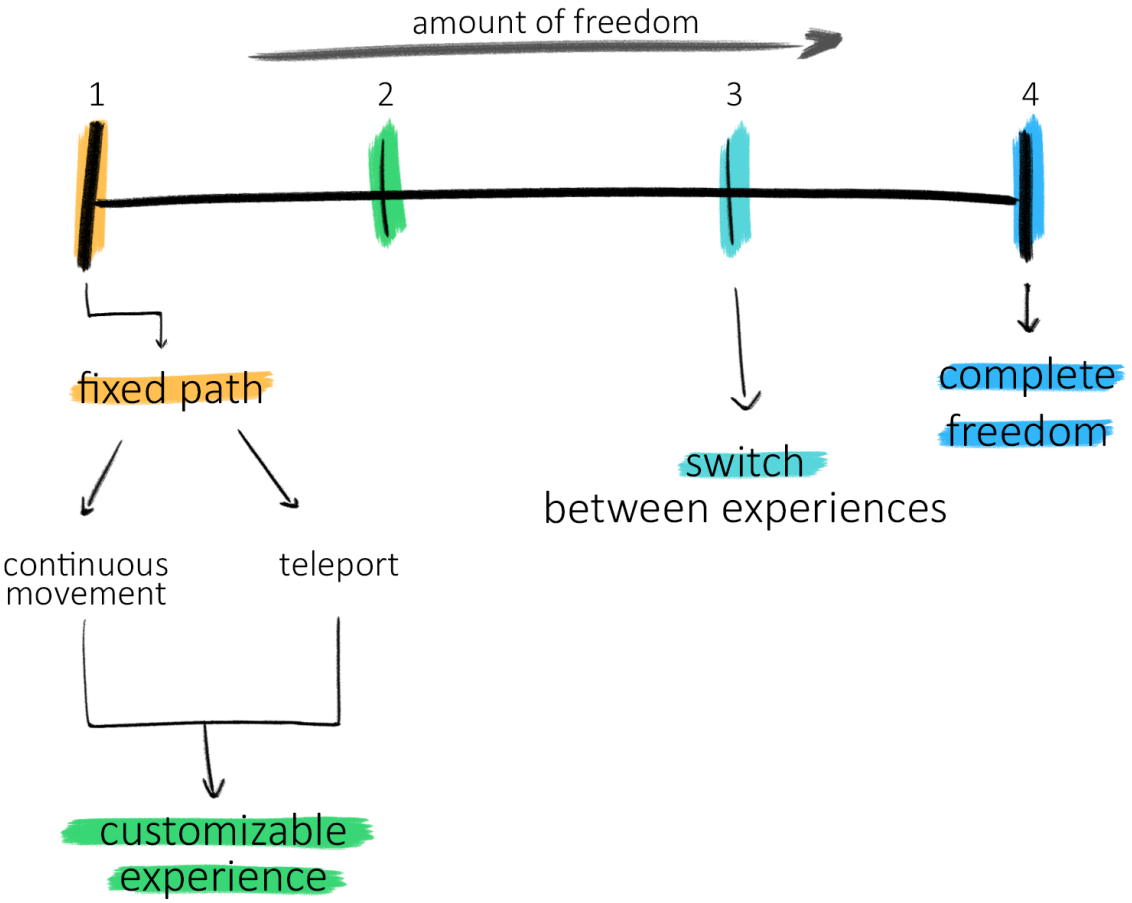

Figure 3.3: Schematic about the original concepts for the new navigation system

1. **Fixed path**. The user will be carried along a fixed path into the virtual environment; they can move the viewpoint, but they cannot change their position.
2. **Semi-automated steering**. The user will move of their own accord along a fixed path, actively dictating the pace of the experience.
3. **Switch between experiences**. A UI button will enable the user to choose if they want to follow the fixed path, or roam freely.
4. **Complete freedom**. The user can go everywhere they please; the interface will give hints of the narrative path, letting the user explore the environment.

Fixed path

This option would translate the installation into a 360° video tour; the travel would be automated, leaving the user to focus only on their surroundings. I considered two ways to implement this concept: by continuous movement, or by teleportation.

The continuous movement recreates the walking metaphor; the pace must be carefully studied, so that it would be quick enough not to be boring and frustrating, but also slow enough for the user to appreciate all the details and read the texts at the info-points. The advantage of this method is that it allows the user to walk around the Pavilion in its entirety, focusing only on the environment; the disadvantage is that to find a pace universally applicable could be very difficult, and a non user-controlled continuous movement is likely to cause simulator sickness (as per conflict cue theory).

Another approach is the teleportation to predetermined points; the teleporting spots would be chosen for their relations to the narrative and interesting points of view. There would be a timer to regulate the duration of every stop, which can be either equal or distinct by the spot “quality” (if it is an info-point or a view spot). This system allows to skip the walking parts of the tour, teleporting to the fixed spots directly, making the experience quicker; the teleportation can, though, cause disorientation.

Semi-automated steering

In the first option, the user interaction is kept at minimum; the Vive controller, provided by the Design Museum, has not been taken into consideration. The functionalities of the controller can be exploited to give the user the possibility to customize to a certain degree the virtual experience. After having defined a path, an intuitive controller movement can be used to proceed back and forth along it: e.g., tilting the controller up or down. The trigger and the pad on the Vive controller can also be employed for this task. UI elements can also be added, such as arrows or other icons, and use the controller as a remote control to interact with them.

This approach allows more interaction and gives the user the freedom to choose the pace of the experience; the addition of the UI could however reduce the realism.

Switching between experiences

Whichever degree of freedom is chosen for the fruition of the installation, it may nevertheless feel too much constricted for a more experienced user. A UI switch can be implemented to consent the user to leave the fixed path and swap to the current interface; interacting with the same button, the user could shift again to the controlled

experience. In doing so, the desire of the more experienced users to freely explore the Pavilion is taken into consideration, introducing another element in the UI.

Complete Freedom

The current interface enables the user to go almost wherever they please, leaving them the feeling of complete freedom of movement. If one would just want to incorporate a narrative, without altering the present interface, there is the need to find some expedients to guide the user focus. There have been various studies on the most suitable way to control the focus, one of them conducted by Lin et al. (2017).

The study experiments two focus assistance techniques applied in two different kinds of media, a “sport” and a “tour” video. One is inserting UI elements, like signs, arrows, or other graphic icons, pointing out the intended view direction to the user (visual guidance); the other is to auto-redirect the focus towards the desired spot, when the user comes near it (auto-focus). They came to the conclusion that both of the approaches made it easier to the users to focus on the designed target; while for the sport one, the auto-focus outperformed the visual guidance, in the tour videos the participants’ preference depended on which, between the narrative of the exploration, they each valued most. See Figure 3.4 for an overview.

Figure 3.4: Insertion of a graphic element to redirect the focus. Credit: Lin et al. (2017)

The “complete freedom” option offers the most interaction, maintaining the current interface and addressing only the lack of the narrative; however, it does not solve the problem of the difficulty the inexperienced museum-goers found while using it.

All these concepts can be combined and work together, to some extent: the redirection of focus, for example, can be exploited also in the customized teleportation, to help the user find their bearings again and suggest them what to look at.

The prototypes

From the concept design, I elaborated four different prototypes. The first employed automatic continuous movement: after numerous experiments, I could not find a pace that would be either fast enough not to bore, and slow enough not to cause simulator sickness, so I decided to discard it and chose to focus on teleportation as a means of travel.

The other three use, respectively, automatic teleportation, controlled teleportation, and teleportation manipulated by UI elements. In the UI prototype I also tried to implement a switch to the current interface. Every prototype presents a fixed tour of ten points of interest, seven inside and three outside; the user can teleport only in these locations, in a prearranged order, following the tour narrative.

I drew storyboards (Figure 3.5, 3.7, 3.9) for each of the prototypes, and diagram flows (Figure 3.6, 3.8) for the second and third one, to show how I imagined their working and to compare my idea to the effective user tests we carried out later on. In these prototypes the info-points were still not implemented and were not included in the user tests.

The storyboard

Storyboards have been used for decades now, as a form of previsualization of an idea. The first examples, in a form of “story sketches” that outline an animated cartoon storyline, are found at Disney around the 1930s (Canemaker, 1999). Having a clear graphic outline of the scenes greatly helps cinematographers and directors to find potential problems on the storyline and to experiment with different cuts and combinations. As Steven Douglas Katz pointed out in 1991, storyboards are an essential tool to genuinely envision a screenplay: “visualization must include hands-on pictures making in some tangible medium. Making ideas visible before they are put in front of the camera is a necessity.”

This method can be used in many other fields that benefit from the pre-representation of a concept: one is for sure the design and prototyping process of user experiences. Laurie Vertelney (1989) asserts that narrative storyboards are actually a variation of the cinematographic storyboard found in planning movies, except applied to interaction design. Expressive techniques from cinema and comics can be applied also in product design storyboards, such as framing theories and

timing. What separates design storyboards and cinema ones is the aim: while in feature pictures they are for production purpose, in design they are meant to place the product-user interaction in context and over time. (Van der Lelie, 2006).

Greenberg et al. (2012) present two alternative ways of creating a narrative storyboard for UI design: sketching stories by hand or using photos as source material. In the first method, the storyboard is entirely composed of hand-drawn sketches. Firstly, the storyboard frames are outlined; five is the recommended number of rectangular boxes that assemble the basic template, to limit the interaction shown in the storyboard to just one scenario. Depending on the context and the complexity of the interaction, though, more frames can be drafted.

Secondly, one develops the storyline: where the interaction takes place, what is the task, what kind of devices are used, are examples of the aspects to consider in describing the story. The scenario would be established in the five or more frames, usually in the form of a beginning, developing of the story, climax and end. Thereafter, one sketches the frames in appropriate camera shots. Annotations can be added to the sketches to emphasize the emotions and actions of the user.

In the second technique, the storyboard is photo-based: instead of hand-drawings, pictures will be used as source material. As before, one needs to outline the scenario. After taking the photo snapshot, five are selected to compose the story. In the end, storyline text and comments are added below the pictures; one can also add annotations, with the same aim of the hand-drawn method. Greenberg et al. (2012) suggest printing out the pictures in black and white, and to use office supplies to add movable annotations atop the storyboard.

Automatic movement

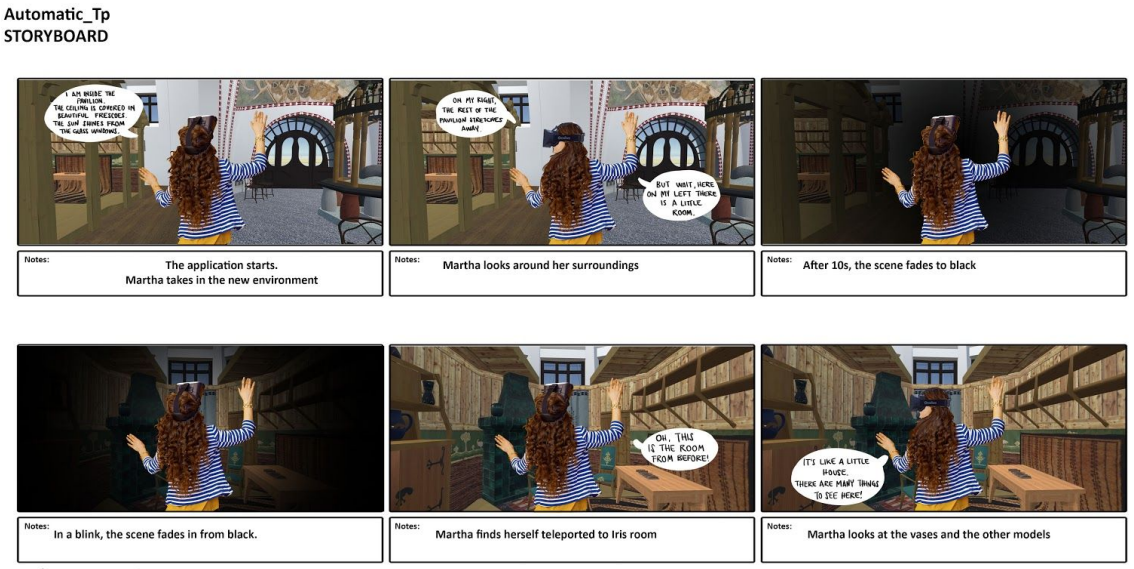

Figure 3.5: Storyboard of the automatic movement prototype

The first storyboard I drafted shows the interaction of the automatic movement prototype. I decided to create a photo-based storyboard; I however worked digitally, manipulating the pictures in Photoshop: I took screenshots of the Pavilion's inside, and added a user from the website Alamy Stock Photos (Figure 3.5).

In this prototype, the movement is automatically managed: after a fixed amount of time, the user will auto-teleport to the next point of interest. The viewpoint is aimed towards the direction of the artifacts or other compelling views.

Teleport

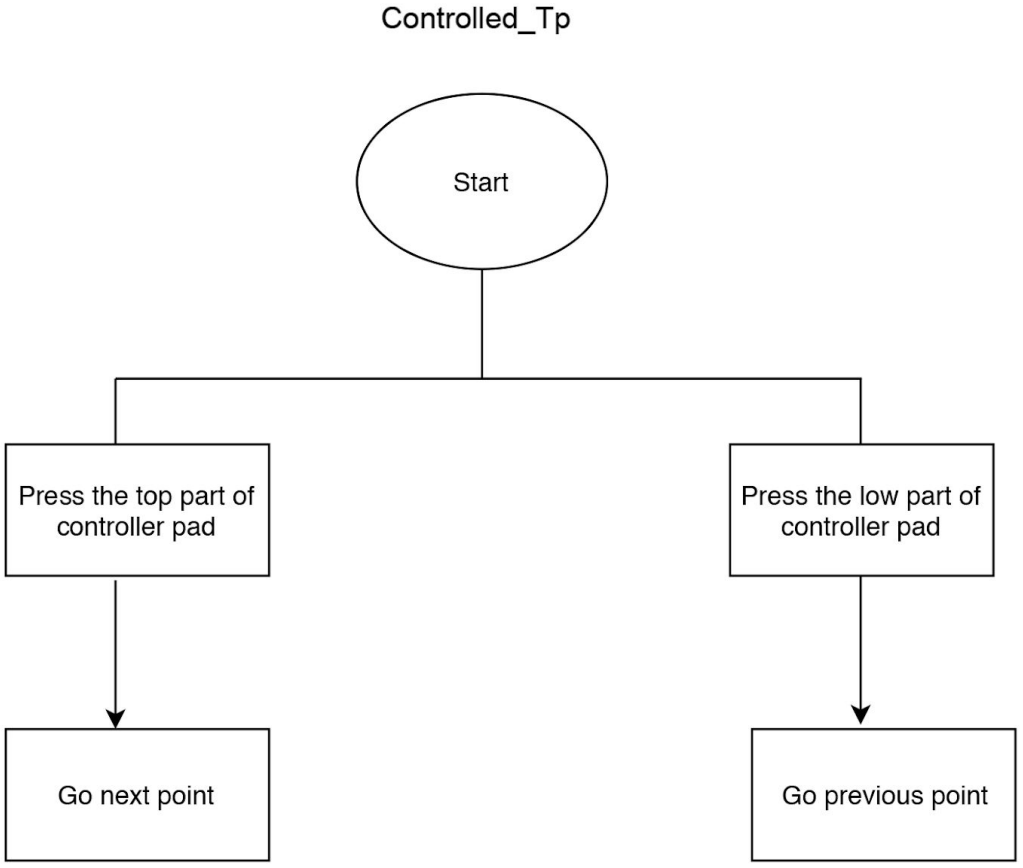

Figure 3.6: Diagram flow of the controlled teleport prototype

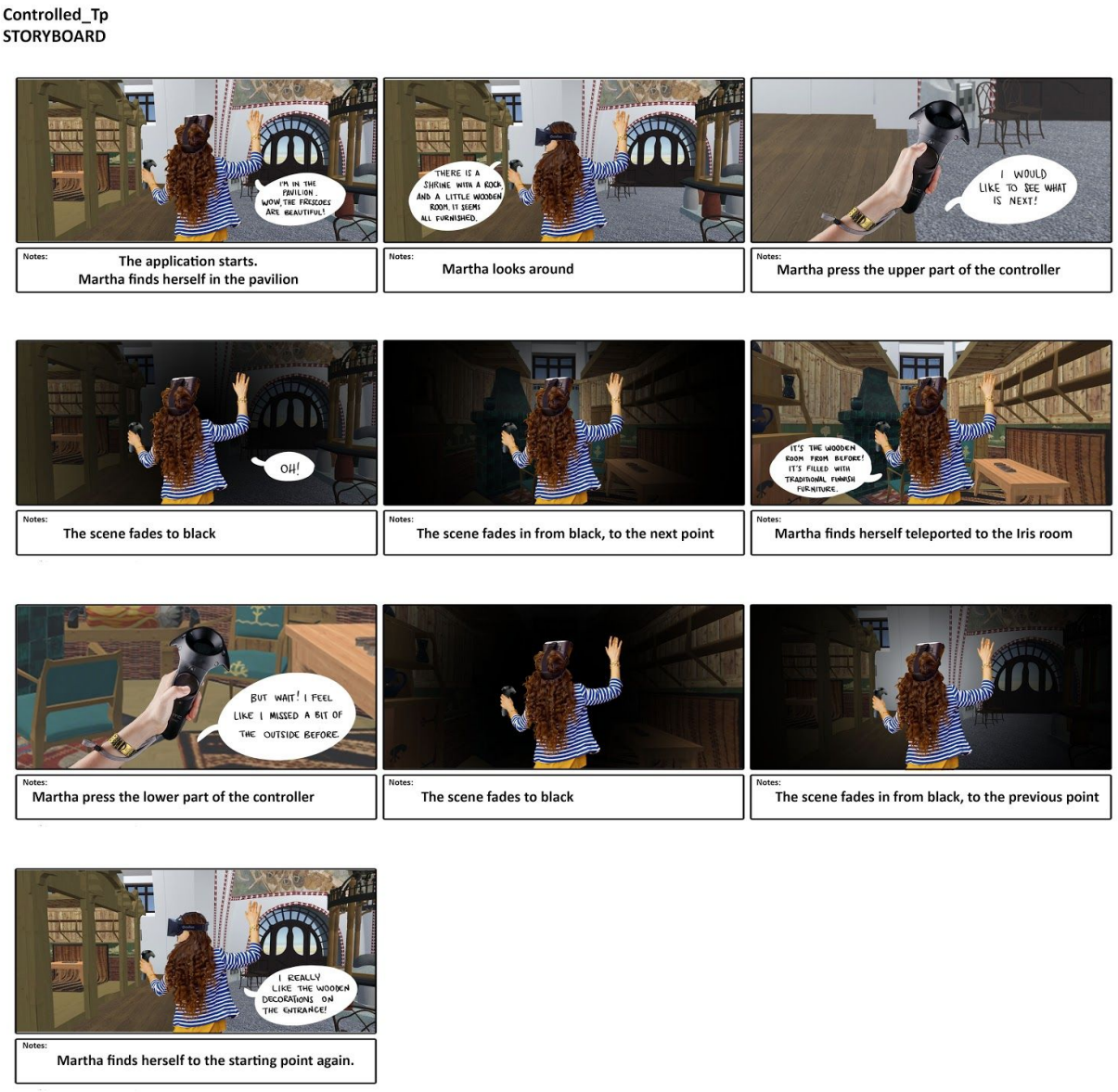

Figure 3.7: Storyboard of the controlled teleport prototype

In the controlled teleport prototype, the user can control the pace of the movement: pressing the upper part of the pad on the top of the controller, the user will teleport to the next point of interest; while pressing the lower side will make them go back to the previous one (see Figure 3.6 and 3.7).

UI

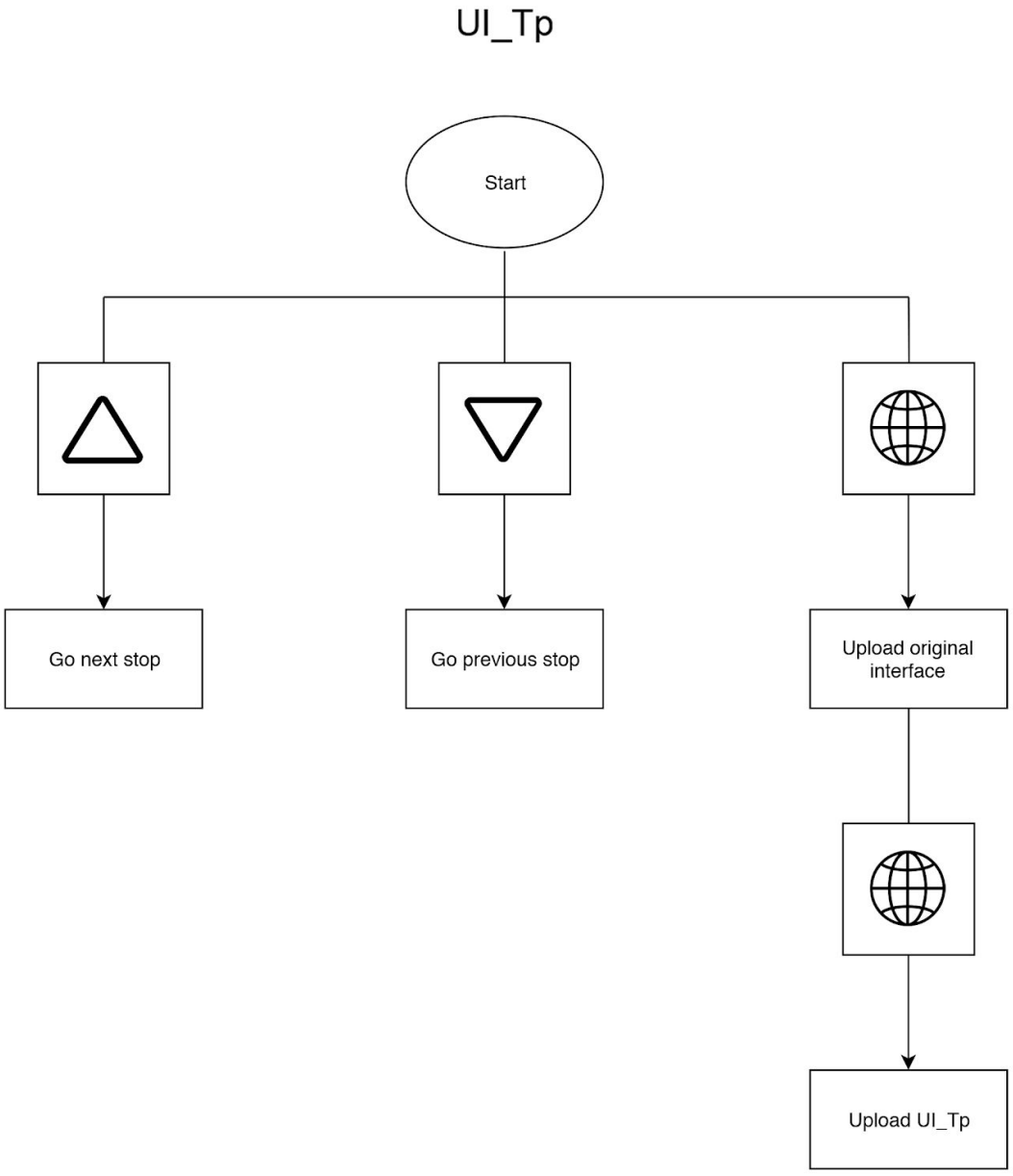

Figure 3.8: Diagram flow of the UI prototype

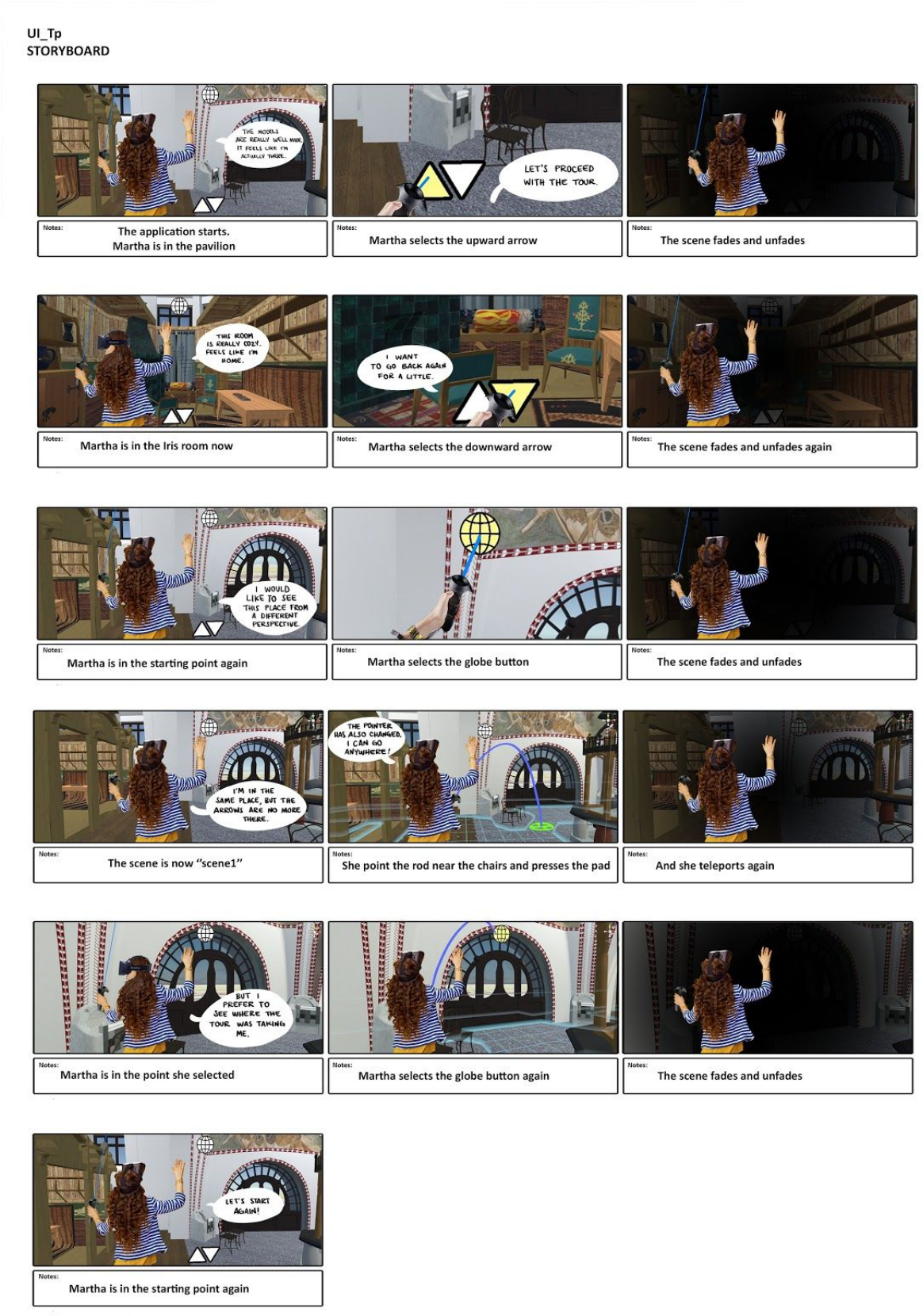

Figure 3.9: Storyboard of the UI prototype

For my last prototype, I considered adding three different buttons: two arrows, to proceed forward and backward with the fixed tour, and a globe, to access the “free navigation” mode that the original interface allows: the user can interact with these elements through a ray-casting pointer coming from the hand controller (see Figure 3.8 and 3.9).

When developing this prototype, I came across the problem of the compatibility of the UI buttons with the rod-like pointer in the original interface; when switching to scene1, the pointer could only recognize the teleport areas and not the globe button, so it was impossible to switch back to the fixed tour mode. To get around this issue, I created another Unity scene exploiting the free teleportation, making sure to use the same ray-casting pointer I used in the UI prototype; this made it possible to teleport everywhere in the Pavilion, and also to interact with the globe button.

Two other complications arose, though: not having set clear teleportation areas, there is no limit to where the users can move, which means they can also penetrate the models and travel out of the terrain. Moreover, a ray-casting straight pointer does not allow access to places obscured from the user viewpoint (Olwal et al., 2003).

The user tests

To analyze the pros and cons of the different prototypes, and to identify the problems of the current interface, my project supervisor, professor Lily Diaz-Kommonen, and I decided to perform a user testing in the Design Museum; thanks to the unreserved collaboration of Dr. Leena Svinhufvud, the museum educational curator, we could have four guides as participants.

We chose methods of empirical evaluation, which have been used in several other studies (as Nikolakopoulou and Koutsabasis (2020) reported) on CH UX: in particular, for the data collection, a self-developed questionnaire combined with video recordings and post-hoc interviews was adopted. An example of similar modus operandi can be found in the user evaluation of Loizides et al. (2014).

The questionnaire (see Appendix A) and test were devised in association with Ms. Neha Sayed, a PhD candidate from the Department of Media of Aalto with previous experience of user testing. Together, we defined the main informations we wanted to gather, as well as the equipment we would need; we decided to rent two cameras (Everio GZ-HM330 BE), with integrated microphones, one to film the test from observational point of view, and one closer to the users, to film the interviews.

The user tests were held where the Pavilion installation is exhibited: we occupied one of the two VR stations present in the room. Due to this setup, we were also able

to observe museum-goers interact with the current application while conducting our tests. All the users were asked permission to handle the interviews and the resulting data in respect of their privacy, and the data was similarly protected and solely used for the purposes of this research.

The questionnaire

The questionnaire was composed of 15 questions; after two short inquiries about the age and the education of the user, it focused on the prototypes' usability and naturalness. It then briefly investigated the current interface and the most common problems the guides noticed about it with the museum goers. In the end, we asked a few questions about their knowledge of VR and heritage-related VR applications.

The questions were structured as yes-or-no questions followed by open-ended ones: knowing we would not have much time for the interviews, we preferred to focus on qualitative information about the prototypes and the application itself. The entire questionnaire can be found in Appendix A of this thesis.

As other UX evaluations (Reunanen et al., 2015, Kyriakou & Hermon, 2019), also our questionnaire put the accent on usability and the overall UX: as Nikolakopoulou and Koutsabasis (2020) noticed, these seems to be "the primary "lenses" for the evaluation of interactive systems in CH", probably because the majority of the end-users may be considered new to this kinds of interactions. They also reported that most of these evaluations miss to acknowledge the cultural value that is or not conveyed by the CH UX, which was not the case with our questionnaire.

About the users

The four users were museum guides, with previous experience of the installation and precious insight on the main issues of the visitors. They were from 23 to 46 years old, three females and one man, most of them with an educational background in Art (one did not specify). Two of them had never tried another VR application, aside from the Pavilion; the other had some other experiences, mostly gaming-related: no one had tried another VR application designed for heritage.

In comparison to other evaluations, our number of participants was scarce (Nikolakopoulou and Koutsabasis, 2020); unluckily, for matters of time and organization, it was out of our hands. We were fortunate enough, though, to have museum guides as users; "to include CH professionals and experts in assessments of digital heritage can contribute to content validation" (Nikolakopoulou and Koutsabasis, 2020), and so even more their informed opinion was really valuable.

The Grounded Theory

To analyze the interviews, I used the techniques of the Grounded Theory, by Strauss and Glacer (1967). The Grounded Theory is a systematic methodology to analyze qualitative data: the analyst extracts codes from the data, which are linked to recursive ideas or concepts, and then catalogues them in categories. These will be used as a basis for new theories, or, like in this case, to better understand the strong and weak points of the prototypes, and, possibly, upgrade them.

The Grounded Theory gets its name from the assumption that the theories should be developed from rigorous analysis of empirical data. Strauss and Glacer elaborated their methods to challenge the division between theory and research that originated with the advent of sophisticated quantitative methods: during the 60s the qualitative methods were disregarded as impressionistic and unsystematic. As Charmaz (1996) wrote, Strauss and Glacer articulated explicit analytic procedures and research strategies that previously had remained implicit among qualitative researchers.

Firstly, the researcher collects the data: the aim is to analyze processes in the data, and to understand the multiple layers of meaning of the users' actions and words, stated or unstated. Then it starts the coding phase: "coding is the process of defining what the data are all about" (Charmaz, 1996). In the Grounded Theory, the codes emerge while studying the data: Glacer (1978) propose to use line-by-line coding, as naming and analyzing each line of data, in an analytic and unbiased manner.

The different codes will be naturally arranged in different categories: the categories are the result of the conceptualization of the data. Conceptualizing is essential to develop a theory: "If the researcher can conceptualize, then he or she will trust the emergence of a theory. It's part of their vision and realization that concepts will emerge" (Glacer, 2002).

Between the advantages of using the Grounded Theory as a method of inquiry, it is important to note that it has no limitations to a specific field or type of data (Glacer, 1992); it also has a intuitive appeal, it stimulates creative thinking, it provides deep and rich data, and it anchors the theory development in the simplification of concepts. (El Hussein et al., 2014). On the other side, the Grounded Theory is deeply time-consuming and exhaustive (Sifat, 2018); the amount of data can be difficult to manage (Bryant and Charmaz, 2007); there is a high potential for methodological error and the richness of approaches to the Grounded Theory sometimes creates confusion about the correct method of conceptualization and analysis. (El Hussein et al., 2014).

Analysis

The four interviews were singularly transcribed, and every line numbered, to easily refer to the exact passages: I will refer to the documents specifying the interview's number, and the line number(s), separated by a dot. See Appendix C for the complete referenced quotes.

From my analysis, I extracted four categories. The first I identified concerns the hardware problems. We asked the guides for insight about the most common problems of the current interface, to verify if the new prototypes would help solve them or suffer them as well. Walking (1.69, 2.105, 4.50) is surely the most common: as the Vive headset reacts to movement in space, people tend to physically walk rather than using the controller. This is particularly dangerous, as they can tangle themself in the wire that connects the headset to the station, or bump into the station itself.

Another very common problem is the low familiarity with the handheld controller: the visitors cannot immediately figure out the right button to press, often turning off the controller or accessing the Steam menu (2.108, 2.113, 3.65−67, 4.54). When pushing the right button, they find it hard to keep it pressed (2.118), and to point it to the grid (2.120−121), as me and my colleague could witness as well during the tests at the museum. I also noticed the central button of the hand controllers is rather worn out, being used daily for long periods of time, and sometimes is defective. This problem directly affects my second prototype, which heavily relies on the central button.

These challenges are difficult to tackle because the main source is the visitors' inexperience and lack of confidence in the use of the technology: there is nonetheless hope that, as the technology improves and becomes cheaper, users will handle the hardware more confidently. (Kidd and McAvoy, 2019).

One last problem to keep in consideration, is that visitors often don't stop to read the instructions placed right near the station before using the application (1.70−71, 4.45). This results in missing the context of the installation, since there is a brief historical description of the Pavilion and the 1900 World Fair, and, more importantly, the guidelines on correctly using the Vive gear.

A second category gathers the reaction to the prototypes, the simplicity and naturalness of the navigation mechanics being the focus (see Nikolakopoulou and Koutsabasis, 2020). The first prototype, which has less interaction, was recognised as the easiest one (1.20, 1.34, 2.14, 4.16); however, it was also considered slow and

slightly boring (1.22−23, 2.80, 2.96−97, 4.34). It has to be noted that the guides are very familiar with the Pavilion, so they lack the wonder and curiosity a first-time visitor could have.

The third one, having the buttons on screen and the possibility to change the interface to free navigation, was esteemed as likely difficult for the museum audience (1.13, 1.26−27, 2.16−17, 3.59−60, 4.18−19); the buttons, though, were considered rather straightforward (2.18−20, 4.23), and the free navigation was the most exciting feature of the prototypes (1.14, 1.34, 2.16, 3.29, 4.47). The second prototype was almost unremarked, except in the third interview, where it was described as “clear, and very simple and easy to understand” (3.19−20), and in the fourth, where instead the user was frustrated because she felt she didn’t know what she could do (4.17).

The last category is about Finnish heritage, and how this installation contributes to it. The Pavilion was repeatedly deemed unique, especially as the original structure was dismantled and it can no longer be visited. As our users said:

“[...] you don't have the chance to perceive it anymore, so it is, in that way, it is motivated, it has a special meaning, in that sense.” (2.175−176)

“[...] it's your only chance to see the Pavilion, and it's a very life-like form, I think that it's... it definitely gives an insight on how it was... it preserves some of the qualities that had.” (4.85−87)

There were conflicting opinions over the insertion of information in the VE. On one side, it would taint the realism of the experience, of walking through the Pavilion like it was in the 1900 (1.128−129, 3.98−99). On the other, it would give the museum visitors, the foreigners in particular, insight on the history and art it contains (2.185−187, 3.96−99, 4.78−81). In the words of our users:

“One would just need to decide if it's part of some educational program, or not, or if it's just... experience for visitors.” (1.128−129)

“I think that a lot of people ask us, like, what is this place, and like that, so it would be, maybe, very interesting that, if inside the Pavilion there would be, like, something that you could read, that would be nice, but, I think it's also very, very cool that it's very... appreciating the original Pavilion that was” (3.96−99)

Discussion

From the first category of the analysis, emerges the need for a very simple and straightforward interface, which can inhibit as much as possible the exigency of

physically walking; it must be clear at first sight, or contain the instructions on screen (like in the “Interactive Diorama”, Ling, 2018), to mitigate the problem of the visitors not reading them before interacting with the installation.

About the prototypes, the first one, the automatic movement, even if it was deemed as the easiest, proved to be too poor interaction-wise, which made it look boring, “slideshow-like” (2.80). The third one, the teleport combined with the free navigation, on the other hand, demonstrated to lean too much on the other side of the spectrum, with different buttons and the unbound teleportation: it would be overly complicated for the museum audience. The free navigation, however, was a very appreciated feature (a “dialogical approach”; cf. Poole, 2018). The second one, the user-controlled teleport, maybe because it was the most balanced in the interactions, did not raise particular feedbacks, the experience not standing out in comparison with the other two prototypes; it also suffered the wear of the controllers on the central button.

A compromise between the simplicity of the first one, and the excitement brought from the free navigation, would make the perfect prototype. A solution could be to bind the navigation to the specific places I appointed as the tour, but to let the user select the points with the controller; also add the instructions on the UI or affix them to the controller itself would clarify the interaction mode right away.

In the end, the importance of this project for the Finnish heritage is clear, for its unicity and realism. In contrast with the majority of VR applications in museums (Bekele et al., 2018), it is a fully immersive experience. Including notes about the Pavilion and the art it contains directly in the VE would help create a narrative of the whole tour, giving the visitors one more reason to explore the entire installation. The information points must not be intrusive, however, to maintain the feel of the original structure: as CH professionals in the survey of Maye et al. (2014) stated, “the design of the interactive exhibitions should not be driven by the technology, …(but) stories, themes, museum objects or experiences that the exhibition aims to portray”.

The info points

As was pointed out in the user tests’ interviews, visitors very often do not read the panel situated near the VR station, which contains, apart from the instructions, also a brief description and general history of the Pavilion. The singular works inside the installation, however, do not have their own explicit definition. If one of the fundamentals of a museum is communication, as “means of transferring knowledge” (Antinucci, 2014), giving the right context to the artifacts is paramount. In addition, it helps the visitors to feel “the motive and the value of the place and how the work is

intimately tied to the objects that the environment gathers together.” (Casale et al., 2017).

In the original project, the Finnish Pavilion did incorporate information hotspots, which consisted of textual captions, short descriptions of the modelled exhibits. (Diaz-Kommonen et al., 2010). The visual design took inspiration from the graphic style of early 1900s, and silent movies text screens; the font was also reminiscent of the letters drawn by Finnish golden-age artists. The hotspots were signaled by 2D UI vector icons.

In order to set a narrative navigation in the Pavilion, I reinstated the information spots. I could not use the original captions, having prototyped a specific fixed path: the new descriptions have been entrusted to the Design Museum curators. Upon arrival at every stop of the tour, a text screen with a brief explanation of the point of interest can be found near the user position.

Conclusion

In this thesis, I discussed the creation of prototypes of a navigation system to be used in the Finnish Pavilion, a VR installation placed in the Design Museum of Helsinki, and the design of a narrative path to guide the visitors through the architecture. I addressed the interactions in a 3D application: four common metaphors were found for travel, by Bowman et al. (2017), walking, steering, route selection and travel-by-manipulation. The UI designers choose different techniques for specific tasks and objectives; being the VR a still developing medium, there are not fixed metaphors for given situations yet.

I also approached how stories are told in our increasingly visual-based society, finding that storytelling and narrative both shape and are shaped by the VR experience. I observed that museums are embracing these new technologies, making space for original ways to experience CH.

The Finnish Pavilion built for the 1900 World Fair, and dismantled the same year, has been brought to life again thanks to this complex and ever-evolving VR installation, rich in details. The application has been visited numerous times by the museum visitors, and some UI problems were uncovered: in particular, the need for a new navigation interface. A narration to give context to the artifacts and the Pavilion itself, was also planned to be added.

I designed three different prototypes of navigation, that I then storyboarded and coded in the Unity. These models were then submitted to user testing, with the aid of my colleague. The users were then interviewed for further analysis.

Based on the reflection upon the different metaphors and the results of the user testing, I laid out possible solutions. I also made considerations on further supplements on the application. I think that, for the navigation, it is necessary to bind the user to a fixed tour, like the one you have in a museum, to give sense to the narration; it is also important not to completely deprive the user of their freedom of interaction, to keep the VR application engaging. The pace of the experience can be dictated by the user, by selection of the info points with the controller; also to add the instructions on the UI or affix them to the controller itself would clarify the interaction mode right away: being the texts inside the VE, they should be easily noticed.

Virtual Reality is a rich, rising technology, and the right interactions and UI are still evolving with our comprehension of the medium. The Finnish Pavilion has been an amazing opportunity for me to experiment on intuitiveness of interfaces and on VR and I feel there are still so many possibilities to explore and stories to narrate.

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Appendix A

The questionnaire

Venue: Design Museum, Helsinki 21/06/18
Conducted by: Elena Lamura, Neha Sayed
Advisor: Prof. Lily Diaz-Kommonen

1. How old are you?
2. What is your basic education?
3. Did you enjoy the prototypes?
    a. If yes, which one of the three did you enjoy most? Why?
    b. If not, why?
4. 4. Did you find it easy to move in these prototypes?
    a. If yes, which one was the easiest and why?
    b. If no, why?
5. Did it felt natural to use the hand-controller to move?
    a. If yes, which felt the most natural?
    b. If no, why?
6. Could you see all the objects clearly?
    a. If not, which ones and why?
7. Did you like the sequence of the tour?
    a. If yes, what was good about it?
    b. If not, why?
8. Should the sequence be longer, or shorter?
    a. If longer, what would you have liked to see?
    b. If shorter, what would you remove?
9. Which one do you think it would be easier to use for the museum visitors?
10. How have the people used the one that is already installed? What are the most common problems?
11. Did you know about the Finnish Pavilion before?
    a. How?
12. Have you used VR applications before?
    a. If yes, which ones? How was to move in those?
13. Did you know of another VR application designed for heritage before?

    a. If yes, which ones? Have you used them? How were they in comparison to this one?
14. Do you think this project is informative enough about the history of the Pavilion?
    a. If yes, how?
    b. If no, what does it lack?
15. Do you think this project works as an archive?
    a. If yes, how?
    b. If not, why?

Appendix B

The user test report

Report compiled by Neha Sayed.

Date: 21/06/2018

Conducted by:
Elena Lamura, MA Student (Erasmus), Department of Media, School of Art, Design and Architecture, Aalto University
Neha Sayed, PhD Candidate, Department of Media, School of Art, Design and Architecture, Aalto University

Guided by:
Lily Diaz-Kommonen, Professor, Department of Media, School of Art, Design and Architecture Aalto University

Introduction:
This is a brief report of the User Testing done on VR prototypes created by Elena Lamura as part of her Erasmus project. The VR prototypes are of the Finnish Pavilion showcased at the 1900 world fair and is part of a permanent exhibit in the Design Museum, Helsinki. It has been developed through various careful iterations giving a user most flexibility in VR experience. In spite of this the project continues to develop and Elena's effort on improving the user experience is the latest attempt in making it more immersible. Rather than dwelling on the differences in the prototypes we would explain the conceptualization and execution of the method of User Testing. The results of the exercise can only be availed after a thorough analysis of transcripts of video recordings.

After a visit to the museum by Elena and Prof. Diaz-Kommonen it was decided that the museum guides can perform as participants. Their feedback should be valuable considering their engagement with the exhibit over the course of last year. Ms. Leena Svinhufvud, one of the co-ordinators of the museum kindly arranged for four participants. Elena has three prototypes of the VR model. All of them are distinct from each other. We decided to test them all, one after the other.

Aim:
To do a user test of the VR gear and three prototypes of the VR model in the museum itself and get a feedback not only in the form of observation but also through an interview.

Why an interview?
After a discussion with our advisor Prof. Diaz-Kommonen we decided on a method where we let the users use all three simulations and then ask them questions regarding the simulations, the gear, the project and so on. We drafted a detailed questionnaire to which the users responded whole heartedly giving us concrete feedback. The interview allowed participants to narrate their experience more intricately referring to the minor details in a relaxed manner. It led to an informal discussion which has elaborated on the nuances of the VR walk in the pavilion, the proximity of the objects in it and most importantly the navigation aided by the device.

Setting of the user testing:
A day prior to the testing we gave a visit to the museum and tested our equipment. We decided to use two cameras, one which will avail an observer's point of view and the other for the interviews.
We arrived an hour before the testing and the cameras were set. One by one four participants came and we recorded how they use the VR gear and also the feedback in the form of an interview.

Actual execution:
We tested the prototypes in the actual context giving us more understanding about how visitors of the museum would use it. There are two installations in the museum and we used one letting the other be used by the visitors. We could observe the visitors simultaneously as we recorded our participants. Most of the time we interacted with them helping them solve some of their queries. We invited one participant at a time and Elena explained to them how they will try each prototype one after the other. After they tried all three we asked them a series of questions which were printed on a paper. Within two and half hours we completed four user tests.

General observations about the participants:

- **About the participants:**
    - The participants were all museum guides and had used the same VR gear before and they were also aware of the problems visitors face in the current simulation. The testing began with Elena explaining the new navigation in her first prototype and they used it as advised. Similar pattern followed in the other two. In all cases they needed to be told what they were supposed to do. They needed her guidance. The first two prototypes were easier and were used quite smoothly as compared to the last one. The last one allowed more freedom of navigation hence required more assistance. It also required the user to use the handheld device much more than the previous.
    - All of the participants asked questions while using it to which Elena was providing answers. Two of the users gave constant feedback even while using it which was very nice as then Elena could react to that immediately. It was more informative than the other two, where the users just preferred to go through and talk about it later.
    - It was also observed that three of them chose to go through it without exploring all the aspects of the model, because they knew the model beforehand. One of the participants actually used it to the fullest as he wanted to know what is different, even though he knew the model very well.

- **About the visitors of the museums:**
    - While we were recording the users, the visitors of the museum came to try the other VR replica of the Finnish Pavilion. We observed that the ones who had never used a VR had to be assisted, while the younger and the experienced could use it quite well. The elderly had a very exuberant experience, proclaiming surprise and awe, while some of the younger ones actually talked about how some things are not working properly.
    - The installation is done quite nicely with all the guidelines to use the VR gear and a bit about the pavilion. But, in all cases the visitors did not read the instructions and directly attempted to use the gear. This proved detrimental to both novice and proficient. As the novice slowly became disinterested as she could not figure out what to do and the proficient being confident pressed the wrong buttons on the hand held device or walked away from the tracking cameras.

Appendix C

Extracts from the interviews

Interview 1

U User 1

13 U: I did enjoyed the last one most, but it's certainly the most kind of difficult, but... I had you to

14 kind of tell me what to do, so it was... It was nice. It was more exciting than the others, I think.

20 U: Maybe the one which had only the... kind of a slide-show, that took me to different places.

21 That's the easiest, I think. It was also, it was really nice... I kind of liked the first one, and then the

22 number three. But the first one was too slow for me to kind of, ah... I wanted to see something...

23 yeah, quicker.

25 U: Ehm, maybe, yes, because it's familiar to me, but when you had those buttons, inside the

26 program... It wasn't just the remote, I think it was a bit difficult, because I didn't kind of understand

27 what the symbols meant.

33 U: Ehm... Most natural? Well, maybe the first one, because it's the easiest, and it's quite nice, but

34 the most exciting, it was the third one, because it took me... yeah.

69 there is this hazard with the technical objects, because people start walking, and then they just...

70 It's actually really... it's really kind of a small thing, or tiny thing that people care to read the

71 instructions... they have to be really short and… (...)

128 U: Yeah, this is kind... This is a bit difficult. One would just need to decide if it's part of some

129 educational program, or not, or if it's just... experience for visitors.

Interview 2

U User 2

14 U: Ok. Well, it was very sl... easy, very simple for me. Ehm... it was very clear.

16 U: ...But, in a way, the last one was naturally exciting, and, in a way, I felt it... it... Well, you told me

17 all the instructions, so... at first was hard to know what the globe, for example, means, but... then I

18 think it is easy, because... IF that would work, so I... I mean, there is this stream coming out there,

19 so in that case it would be, like... easy to, like, point, so you would get the idea, "oh, I have to point

20 something"... so, in that sense... But I've been study choreography, so I felt that I... I could adjust

80 U: Not, not hurrying that much, but in a way, like... you get the idea, "ok, this is a slideshow", in a

81 way.

96 (...) Maybe if it would be just, like,

97 slide-show versus all, it would be... not so interesting for some people. But for everyday, where

98 maybe I'm guiding people, so, that would be quite easier. That's right.

105 some people, they really want to travel quite a lot in the room, so, it can be really, "ok, you, just

106 stay here", and you can just turn on your spot. So, how to put it in a nice way; you really have to

107 find your words. And that's where it is the desk, because you can really hit the controller on the

108 side. And naturally it is that they are using also this button (the on/off button, tn)...

113 U: Then they may use the other material, the demo material they have...

118 U: Maybe for some people it is, like, hard to press it, hard to... and you really have to keep it

119 pressed and then you can release it.

120 U: Maybe for some people it is also... they are pointing like that, so they don't realize that they

121 have to point... completely on the grid. (...)

174 U: I also tell them that we have the chance to visit a special Pavilion that has been taken down, so

175 you don't have the chance to perceive it anymore, so it is, in that way it is motivated, it has a

176 special meaning, in that sense.

184 U: Not necessary so. I... I understand that people get the idea of the architecture, naturally, and

185 they feel some sort of "wow" effect there, and it can be beautiful, and aesthetically can be

186 meaningful, but I mean, it is hard to realize, ok, this is a meteorite there, for example; there are

187 some details that are not so easy to understand.

Interview 3

U User 3

19 U: ...like, of how the thing has, how this has working for the museum, because I think it was clear,

20 and very simple and easy to understand, and, yeah, that's also why I liked it…

29 U: Yes! I think my favourite one was where I can myself point and choose where I go.

58 one would be the least troubling one, but maybe not the most fulfilling, so... But I think the least

59 easy would be the one where you point at the arrows, because I think that that would confuse a

60 lot of people.

65 U: The most common problem is that they have no idea which button to press, and that causes

66 them to, for example, put it in a weird mode where they can move, or something like that, so I

67 think, that one.

96 U: Yeah, kind of. I think that a lot of people ask us, like, what is this place, and like that, so it would

97 be, maybe, very interesting that, if inside the Pavilion there would be, like, something that you

98 could read, that would be nice, but, I think it's also very, very cool that it's very... appreciating the

99 original Pavilion that was.

Interview 4

U User 4

16 U: Well, I think the first one is the easiest because you know that you can't do anything, and the

17 second one, I feel like, I really didn't know what I can do, and in the third one, I had the most

18 freedom, but then again, if that would be my first time trying the VR glasses, I think it might get a

19 little bit... confusing on how to operate it, because I had some difficulties.

23 U: In the last one, because it's sort of, like, point and click.

34 U: Well... for me, it felt like the first one was a little bit slow, because I pretty much knew what was

45 operating it because they don't really... read the instructions, and then they ended up in trouble or

47 have any kind of control on yourself, and then the last one is the most interesting, and maybe for

50 U: People try to walk, so... they end up maybe hurting themself sometimes; people feel vertigo

54 U: ...then they press the wrong buttons, like... kind of what's going over there, right now, because

85 U: Well... well, you can store there more objects, and, for example, it's your only chance to see the

86 Pavilion, and... it's a very life-like form, I think that it's... it definitely gives an insight on how it

87 was... it preserves some of the qualities that had.

78 U: Yeah. It gives... of course, it's a nice introduction to it, for sure. Yet, if it would be possible to

79 include more informations, that would be great, because a lot of people, when they just walk

80 through the application, I don't think they... you know, they might not get the whole idea, what's

81 so important about it, but it's a really great application, for sure.