TAMPEREEN TEKNILLINEN YLIOPISTO
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SOCIAL ACCEPTABILITY OF VIRTUAL REALITY INTERACTION: EXPERIENTIAL FACTORS AND DESIGN IMPLICATIONS

Master of Science Thesis

Examiner: Prof. Kaisa Väänänen
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ABSTRACT

POUYA EGHBALI: "Social acceptability of Virtual Reality Interaction: Experiential factors and design implications"
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Virtual Reality (VR) has been the hot topic of discussion over the past couple of years. A major part of the interest in VR comes from the fact that the technological aspects of VR has grown dramatically and today there are lots of choices for VR users based on their budget ranging from cardboard VR requiring mobile devices all the way to high end VR devices requiring high end computers.

When the user wears the VR device and the headphones, he or she is separated from the real world and can no longer see, hear, or interact with anyone else present in the same context. When the context is public and there are other people around, the separation can be problematic. Added to the separation, the user interacts with the system using a form of motion controller for input coupled with head movements to look around the virtual world. This brings forth the point of questioning the social acceptability of virtual reality and the need to identify influential experiential factors from the perspective of those using the VR in public context and the others present in the same context.

To answer the research questions, a series of field tests were conducted with users in the public context of a university. The empirical research of this thesis consists of interviews, surveys, and observations, including both qualitative and quantitative data from the users and spectators in addition to three co-creation sessions with user experience experts to identify key design principles.

The empirical findings of this thesis suggest that it is socially acceptable to use VR devices in a public context of a university and a majority of users and spectators do not find it as awkward or rude to use the technology. Additionally, while it may feel a little out of place, once a user starts the VR experience, he or she will forget about the others present and will start to enjoy the sense of being in a virtual location while in the same place as others. Based on the findings, the most important experiential factors from the perspective of users are identified as *freedom of interaction*, *uninterruptable immersion, un-intrusive communication*, *freedom to switch realities*, *a sense of safety*, *a sense of privacy*, *having a shared experience*, *and a sense of belonging*. From the perspective of the spectators a *shared experience*, *enticing their curiosity*, *providing relevant experiences*, *being a norm*, and a *sense of privacy* are found as the influential factors. Finally, a set of design principles with 11 distinct items across six sections of *content*, *interaction*, *safety*, *privacy*, *communication*, and *connectedness* are identified.

The insights of this thesis can be used in the future as a reference point for creating socially acceptable VR experiences and understanding the most important factors from the perspective of VR users as well as others present in the context.

PREFACE

"Research is to see what everybody else has seen and to think what nobody else has thought."

Albert Szent-Györgyi

The journey of this thesis started with my own interest in virtual reality, and my sense of curiosity to explore the social acceptability of VR. This journey has taken me eight months to complete and the information in this work has spanned across two different countries and three different seasons.

The biggest lesson learned from conducting this research is how little I know, and the more I researched, the less I knew. The work has challenged me positively and has helped me grow as a researcher and a degree student. The hands-on experience of this thesis has provided me with the new tool of research-based solutions at my disposal that I can utilize in my professional career in the near future.

I would like to thank Nokia for granting me the opportunity and providing me with the freedom to conduct this research and TUT foundation for providing me with funding for this work. I am grateful for having a great supervisor as Professor Kaisa Väänänen, who has provided me with concrete and valuable feedback throughout this research and has helped me find my way and guided me in the correct path. A big thanks to Tero Jokela from Nokia for his constructive feedback and constructive criticism and interest.

My gratitude goes to all those who supported me during this time and helped me move forward. Firstly, I want to thank my mom and sister for always believing in me and giving me positive energy from thousands of kilometers away. I also give my gratitude and appreciation to the people in the pervasive computing for giving me feedback and comments every time I went to them. Thank you Aino Ahtinen, Kirsikka Kaipainen, Jari Varsaluoma, Iikka Pietilä, and Aparajita Chowdhury.

I especially want to thank my wife Nasim Beheshtian, who has been an incredible partner and was always there for me day and night, providing me with help and support and challenge me whenever I needed it.

Lastly, I know my father, who is no longer with us anymore would have been proud of me today.

Pouya Eghbali

19 November 2018

Tampere, Finland.

CONTENTS

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LIST OF SYMBOLS AND ABBREVIATIONS

3D	Three Dimensional
AR	Augmented Reality
HCI	Human-Computer Interaction
HMD	Head Mounted Display
PTSD	Post-traumatic Stress Disorder
TUT	Tampere University of Technology
UX	User Experience
VE	Virtual Environment
VR	Virtual Reality
VRE	Virtual Reality Exposure

1. INTRODUCTION

This chapter discusses the topic of the study which is the social acceptability of virtual reality in addition to the reasons behind studying this topic and how this thesis can be beneficial to the field.

1.1 Background and motivation

The research topic of this master thesis is the social acceptability of Virtual Reality (VR) interaction. Earlier research by Disler et al, (2018) has identified acceptability as a form of judgment of a certain technology that is going to be introduced in the future whereas acceptance refers to judgment after using the technology. This means that social acceptability is the outlook before usage and social acceptance is considered the outlook after usage (Distler, Lallemand, & Bellet, 2018). Even though VR is quite an old technology, the use of VR in public and semi-public context is still considered novel and VR is not used in the everyday life of a major portion of the population. Therefore, for the purpose of this work we will refer to the term social acceptability. Social acceptability can greatly influence the success of technology and therefore we must address the issue before we can provide public VR experiences.

Figure 1.1 Users wearing HMD

VR is defined as "The illusion of participation in a synthetic environment rather than external observation of such environment. VR relies on three-dimensional (3D), stereoscopic, head-tracked displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience" (Earnshaw, 1993, p.3). Jerald (2016) explains that a VR system consists of input, application, rendering, and output. The input gathers data from the user using different methods such as eye gaze and hand location. The application provides the necessary framework for the creation of the virtual world. The rendering portion creates the illusion of reality by providing audio, video, and haptic rendering. Finally, the output is what the user experiences and sees though the display and headphones (Jerald, 2016). In addition to VR, there are other types of reality as well. For instance, whereas VR creates a new world for the user, Augmented Reality (AR) augments computer generated input and graphics on to the real world (Chavan, 2016). While VR and AR can have some commonalities and share similar features, our main focus is in VR for the purposes of this thesis.

While there are different types of VR, our reference is to those devices that users wear on their head. While using VR, the user wears a Head Mounted Display (HMD) (Figure 1.1). The HMD is a visual display which attached to the head of the user and can be either non-see-though, video-see-through, optical-see-through (Jerald, 2016). In addition to the HMD, the user wears headphones in some cases, to be fully immersed in a virtual environment (VE). This immersion means the user is isolated from the real world, which can be considered as a form of social gap between the user and anyone else who is a spectator (Figure 1.2). This **social gap** is the result of the user not being able to see or hear anyone else while in the VE. In addition to this social isolation, the VR user interacts with the virtual world elements via hand gestures, joystick or joypads, and different forms of body gestures such as leaning, crouching, jumping, pointing with the hands, and turning. In addition, head movements are performed while the user is looking in different directions while possibly interacting with the handheld devices or joypads to perform certain actions.

Figure 1.2 User Immersed in VR (courtesy of HTC https://www.vive.com/eu/product/vive-pro-full-kit)

Although hand gestures and body movements can provide a realistic and enjoyable experience to the user, they can also be a source of distraction to those not immersed in the VE, cause annoyance, and possibly promote the social gap and a feeling of irritation in the spectators. Part of the reason for this irritation is the fact the spectators cannot see what the user is seeing, cannot communicate with the user, and cannot understand why the user is doing certain gestures and movements.

The social gap between the user and spectators creates an interesting opportunity for researchers User Experience (UX). UX is defined as a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" (ISO, 2010). By being able to use the tools and knowledge from the UX world, the aim of this thesis is to find out more details about the social acceptability of VR using a systematic approach that includes previous research done in the field, empirical research, data collection, and analysis. The project is quite interesting to the writer as he believes VR is going to play a key role in the everyday life of people in the future in addition to possibly providing value for the industry and the developers in terms of UX and interaction design.

In terms of the industry and market place, there has been large sums of investments by some of the most well-known brands of technology such as Microsoft and Facebook in the past years. With large amounts of investment and development of VR applications we can expect the fusion of this technology into our daily routine in the near future. This implies that regardless of the nature of the VR experience, there will be times where the devices will be used in social context where there are other people present. By exploring this topic and understanding the effects of VR in social environments, we can perhaps in turn shape part of the future of VR and help create better experiences in semi-public and public context, not only for the users, but also for the spectators as well.

1.2 Research objectives

There has been a few focused studies on the social acceptability of VR earlier such as (Profita, Albaghli, Findlater, Jaeger, & Kane, 2016) and (Schwind, Reinhardt, Rzayev, Henze, & Wolf, 2018b), and this provides a research gap that we can utilize as an advantage. By being able to answer the research questions and achieve the research objectives, we hope to contribute to the advancement of knowledge in the UX of VR and help guide the content creators in designing more socially accepted experiences and interactions. Since the effect of the VR are being measured in context where others are present, it is important to understand the perspective of those using the VR in public and those who are present and interested in the VR user which we refer to as spectators. The role of spectators is therefore as important as the users and we need to consider both these groups.

General objective: To identify the experiential factors that affect VR interaction to be socially acceptable. The main emphasis of the study is on the factors that affect the *social acceptability* of VR rather than the experience of the user in terms of using VR for the specific purposes of the VR application.

Specific objectives:

- To identify the influencing social acceptability factors that affect the users of VR while being immersed in it.
- To identify the influencing social acceptability factors that affect the spectators when they see a VR user immersed and disconnected from the real world.
- To establish a set of design principles for the designers of VR interaction to enhance the social acceptability.

Research Questions:

The research questions focus on the experiential social influencing factors affecting both the user and the spectator of VR devices. Furthermore, the goal is to identify a set of interaction design guidelines that can contribute to creating more socially acceptable VR experiences.

RQ1: What are the influential experiential factors in the social acceptability of VR use from the perspective of users?

RQ2: What are the influential experiential factors in the social acceptability of VR use from the perspective of spectators?

RQ3: What are the interaction design guidelines for VR systems to enhance social acceptability?

1.3 Structure of the thesis

In chapter 2 a brief history of VR devices and a few selected snapshots of historical moments in the field are presented. Previous work done in the field is presented with different aspects of VR such as UX of VR, interaction techniques in VR. Finally, the key factors based on literature review are drawn followed by defining the different roles involved in social context. Chapter 3 presents the research approach, phases, method, and process. Chapter 4 identifies the details of three research studies and analyses the spectator surveys, user interviews, and co-creation sessions results including important quotes and key findings. In chapter 5, the results of the thesis are presented by identifying experiential factors from the viewpoints of users and spectators in addition to design guidelines. Chapter 6 presents the research significance, discussions, the lessons learned, and the possibility of future work. The references and the appendices are provided in the last sections of the thesis.

2. THEORETICAL BACKGROUND

This chapter presents the previous work in the field of VR. After looking at a historical timeline of VR and some key historical moments of VR, the UX of VR and the important elements are presented in addition to previous work related to the spectatorship of VR., The social acceptability of warble technology is presented and factors that can affect the social acceptability of VR are identified.

2.1 Virtual Reality

A quick glimpse at the history of VR and how the technology started and where it has reached, and how it is being implemented can explain why the topic is important and has been getting a lot of attention in the recent years.

2.1.1 A Brief History of Virtual Reality

While in the past few years Virtual Reality (VR) has received a lot of focus and attention, its history stretches far beyond that. In fact, it may come as a surprise to know that more than 100 years have passed since the idea of VR has come across. A timeline of the history of VR by Sherman (2002) identifies that first ever patent of a VR resembling device was submitted in 1916 which is 102 years ago as of the writing of this thesis. The patent was for a head-based periscope display by Albert B. Pratt (Figure 2.1).

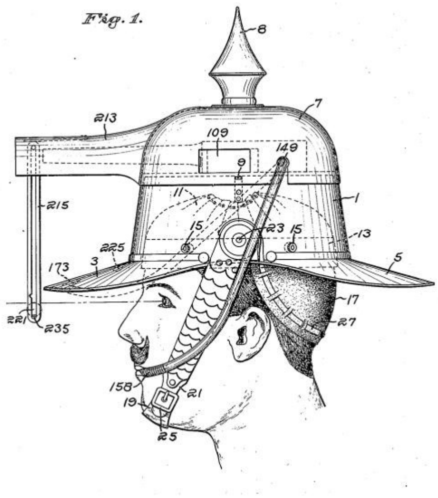


Figure 2.1 Albert Pratt's Periscope patent (https://patents.google.com/patent/US1183492A)

The development of VR continued from to the field of aviation as a form of physical pilot training simulator before moving towards Head Mounted Displays (HMD) in 1960 that are very similar to what we use today patented by Morton Heilig (Figure 2.2). Universities began taking interest in the subject soon after alongside major corporations and technology companies. General Motors focused research in Design Augmented by Computer, which was an interactive tool for designing cars. By 1979 HMDs were designed that offered a wider field of view and had parties such as NASA interested.

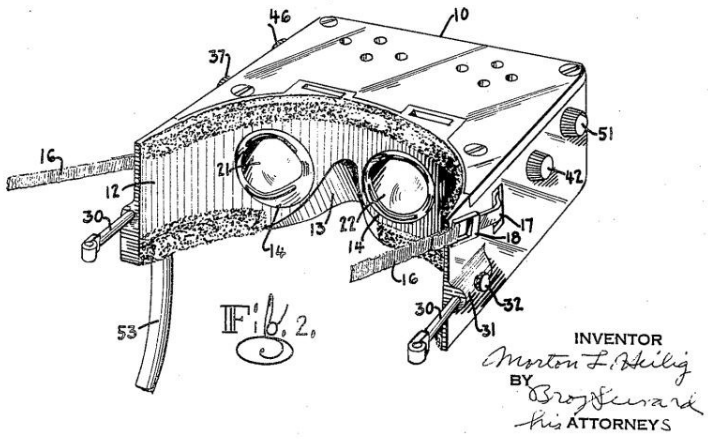


Figure 2.2 Morton Heilig's stereoscopic-television apparatus patent (https://patents.google.com/patent/US2955156A)

By 1981 Stanford and MIT began work on VR related hardware and projects and by 1984 NASA created the Virtual Interface Environment Workstation, which provided many VR companies with funding on the project. 1990 was the year that marked the first dual player public VR arcade system, called Virtuality. By the year 1992, projection VR, Cave was introduced by University of Illinois at SIGGRAPH 92 alongside a similar system introduced by Sun Microsystems. The interest in VR has grown by 1995 so much so that it lead to the formation of IEEE VR while HMDs were now being offered that included head tracking systems. The attention to VR was more visible when Disney opened their first of three planned VR arcade centers in 1998 before closing in 2001. By the year 2000, Iowa State University installed the first six-sided CAVE system (William R. Sherman, 2002, pp-24-36).

Figure 2.3 Google Daydream (https://vr.google.com)

Fast-forwarding to today, VR devices have been getting more attention in the past few years. VR experiences aim at providing a more realistic experience and a complete sense of immersion that isolates the user from the world. There are numerous applications of VR that range from medical purposes to entertainment and games. Technology giants are investing heavily in VR such as the Google with the Daydream (Figure 2.3), Facebook with Oculus Go (Figure 2.4), and Microsoft with a variety of mixed reality devices (Figure 2.5).

Figure 2.4 Oculus Go HMD (https://www.oculus.com/go/)

It is expected that VR devices will be incorporated into the everyday lives of people in the future (Sirkkunen, Väätäjä, Uskali, & Rezaei, 2016). According to Digi-Capital (2018) investments in VR and AR has reached new heights in 2017 with a capital of over 3 billion US Dollars raised by startups in over 28 categories in the field of VR and AR (Merel, 2018). Furthermore, a research report by ABI (2017) identifies that there are already more than 460 companies active in the field of VR and 360-degree videos and that the market is expected to exceed 60 Billion US Dollars by 2021 (ABI Research, 2017).

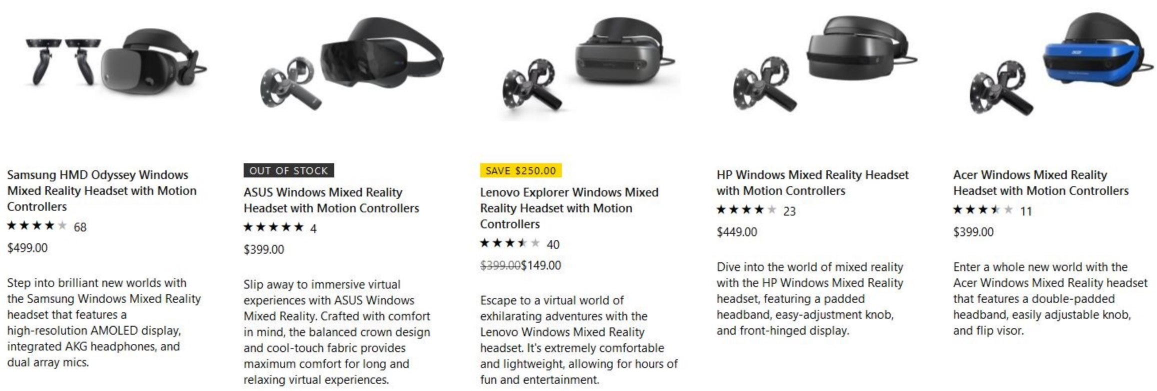


Figure 2.5 Microsoft Mixed Reality Headsets (https://www.microsoft.com/en-us/store/b/virtualreality)

2.1.2 Applications of VR

VR has been widely adapted in different industries and used in many different fields with varying purposes with positive market response. In the 3rd quarter of 2017 alone, the number of VR devices sold reached a whopping number of 1 million which included the Sony PSVR with 49%, Ocolus Rift 21%, HTC Vive 16%, and other devices taking 14% of market shares (Canalys, 2017).

Due to the nature of VR and the immersive experience, gaming is naturally the first industry that has fully embraced the technology with a fast growing market across multiple tiers of devices. To understand just how big the gaming market is, we can have a look at the sales figures of a gaming specific HMD. Sony Interactive Entertainment (SIE), one of the biggest names in the gaming industry and the creators of the PlayStation console introduced the PlayStation VR (PSVR) (Figure 2.6) globally in October 2016 with more than 230 developers and publishers working on over 160 PSVR titles (Sony Computer Entertainment Inc., 2016). By December 2017, SIE announced that they have surpassed 2 million PSVR unit sales worldwide with more than 12.2 million sold copies of the 150 titles of PSVR while more than 130 more titles are set to be released by the end of 2018 (Sony Computer Entertainment Inc., 2017).

Figure 2.6 Sony PSVR HMD (https://www.playstation.com/en-gb/explore/playstation-vr/)

While the dominance of the gaming industry is undeniable and it is forecasted that the VR gaming market is expected to grow at a rate of 30% annually until 2023 (Reuters, 2018), VR has been used in other fields by a variety of industries. Only second to gaming, and with little surprise, VR is used for adult entertainment and viewing pornographic content. According to Forbes (2017), VR adult content on of the biggest adult entertainment websites started in the spring of 2016 with just 30 videos and a few views per day. This number reached over 2,600 videos viewed more than half a million times a day in less than one year (Silver, 2017). The popularity of VR adult entertainment is so much in fact, that more than half of top VR websites are adult oriented and the visits to a certain adult VR website even surpasses the Oculus official website (Murdoch, 2017). With the decreasing VR prices and the increasing number of content, adult VR may even take the top spot from the gaming industry in the upcoming future.

Other than gaming and adult industries, VR is used by the military, healthcare, fashion, business, sport, media, entertainment, along with many other industries and usages (Zajtchuk & Satava, 1997). Research by CB Insights (2017) on startups active in the field, have identified several industries that are ready to dive into the world of AR and VR (CB Insight, 2017):

Retail: VR used as a solution to retail challenges such as stores closing in addition to providing an immersive experience to users.

Military and Defense: VR is being investigated as a possible solution for crisis planning and management in addition to being used in the military to simulate environments.

Events and Conferences: In addition to 360-degree concerts, VR can be used in virtual conferences and demonstrations.

Marketing and Advertising: VR provides new opportunities to showcase products to customers and provide a distinctive audience interaction.

Law Enforcement: VR can be used to train police forces using simulation and different training scenarios in addition to stress manager of officers.

Recruiting, Talent Management, and HR: VR can help companies asses possible recruit talent virtually in addition to providing opportunity for the candidates to virtually visit their future workplace. VR can also be a great tool for remote work and meetings.

Healthcare and Medicine: VR has a variety of purposes in the field of healthcare ranging from VR telemedicine and elder care to behavioral treatment and mental health problems.

Journalism and Media: Media has been eager in providing VR content via storytelling and immersing the users in the stories.

Film and Entertainment: In in entertainment can bring a new level of experience to the audience and provide a cinematic virtual reality experience. Sony is already working on creating a VR based on the popular TV show Breaking Bad.

Construction and Real Estate: VR is used by real estate companies to showcase properties to potential buyer so that they can visit the property in addition to the neighborhood without the need to physically visit the property.

Automotive: VR is a great tool in the automotive industry where it has been used by Ford for iterative design and prototyping purposes, for virtual test drives by Volvo, and even VR dealership experiences by Audi and Ferrari.

Space Exploration: VR is also being used by NASA researchers to accurately analyze locations on planets far from our reach such as Mars.

As the above overview shows, a large number of industries and for different purposes are jumping onto the VR trend and this goes to show that there is a good potential for VR growth in the near future. Historically, while there are many examples of VR uses and application, we will briefly discuss a few examples that have been implemented in the field of psychology in addition to VR use for training purposes and data visualization. Finally, we will explore the implementation of VR in journalism and the reasons behind not being widely adopted by the field fully yet.

In the field of psychology, VR is considered an acceptable form of therapy method. According to Rizzo et al. (2018), the first instances of VR were used in the 90's to address psychological disorders such as phobias ranging from acrophobia to fear of flying, spider phobias, to claustrophobia. This type of therapy works by creating virtual reality exposure (VRE) for the patient in specific situations and allowing the patient to explore VRE at own pace to decrease the anxiety levels while being monitored by a therapist. Additionally, VRE has been utilized as a therapy method for the treatment of posttraumatic stress disorder (PTSD) for soldiers with specific environments ranging from Vietnam, Iraq, and Afghanistan. VRE was also used for the treatment of post 9/11 PTSD by providing a VRE experience including video and audio stimuli similar to what the patients experience earlier (Rizzo et al., 2015). More recently, in the field of forensic psychiatry. Benbouriche et al. (2014) noted that VR has been used to study the etiological factors behind violent behavior of individuals by transforming them into a specific virtual environments and monitoring their response. Additionally, VR coupled with physiological measures such as eye tracking and EEG allows for a detailed observation of the subject and measurement of the violent behavior in addition to the underlying causes (Benbouriche, Nolet, Trottier, & Renaud, 2014).

By being able to create realistic virtual worlds, VR can be a great tool for training and simulation purposes. According to McGrath el at. (2018) VR simulations have already been used to train surgeons for different procedures and showed that the can be a great tool in increasing learning in addition to enhancing technical abilities. VR has also been used in the training of emergency medical learners by providing a realistic virtual environment and a pilot study showed that medical learners had the same results using virtual emergency versus traditional patient simulation (McGrath et al., 2018). VR environments provide great training opportunities for work context that are otherwise too dangerous or extreme and require prior training. Such example can be seen in a study by Van Wyke & De Villiers (2009) for the South African Mining Industry where the methods of classroom learning and teaching using physical mockups does not represent a real working environment situation. Various VR prototypes (Figure 2.7) were developed for the training of the miners creating realistic environments virtually in addition to different scenarios such as hazard awareness, ground falls, and accident reconstructions. The survey results after the implementation of the prototypes revealed that more than 80% of the miners believed the VR training method to be more useful for their training purposes (Van Wyk & De Villiers, 2009).

Figure 2.7 VR Prototype for worker safety training (courtesy of Van Wyke, 2009)

VR can be also helpful in data visualization. By visually immersing the user in the data set, VR can greatly help scientists and researchers in identifying patterns that are otherwise not seen or easily interpreted. Previous research by Donalek et al. (2014) has shown that VR has already been helpful to visual data investigation in paleontology, brain tumors, chemistry, and physics. In fact, the authors proposed that immersive data visualization should become a main foundation for big data analysis in the future. Furthermore, it is shows that VR can also support collaborative tasks since it is linked to increasing situation awareness, interactivity, and media richness amongst other benefits (Donalek et al., 2014). Data visualization can be greatly beneficial to the medical field particularly. Reddivari et al. (2017) created a tool developed VRvisu (Figure 2.8), a tool for visualizing complex medical data virtually and enabling interaction with the data. The system works by using VR headsets and a motion camera and the research of VRvisu focused on tumor data. After collecting the data, a 3D model of the tumor are created and transferred into the virtual world. This allows the researcher to physically see the data in 3D and in addition to being able to touch and even pick up the data point in graphs virtually. (Reddivari, Smith, & Pabalate, 2017) The visualized data of such systems creates a new experience of data visualizations, which offers a richer approach to data analysis.

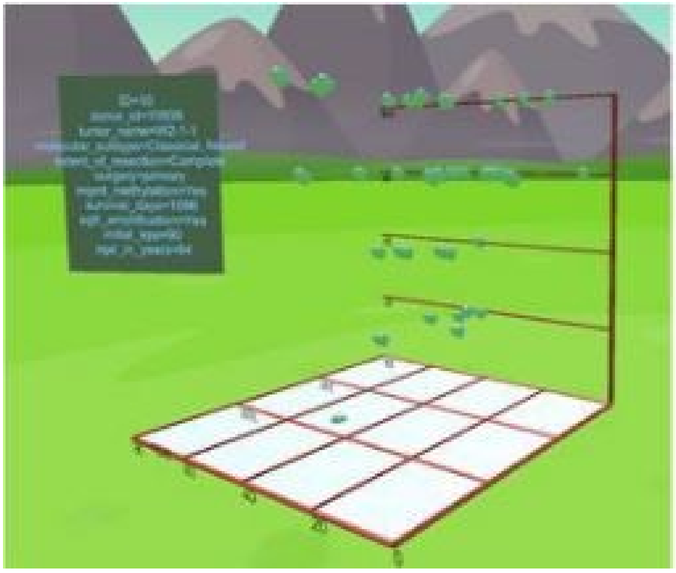


Figure 2.8 VRvisu tool data in virtual space (courtesy of Reddivari et al. 2017)

VR has also gotten some attention in the field of journalism and media lately. According to De La Pena et al. (2010), immersive journalism is achieved by producing content that allows the viewers to gain a first-person view of the experience. By creating a real virtual world of the events happening, the viewer can truly feel and even emotionally react towards the situation rather than simply seeing it on a screen. The realism in VR journalism was shown in an experience where the viewers wore a HMD and sat down on a chair while virtually experiencing the first-person view of a Guantanamo Bay prisoner being held in confinement (Figure 2.9). The interview results with the viewers confirmed that the experience was truly realistic and that the viewers felt what the prisoners felt in the real situation (De La Peña et al., 2010). It must be noted that although VR in journalism is an interesting subject, it has still not been widely adapted in the field. Sirkkunen et al. (2016) argue that there are several reasons for not having a major breakthrough of VR journalism. Firstly, the technical development has not evolved enough to create cost effective and affordable experiences. Second, there is a lack of a process and production tool that can be utilized by journalists. Finally, the focus of VR in journalism is limited mostly to documentaries (Sirkkunen et al., 2016).

Figure 2.9 Virtual view of a prisoner in Guantanamo Bay from different viewpoints (De La Pena et al. 2010)

2.1.3 User Experience of VR

When researching the topic of User Experience (UX), we can identify that there are multiple definitions, explanations, and interpretations of the UX. Law et al. (2008) argue the variety of definitions can be confusing to customers in addition to undermining the research, management, and teachings of UX (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008). The ISO *definition of UX* is "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" (ISO, 2010). The Nielsen Norman Group (2016) explains that *superior UX* is delivered only through providing a unified process that merges the services of different disciplines in a company to deliver the experience to the user (Norman & Nielsen, 2016). This goes to show that user interface, design elements, modalities, and physical design of the product are just a few of the elements that can play a role in delivering a positive user experience. Peter Morville's *User experience Honey Comb* (2004) identifies seven qualities for UX, which are useful, desirable, accessible, credible, findable, usable, and valuable (Peter Morville, 2004). For the purposes of this thesis, we will consider on the ISO definition of the UX, as the social acceptability of VR is the perspective of both users and spectators on the use of the technology in public context. Our focus will be on the aspects that affect those present in the social context rather than the UX of VR itself.

Although Peter Morville's seven qualities and factors can be used as a guideline on a broad perspective to help create a positive user experience for VR, they are not specific enough to cover the UX of VR devices. While there are many guidelines for the design of VR applications, at the time of time of writing this thesis, there are no guidelines addressing the UX of VR that identify different experiential factors for public context. However, the most important factors that stand out from past research, which we hypothesize as central VR experiential factors, are *immersion*, *presence*, *flow, self-embodiment*, and

VR interaction. We will discuss the first four factors below while next section discusses VR interaction techniques in detail.

Immersion (Figure 2.10) is one of the most essential factors that can have an impact on any VR experience. The three I's triangle of virtual reality by Burdeaet Coiffet (1993), represent VR in schematic manner with the I's representing immersion, interaction, and imagination (as cited by Jdid, Richir, & Lioret, 2013). Immersion is described by Slater and Wilbur (1997) as "the objective degree to which a VR system and application projects stimuli onto the sensory receptors of users in a way that is extensive, matching, surrounding, vivid, interactive, and plot informing" (as cited by Jerald, 2016). In other terms, immersions refer to how real the experience of VR is for the user and how good the technology creates the virtual environment. Immersion is such an important part of the VR experience, that it can complement or even replace the term virtual reality in some cases. Immersive journalism for instance, refers to producing a new form of news content that lets the user experience the event first hand by using virtual worlds (De La Peña et al., 2010).

Figure 2.10 User immersed in the virtual world (https://www.microsoft.com/en-us/store/b/virtualreality)

Presence (Figure 2.11) is another important part of the VR experience. Jerald (2016) explains that presence is the sense of being somewhere while physically not being there, however defining the concept of presence is much like trying to define love, which is something that can be understood only when experienced first-hand. Unlike immersion, which is about the technological aspects, presence is about the psychological and physiological aspects of the user. Presence is felt by the user only when the system provides immersion and the greater this immersion is, the greater the chance of creating a sense of presence. Presence can break down easily when the user interacts with the real world physically or the system glitches causing an episode called break-in-presence (Jerald, 2016).

Figure 2.11 Presence felt by the user (https://www.playstation.com/en-gb/explore/playstation-vr)

Tham et el. (2018) have identified six types of presence based on previous work which are derived from factors that can affect presence. *Conveyance of social cues* is about the ability to transmit perceived information by the medium. *Fidelity of representation* is about the imagery and sensory inputs of the communication medium. *Transport mechanism* is about the sense of being transported elsewhere by a medium. *Immersion in a space* is the physical or psychological immersion. *Social actor in a medium* is about the treatment of a character in a medium. Finally, *computers as social actors* is about the socially sound treatment of non-human objects (Tham et al., 2018). Recent research by Shin (2018) has also identified an extension of presence referred to as the **flow** (Figure 2.12). Whereas presence is being immersed in to a VE, flow refers to a user performing a specific action as a result of that immersion. Flow and presence are interconnected; when the level of enjoyment by the user reaches new heights, it becomes flow (Shin, 2018). For instance, flow in the context of gaming refers to a player being engaged in the game in an extremely focused manner while fully immersed and even losing track of time (Nah, Eschenbrenner, Zeng, Telaprolu & Sepehr, 2014)

Figure 2.12 Flow, a state of focus by the user and concentrating on the task fully (https://www.playstation.com/en-gb/explore/playstation-vr/)

Self-embodiment (Figure 2.13) is also an influential factor that can affect the user experience of the virtual reality. Jerald (2016) explains that Self-embodiment is seeing our own body in the virtual world and being able to identify our movements and features in the virtual world. Self-embodiment can greatly expand the sense of presence and provide a more realistic experience for the user (Jerald, 2016). Embodiment can greatly affect the sense of presence in virtual worlds and make the user believe the experience to be real since it is an important psychological state of existence (Tham et al., 2018). Self-embodiment can also affect the rate of errors in judging distances in the virtual world by users and providing avatars to users in the VE can enhance their spatial perception (Ries, Interrante, Kaeding, & Anderson, 2008).

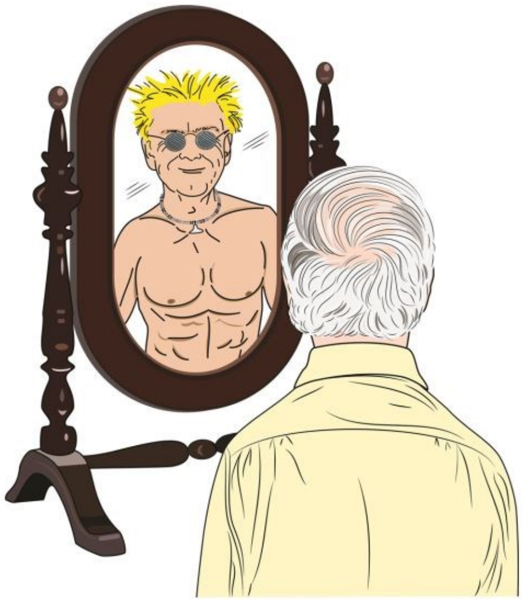


Figure 2.13 Concept of Self-Embodiment (Jerald, 2016)

The experience of VR thus is the result of *presence, flow, immersion, and self-embodimen*t. Earlier research by Shin (2018) has shown that the effect of VR on users is to such an extent that it blurs the lines between reality and the virtual world. The user can be immersed in the VE to such a degree, that they can consider themselves part of the virtual world. VR can also convey another person's experience to the viewer, and let him or her feel another's emotions by being virtually in someone else's body. VR can even stimulate empathy in a person which is one of the primary reasons it has been often used in storytelling by the industry (Shin, 2018).

2.1.4 VR Interaction

Interaction techniques including both *input* and *output* modalities are an important part of any system and can play a major role in affecting the usability of the system. Jerald

(2016) defines *interaction* as “the communication that occurs between a user and the VR application that is mediated through the use if input and output devices”. In VR systems, interaction is particularly important because in order to provide a fully immersive experience, VR content alone is not enough and any form of physical interaction within the VE can enhance the sense of immersion (Jerald, 2016, p.275).

Input

Physical interaction in the virtual environment can be achieved thought the use of input devices. Jerald (2016) classifies VR input devices into two main classes of hand input device and non-hand input device with each class consisting of different input devices as follows (Jerald, 2016, pp.309-321):

- Hand input
    - *World-grounded devices*: Devices that are fixed in the real world such as mice, keyboards, trackballs, and mounted joysticks. Steering wheels, pedals, and handlebars are some examples of these devices.
    - *Non-tracked hand-held controllers:* These devices are used by the user using the buttons and triggers but are not tracked in the VE such as trackpads, joypads, and game pads. The Xbox one controller is an example of these types of input devices.
    - *Tracked hand-held controllers:* Also called wands, these devices are held by the user in their hands and provide a form of physical input as well as being tracked and shown in the VE. These devices are the main input method for many VR applications. Sixense STEM and Ocolus Touch are two example of this type of controller.
    - *Hand worn:* This type of input method as the name implies, can be worn by the user and is considered to be the best-input device type by many. Gloves and muscle-tension sensors are part of these devices. Some example of these devices are the Fakespace Pinch Gloves and the CyberGlove.
    - *Bare hands:* The hands are used by the system as input devices and no form of physical buttons are present even though the hands are tracked by sensors and can be seen in the VE as well.
- Non-hand input
    - *Head tracking:* The head-tracking input is when the users head is being tracked in the VE and in addition to looking around the environment, the head movements can be used as a form of input such as aiming at a target in the VE.
    - *Eye tracking:* The user looks at the target in the VE and the gaze is considered as an input. This form of input is less used and explored by VR systems due to the challenges involved. The eye gaze is used as a form of input in this case.

- *Microphone:* In this type of input devices, the user speaks into the microphone that uses speech recognition software and interacts with the system.
- *Full-body tracking:* This form of input tracks the body of the user who is wearing a motion capture suit. Additionally, full body camera systems can also be used such as Microsoft Kinect.

Output

In terms of output devices for VR devices, previous research by Anthes et. al (2016) identified three main categories, which are *haptic*, *multi-sensory* and *visual*. *Haptic* devices are those that provide tactile feedback to the user such as vibrating vests or controllers. *Multi-sensory* devices are the type of displays that provide additional feedback to user such as olfactory or tactile. Finally, *visual displays* are the main category of output device for HMD devices. These visual displays are further divided into mobile HMD's, which are used without the need of a PC and mostly used for entertainment purposes such as 360 degree videos. Wired HMD's are on the other hand wired, require a powerful PC, and in most cases have a room scaled tracking system. Each category of HMD devices are further divided as the following: (Anthes, Garcia-Hernandez, Wiedemann & Kranzlmuller, 2016):

- Mobile HMD
  - *Simple case:* A display with lenses that acts as a frame and fully relies on a smart phone for functionality. Examples of these devices are Google Cardboard, and Wearality SKY
  - *Ergonomic:* Similar to simple case displays, but with better optics and a more ergonomic and comfortable design. Examples include Samsung Gear VR devices and Zeiss VROne.
  - *Mobile:* Stand-alone display systems that do not rely on a smart phone or PC and have the capabilities built-in. Examples are Gameface Mark V and Auravisor.
- Wired HMD
  - *Room:* Displays requiring powerful pc to run and able to provide VR experiences at the room scale. HTC Vive is an example of such devices.
  - *Seated:* These displays also require powerful pc's but the usage focus on a sitting stance. Some examples are PlasyStation VR, FOVE, and Oculus Rift.
  - *Camera:* Similar to other wired displays, also requires a powerful PC but the built in camera can also enable AR experience. Sulon Cortex and VRvana Totem are two examples of such displays.

Interaction

While there are a variety of input methods and various ways of interacting in VR, perhaps the most common device used in VR in the *handheld controller* (Figure 2.14). The popularity of controllers is observed by looking at some of the most well-known brands in the VR industry. The Oculus Rift, uses the Oculus *Touch controller*, also called Half Moon controllers, as the main interaction device by using optical tracking and gesture recognition (Anthes et al., 2016). Similarly to Oculus and with different variation in technology, Sony PSVR uses the *PlayStation Move motion controller* (Sony, n.d.), The Vive uses the *Vive controller* (Vive, n.d.), and Samsung uses the *Gear VR controller* for their VR platform (Samsung, n.d.).

Figure 2.14 VR user interacting with the VE using handheld motion controllers (courtesy of HTC, image URL: https://www.vive.com/eu/product/vive-pro-full-kit)

Because of the movements involved in VR interaction mainly from hand-held controllers and head movements, these interactions can affect the use of VR devices in social context. According to Hsieh et al. (2016), gestural interaction can be a concern in social scenarios. Therefore, several design principles have been suggested for unobtrusive gestures to enhance the social acceptability of AR devices. These principles provide a primary input device that is not located on the AR glasses directly. The main method is by using *relative pointing* to achieve tasks, using subtle and hidden movements, using familiar and intuitive gestures, and providing a form of tangible feedback such as tactile feedback. (Hsieh, Jylhä, Orso, Gamberini, & Jacucci, 2016). Other than the nature of the gesture, the location of the gesture on the body is also important. Previous research by Dunne et al. (2014) provide a *body map*, which provide comfort zones for users to user as input modality.

Although this map is slightly different for males and females, it avoids areas that can cause social awkwardness such as proximity to genitalia and more acceptable location are the arms, shoulders and the stomach area (Dunne et al., 2014).

2.1.5 Spectatorship in VR

When virtual reality is coupled with a social context, it can affect those in the vicinity and grab their attention. By wearing a device on the had covering the eyes, using headphones that block the noise, and performing certain head movements, gestures, and actions, VR in social settings can pose several possible issues. Previous research by Profita et al. (2016) argue that there are always challenges faced with using any sort of wearable device and interacting with them. Mainly, these include the *physical appearance of the device*, *the ways user interacts with the system, level of familiarity by the bystanders present in the same physical context, and privacy concerns* (Profita et al., 2016).

Figure 2.15 VR user isolated from the rest of the people in the room (courtesy of HTC, image URL: https://www.vive.com/eu/product/)

Due to the nature of VR devices and the way they function, a level of *isolation* is created between the users and the spectators (Figure 2.15) which can be considered a factor affecting the social acceptability of VR. To close this perspective gap there has been several workable solutions in the field. Ishii et al. (2017) have come up with ReverseCAVE, a solution that projects the VR environment of the user onto translucent screens in a cubic form that lets the spectators observe the same virtual world of the user. The results of a survey using video demonstration for the ReverseCave showed that the users were more eager to use the system than without it (Ishii et al., 2017). Additionally, a solution by Gugenheimer et al. (2017) propose ShareVR, which is a prototype that aims to reduce the gap between the users and spectators by enabling interactivity between them (Figure 2.16). The system works by projecting the VR world of the user on a physical space that spectator can interact with using handheld devices without the need to wear a VR headset.

The results of ShareVR showed a higher rating of the system for both the HMD VR user and the non-HMD users in terms of social engagement, presence, and enjoyment (Gugenheimer, Stemasov, Frommel & Rukzio, 2017).

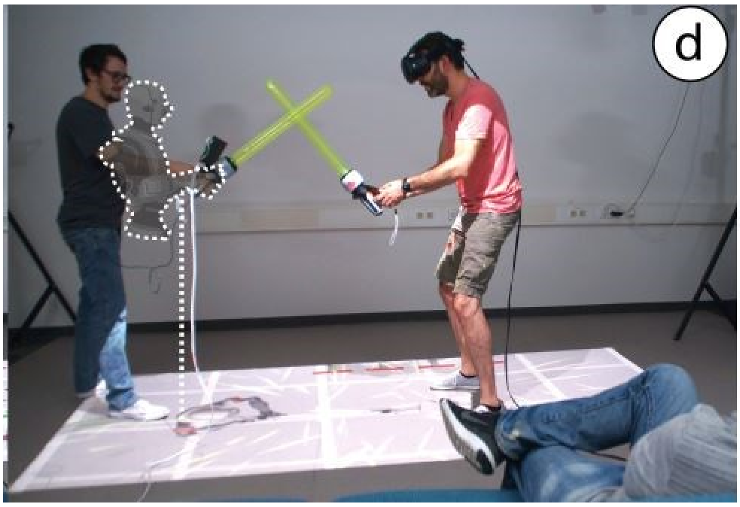


Figure 2.16 ShareVR, VR user interacting with non-VR user (courtesy of Gugenheimer, 2017)

While the VR user is exploring a world that cannot be seen, heard, or felt by the spectators. To solve this *isolation*, there has been some work done to visualize the VR world to the spectators. Earlier research by Chan et al. (2017) have come up with a solution called FrontFace, a concept that utilizes a secondary screen in the front of the HMD that allows the spectators to see what the user sees. In addition, eye tracking is used to show the exact location that the user is looking at as well. Some issues that arise with this system, is that the screen is not visible when the user is exploring the VR world and moving his head around (Chan & Minamizawa, 2017). In another instance, See what I see by Pohl & De Tejada Quemada (2016) propose a similar solution for increasing social acceptance by adding a secondary screen that allows the spectators view the users current state in the VR world (Pohl & De Tejada Quemada, 2016).

Another factor that can be a possible contributor to the social acceptance in VR technology is the fact that the spectator *cannot communicate* with the user via sight or sound, especially if the user is wearing headphones as well as the HMD. FrontFace (2017) allows the spectators to use voice trigger command as a form of communication by calling the users name. Another method is by double tapping the user's front screen to grab his or her attention (Figure 2.17). In addition, the spectators can use mid-air gestures in front of the user to grab the attention of the user. The system works by using the outside facing screens camera to detect the spectator waving gesture and relaying it to the virtual world of the user (Chan & Minamizawa, 2017).

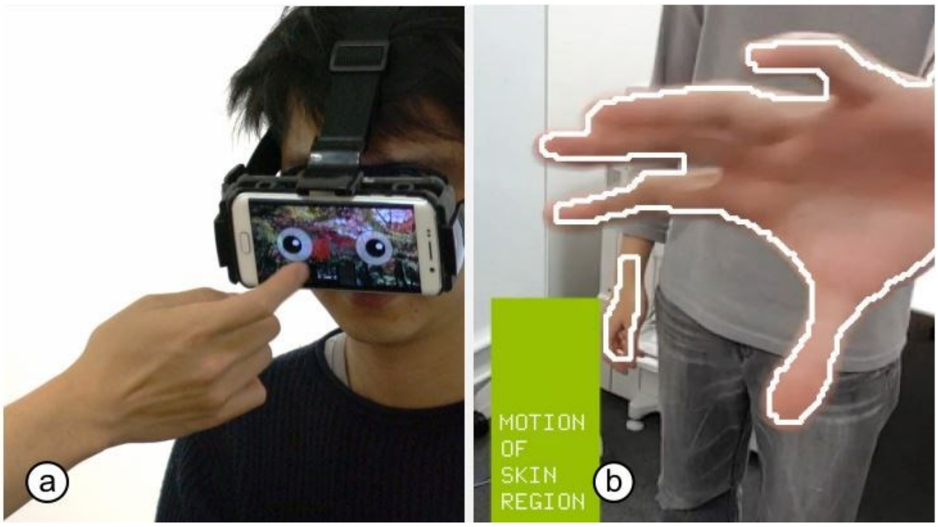


Figure 2.17 FrontFace, facilitating communication between VR user and non-VR users (courtesy of Chan and Minamizawa, 2017)

Additionally, the issue of *privacy* can also be considered a factor in the social acceptability of any form of technology and can be vital in VR devices. In VR devices that are not equipped with front facing cameras this is not a major issue, but when it comes to the latest VR devices that have a built-in camera and the ability to record the spectators, this can cause some immediate issues. In an earlier study by Denning el al. (2014), they investigated the issue of privacy and how it affects the bystanders and spectators. By using a mock-up device resembling AR glasses equipped with a camera, they ran the study in cafes and allowed the bystanders to observe the user followed by an interview. The findings showed that many of the participants felt that they needed to be asked for permission before being recorded and that they were also interested about being able to block the recording (Denning, Dehlawi & Kohno, 2014).

Finally, *safety* can also affect the social acceptability of VR. Safety is considered an important issues in VR and in the health and safety warning document of Oculus Go it mentioned that *"The headset produces an immersive virtual reality experience that distracts you from and completely blocks your view of your actual surroundings."* and *"Serious injuries can occur from tripping or running into or striking walls, furniture, other objects or people, so clear an area for safe use before using the headset."* (Oculus, n.d.)

2.2 Social Acceptability

Social acceptability is important to wearable technology and needs to be addressed before moving into the mainstream and becoming a norm since if social norms are not followed by individuals, the social flow is disrupted (Edwards, 2003).

2.2.1 Social Acceptability of Wearable Technology

The social acceptability of any technology can greatly affect the user experience of that technology and cause it to fail and be forgotten or thrive and become an everyday use item that everyone embraces. Additionally, Social acceptability of a technology can even affect the user to be included in groups or relationship (Schwind, Reinhardt, Rzayev, Henze, & Wolf, 2018a). The effect of what others think about technology is so strong that even perceived disapproval from the society can influence the acceptance of a technology (Koelle, Kane, Olsson, Mitchell, & Williamson, 2018). Part of the reason for the importance of social acceptability is that people are consciously aware of their surroundings and as technology such as mobile phones become part of the daily life, the affect the social appearance become more apparent (Naz, Bashir, & Alam, 2017). Koelle et al. (2018) state that the experience of interaction with an interface is not only what the user thinks, but also what everyone else who is present thinks as well. Furthermore, interactions in public spaces may even cause discomfort and social tension in certain situations (Koelle et al., 2018). Thus, it is important to consider social factors when designing interactions in situations that other people are present. It is imperative to note that social acceptability of technology is not a simple matter that can be characterized by awkwardness or embarrassment but a combination of factors affect social acceptability such as appearance, social status, and culture (Rico & Brewster, 2010).

Designing for social acceptability is not an easy task as there are various concerns that needs to be taken into consideration. Currently, there are no concrete models and frameworks in the field of human computer interaction (HCI) that designers can refer to and that can act as an agreed upon metrics to measure the issue of social acceptability (Koelle et al., 2018). Although models such as Technology Acceptance Model or Unified Theory of Acceptance and Use of Technology have existed for a long time, they originated for management information system and differs from the context of social acceptability (Keylly, 2018). In addition, social acceptability needs to be carefully analysed from different standpoints and all the possible angles. For instance, social acceptability challenges of professional social matching systems can be looked at from five main perspectives as proposed by Olshannikova et al. (2018). The internal perspective is about the user`s views on others accepting their choices and conduct. The interpersonal perspective is about encounters in social situations and the dynamics and norms involved. The organizational perspective is about acceptance of the technology in companies. The cultural perspective is about the culturally implied beliefs and norms. Finally, the ethics and regulations perspectives is about the written rules and regulation that need to be taken into consideration (Olshannikova, Olsson & Huhtamäki, 2018).

Wearable technology can be more prone to facing major setbacks when it comes to social acceptability. Keylly (2018) defines a wearable technology as "a computer or electronic devices that is personal, personally-owned, and worn on the body (on skin or clothing) but excluding wearables that are not visible (e.g., inside or under clothing)." (Keylly, 2018). Some of the challenges that wearable technology faces range from the physical form, where it is located, how familiar are the spectators with the device, privacy concerns, and the interaction techniques (Profita et al., 2016). The physical form of any wearable is important for these devices since they are worn, carried, or even attached to the body of the user and are supposed to provide a continues and unobtrusive experience to the user (Buenaflor & Kim, 2013). Previous wok by Buenaflor and Kim (2013) identified six different human factors affecting the social acceptance of wearable computers. Fundamental needs refer to the degree of need fulfilment of the user. Cognitive activity is about how useful and easy to use is the device and how much risk is associated with its use. Social aspect is about the effect and influence in social interaction. Physical aspect is about the comfort, safety, appearance, and how mobile is the device. Demographic refers to the user's age and gender affecting the adoption. Finally, technical experience is the earlier exposure to similar technology (Buenaflor & Kim, 2013).

Social acceptability is a complex subject as discussed earlier, and in order overcome the issues involved, innovative approaches can be used to create unconventional solutions. Earlier research by Miner et al. (2011) suggested the digital jewellery as a solution to wearable technology. For instance, a signal ring that has an LED and communicates important information along with a bracelet with an active LCD and a necklace with a built-in microphone. Another example is a set of glasses that has built in display that can be navigated using a ring and speakers in earing (Miner, Chan, & Campbell, 2001). In a more recent instance, Dierk and Paulos (2018) suggest that one possible solution for socially acceptable design is the integration of the warble technology with norms and practices that are culturally acceptable. For instance, AlterNail (Figure 2.18) is a small interactive device in the form of a false fingernail with an e-link display, which is wirelessly charged. AlterWear are a combination of NFC and e-link technologies that can be used in a variety of forms such as shoes and heats making them go unnoticed in social situations (Dierk & Paulos, 2018).

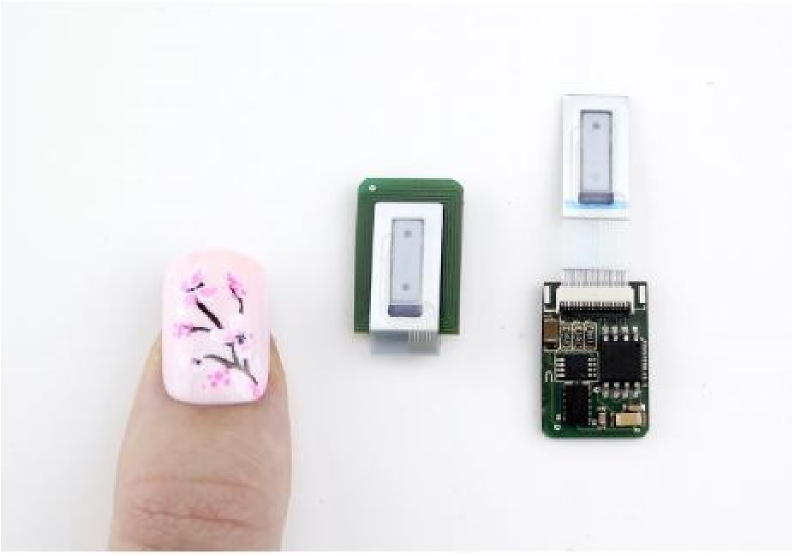


Figure 2.18 AlterNail wearable technology (Dierk and Paulos, 2018)

In terms of measuring the social acceptability of wearables, there are not many sources of measurement; however, there has been some development lately in the field to tackle the issue. Keylly (2018) has addressed the issue by coming up with a list of 14 items known as the WEAR Scale. The WEAR Scale was developed through a multi-step process using earlier studies, expert reviews, validity testing, and exploratory factor analysis. The scale range across two different factors. The first factor is the fulfillment of aspirational designs while the second factor is about the avoidance of social fears. The WEAR scale can be used as an evaluation or a design tool for socially acceptable wearables. The list consists of 14 items as listed below (Keylly, 2018, p3):

1. I like what this device communicates about its wearer
2. I could imagine aspiring to be like the wearer of such a device
3. This device is consistent with my self-image
4. This device would enhance the wearer's image
5. The wearer of this device would get a positive reaction from others
6. I like how this device shows membership to a certain social group
7. This device seems to be useful and easy to use
8. This device could help people
9. This device could allow its wearer to take advantage of people
10. Use of this device raises privacy issues
11. The wearer of this device could be considered rude
12. Wearing this device could be considered inappropriate
13. People would not be offended by the wearing of this device
14. This device would be distracting when driving

2.2.2 Social Acceptability of VR

While there are not many historical works and studies into measuring the social acceptability of VR including *head movements*, *body gestures*, *hand gestures, and the device itself,* recently there has been some interest in the area.

In a previous study by Profita et al. (2016) the social acceptability of HMD use was measured in relation to disability of the user. The study wanted to explore the viewpoint of people when they saw someone using an HMD in public context. The study method was using online questionnaires by participants after seeing different videos of HMD use in public with different information about the user's disability being disclosed in each scenario. The questionnaire had three distinct themes of statements, which were about the *interaction, the user, and the device*. The statements about interaction ranked the interaction from different preservice such as being *awkward, normal, appropriate, rude, uncomfortable,* and *distracting*. The statements about users asked if the respondents found the user was *independent, needed help, needed the device, looked cool,* or *seemed nerdy*. Finally, the statements about the device asked the opinion of the device as being *useful* or *unnecessary*. The questions followed a 7-point Likert scale from strongly disagree to strongly agree. The findings of the study suggest that using HMD was more acceptable when the user had a disability and used the device as a form of assistive technology rather than a daily device (Profita et al., 2016).

In a more recent study by Schwind et al. (2018), they measured the social acceptability of HMD in different social situations. The study had two independent variables, which were situation the VR device was used and the person using VR. Situation showed VR used in six different levels, which were in a car, a metro, a café, a living room, and bedroom. The person had three levels of people wearing the VR device, which were female, male, and both. The online questionnaires were based on the previously study discussed earlier by Profita et al (2016) and had two themes of statements about *interaction and the device*. Much like the other study, interaction had eight statements which were *awkward, normal, appropriate, rude, uncomfortable, and distracting.* Device had statements about being useful and unnecessary. The results of study found that the social acceptability of VR devices is dependent on the context and in places such as a bed, metro, or train it is more acceptable to use that in context that requires social interaction between people such as living rooms, and cafes (Schwind et al., 2018b).

2.2.3 Defining Others in the Social Context

The actors involved when there are other people in a public context can be quite varied. Three different viewpoints are presented in the following.

Based on a previous work by Downs et al. (2015) the roles of different participants in social gaming are based on the level of participation of the users in the context. Mainly, there are three constant roles ranging from lowest to highest levels of participation defined. *Bystanders* are those who are present in the same context, but their focus is not on the game and they show no interest in the player's actions. The *audience* are those who are not playing the game but show interest and engage with the player. The audience is further divided into twelve distinct temporary roles that can change from one to the other as time progresses, below is a summary of those twelve roles. The actions of the players defined their roles and as the gaming sessions progress, the roles can change and the player can be the spectator or vice versa. (Downs, Vetere, & Smith, 2015).

The *spectators* are the type that simply enjoy watching the gaming experience with no immediate need to play the game.

The *orchestration* and *management* take care of the session duration and technology preparation and explanation while the documenters take a video or photo snap form the gaming experience.

The *coaching* and *directing* roles are those that aim towards providing a form of guide and help to the players.

Demonstrating and *puppeteering* group show the others how to perform certain moves and engage with the game.

Rehearsals and *shadow play* involve preparing for the game by warming up and trying out the body gestures and moves before their turn starts.

Heckling and *cheerleading* roles involve demonstrating the competitiveness spirit through mocking, trash talks, or even showing support for the player.

Finally, the *players* of the game are those who actively engage with the system and play the game.

Furthermore, previous research by Cheung & Huang (2011) define nine different personas of spectators. The *bystander* is considered the least form of active spectator and there are mainly two sub groups of bystanders. The *uninformed bystanders* have no idea or understanding about the game while the un-invested bystander has previous experience with arising interest after encountering the game. The *curious* are those spectators that are attracted in order to increase their knowledge about the game and make new discoveries. The *inspired* are spectators that have enjoyed watching the performance would like to try the game themselves, while the *pupil* group go a step further and want to get a better idea of how and why certain actions were performed. The *unsatisfied spectators* would prefer to be playing instead of watching someone else, while the *entertained* are on the other side of the scale and enjoy watching the game played instead of playing. The *assis-*

tant helps the player and the *commentator* provides liveliness and excitement to the gameplay. Finally, the *crowd* is those who came specifically to enjoy the gameplay event (Cheung & Huang, 2011).

In another study by Finke (2008) individuals at a public display location are defined as *actors*, *spectators*, and *bystanders*. While *actors* are the main users who are actively interacting with the system directly and providing the required input. The *spectators* are those who are directly observing the actor, while trying to identify and decode the actions of the actor and follow the feedback on the display. Finally, the *bystanders* are those who glance at the display and shortly give their attention towards the large display. This glance can be as short as a two-second attention towards the system (Finke, Tang, Leung, & Blackstock, 2008).

While there are various ways to define the actors involved in social context, for the purpose of this thesis we will adapt the definitions provided by Finke (Finke et al., 2008). In this work, *we refer to the actors who use the VR in public as the **users**. The **spectators** refer to the others present in the same context in the vicinity of the user who are interested in the VR use and try to decode the user actions and show interest in the user.* The decoding of the information is when the spectator deviates from their own actions and starts to look at the VR use and try to make sense of their interaction and movements. As described earlier, this observing of the VR user can be due to their curiosity or their interest in the VR.

2.3 Summary and Hypothesis of Central UX Factors of VR

The origins of virtual reality dates to more than 10 decades ago and there has been a lot of time and money since then spent by countless individuals and companies to satisfy the virtual world need of humans. Historically, interest in VR ranges from organizations such as NASA, General Motors and Disney to institutions such as Stanford and MIT. Today the leading tech giants such as Google, Facebook, and Microsoft are leading the charge with VR and market forecasts suggest a bright future for VR. VR has been adapted by many fields such as the gaming industry, the adult entertainment industry, military purposes, medical fields, design field, training purposes and even journalism. With the new and upgraded hardware and software developed and the lower prices, high end VR has become more accessible than ever and many other industries will venture into the field in the near future.

Success of VR is mostly derived from the unique user experience it provides. By providing an interactive immersive experience to users, a feeling of presence is felt by the user that no other medium can convey. This presence is turned into a state of deep focus and attention referred to as flow, which makes the user fully dedicated to reach the goals in the VE. Some factors that help reach flow are the ability of the user to feel real in the virtual world through the concept of self-embodiment and by being able to interact with the virtual environment. The interaction with VR can be in a variety of ways and by using different devices such as body tracking, joysticks, eye tracking, and even speech recognition. However, the most used form of interaction device in the market are handheld controllers that translate users hand gestures into the virtual world. VR HMD’s can have different forms such as mobile HMD’s that are simple and affordable but or wired HMD’s that are high end and require high-end computers to run the software.

Any kind of warble technology usually faces some challenges to be accepted socially. This can be related to the physical appearance of the device, the familiarity of those who spectate it, the interactions, or privacy concerns. For VR this acceptability can even be more obvious. Due to the fact that VR requires an HMD and headphones which isolate the user form the real world, some potential challenges arise when using VR in context that includes other people such as spectators and bystanders. The issues with VR in public context are mainly user isolation and lack of communication, the interactions of the user with the virtual world, and privacy concerns.

Based on the literature review and the research provided in the section 2.1.5, **we hypothesize the following as central experiential factors** that can affect the use of virtual reality devices in social context along with the earlier sections in the thesis that highlights the factors.

VR Interaction – The user interactions such as head movements in different directions, and hand gestures pointing in different directions can seem unusual to everyone else present, especially if they have never experienced VR and interacted with the technology.

User Isolation – The user being in the same physical space as the others, but also are present in a virtual world, can cause a separation feeling between the user and the others present. This state is a psychological state that might affect others not using the VR.

User Communication – The user being disconnected from everyone else and not being able to see or hear anyone in addition to no one being able to communicate with the user can be a source of annoyance to the others.

Using HMD in Public Context – The user wearing a HMD covering his or her face in a public place may seem awkward to anyone else present and cause distraction.

Privacy and Safety Concerns – Being equipped with front facing cameras, those passing by in front of the user can be in doubt if the user is recording their actions. Additionally, the user might bump into people and objects, which poses safety issues.

For the purpose of this thesis, and in order to find the answer to our research questions, we will focus on the above-mentioned issue and base our questionnaires, interviews, and co-creation sessions on them.

3. RESEARCH APPROACH AND METHOD

In this section, research approach and phases are presented. Key questions that are going to be addressed are identified and the forms of data gathered and the analysis type is presented in detail.

3.1 Research Approach and Phases

This thesis is based on empirical research (Wobbrock & Kientz, 2016) seeking the viewpoints of users, spectators, and experts with the goal of identifying influencing factors in social acceptability of Virtual Reality in addition to design guidelines.

The main approach of this thesis is through field research (Goodman, Brewster, & Gray, 2004) of VR users and spectators in public context. While it may be argued that the results of in the case of VR studies in the field can be misleading and not valid, previous work (2017) confirm that it is feasible to get reliable data by conducing VR studies in the field (Mottelson & Hornbæk, 2017).

After initial literature review phase and identifying the key influencing factors of social acceptability of VR, we conduct our research and use the factors found earlier as the basis of our studies and form our surveys, interviews, and discussion topics around them while adapting our questions from earlier studies (Profita et al., 2016).

This research includes the viewpoint of both the VR users and the others in the same context. Additionally, we compile a set of design guidelines through discussion sessions held with UX academics. The VR device used for our studies is the Samsung Gear VR and Motion Controller which provides a 3 degrees of freedom, paired with a Samsung smartphone, the VR device requires no wires or cables and it allows the users freely move in all directions.

Research Questions

The research questions (RQ) focus on the experiential social influencing factors affecting both the user and the spectator of VR devices. Furthermore, the goal is to identify a set of interaction design guidelines that can contribute to creating more socially acceptable VR experiences.

RQ1: What are the influential experiential factors in the social acceptability of VR use from the perspective of users?

RQ2: What are the influential experiential factors in the social acceptability of VR use from the perspective of spectators?

RQ3: What are the interaction design guidelines for VR systems to enhance social acceptability?

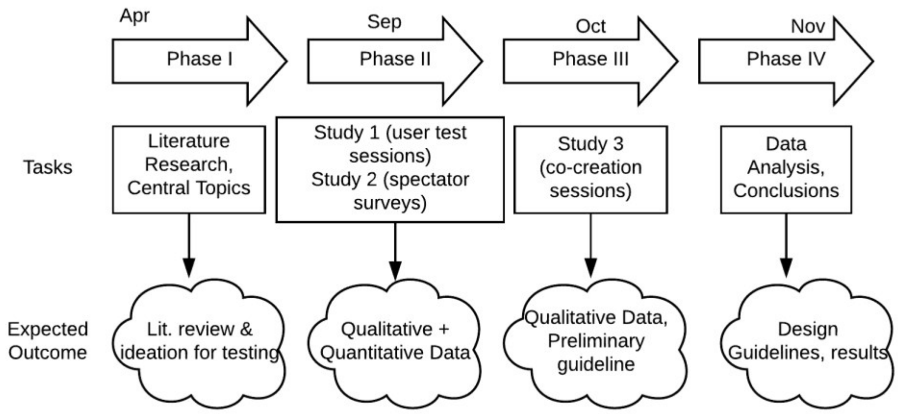


Figure 3.1 Summary of Phases

The research mainly consists of 4 main phases (Figure 3.1), as described in the following.

Phase one: This phase is the literature research part followed by a hypothesis formation and identification of central topics to be explored later. The phase was completed on August 2018.

Phase two: User testing. The user test sessions and data collection including field spectator surveys, field user surveys, field user interviews. This part helps answer RQ 1 and 2 and identify the most influential social acceptability factors in VR. The phase was completed on September 2018.

Phase three: Co-creation sessions. The sessions provide a clear idea of what the users and spectators expect in terms of socially acceptable interaction with VR. This phase assists in answering research question 3 and the results from the previous phase were utilized in this phase. The phase was completed by October 2018.

Phase four: Data analysis. Using UX methods and tools such as thematic coding and statistical analysis, the main conclusions are made and the results summarized. The phase was completed by November 2018.

3.2 Research Process and Methods

This thesis includes three main research studies. Two of the studies are field research while one is a participatory design session. Empirical findings of the first study help understanding the viewpoint of VR users and answering RQ1 while the findings of the second study aim to identify the viewpoint of spectators and answering RQ2. The third and final study helps in the compilation of a set of design guidelines and answering RQ3.

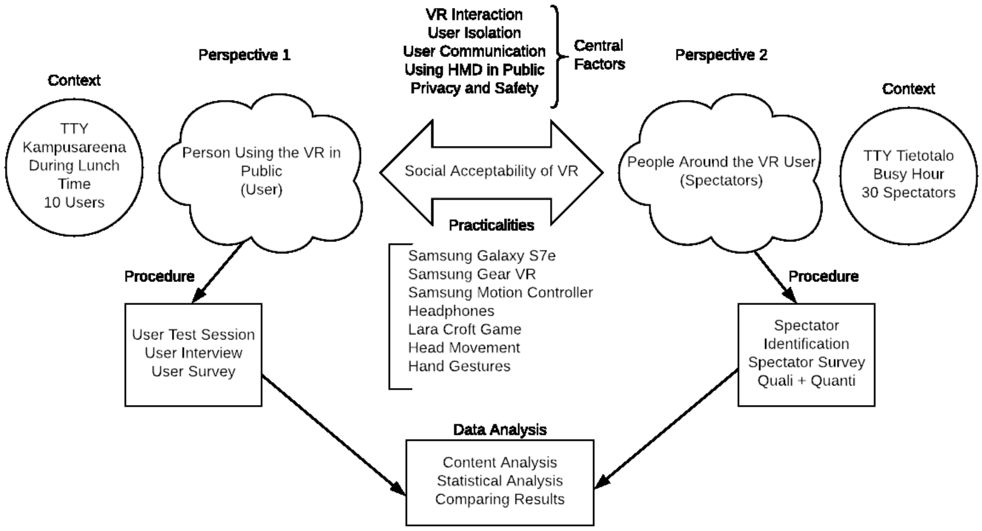


Figure 3.2 Field Research Summary

Figure 3.2 is a visual summary of the field research from the perspective of users and spectators to reach the goals of this thesis work. To identify the social acceptability of VR, the *central factors* identified are considered as the main topics. The two main perspectives of research are the *users* and the *spectators* of which both take place in a *public context* of a university. The *practicalities* provide detailed information on the device and interaction used in the public setting. *Procedure* describes the approach in each perspective and the *data analysis* show what form of data analysis is performed.

Data gathering methods

Surveys provide the quantitative data for the users as well as the spectators. To encourage participation and efficient results, the surveys are short and focus mainly on the key identifying and influential factors in the acceptability of VR devices. The quantitative data enables the identification of influential experiential factors and help answering the research questions in an accurate manner.

Interviews, short answer questions, discussions, and observations provide the qualitative data for the users and spectators in addition to the experts. The qualitative data provides a good foundation for answering the research questions by creating an understanding of participant thoughts, ideas, and actions.

We adapt our survey questions for the users and spectators from a previous study by Profita et al. (2016) that evaluate the viewpoints of individuals on social acceptability of wearable computing and head-mounted displays in relation to disability of the user. The study uses three themes about the interaction, the user, and the device (Appendix A). Each theme has different statements that the respondents score of a 7 point Likert scale of

Strongly Disagree, Disagree, Somewhat Disagree, Neither Agree nor Disagree, Somewhat Agree, Agree, Strongly Agree. Additionally, there is a background section in the beginning of each survey (Profita et al., 2016).

Overall 49 participants took part in the studies conducted. Study 1 identifies the social acceptability of VR from the viewpoint of 10 users through interviews, surveys, and observations. Study 2 identifies the social acceptability of VR from the viewpoint of 30 spectators through surveys and observations. Study 3 explores possible design guidelines from the perspective of 9 UX experts through participatory design discussions. Table 3.1 is a summary of the research studies conducted in this thesis.

	Study objective	**RQ Goal**	**Methods**	**Data gathering**	**Analysis method**
Study 1 User test sessions	User experiential factors	RQ1	Structured Interviews, surveys	Audio/Video recordings, Responses, Observations	Statistical analysis, content analysis
Study 2 Spectator surveys	Spectator experiential factors	RQ2	Surveys	Responses, Observations	Statistical analysis, content analysis
Study 3 Co-creation sessions	Design guidelines	RQ3	Participatory design session	Audio/Video recordings	Content Analysis

Table 3.1 Research study summary

Analysis methods

For the analysis of the *quantitative* data we used *basic statistical analysis* such as mean and standard deviation for the 7-point Likert scales. We then analysed the results of each question with regards to how the data was spread and justified our answers based on the findings. Additionally, we performed two tailed t tests (Sakai & Tetsuya, 2016) to compare the results of the user and spectator data in order to find out any statistically significant difference between the two results. We chose this method primarily as it provides a clear and unbiased view of the results and it provides a clear understanding of what the data means to the reader.

For the analysis of *qualitative* data, we used content analysis (Elo & Kyngäs, 2008) using Microsoft Excel. We started the process by transcribing the interview results and other qualitative data into digital format. We then created one sheet in excel per question which had all the responses for that question in addition to some selected quotes from the responses. After going through the responses, we created the main themes and a code for each theme followed by matching the codes to the responses. We separated the responses that had multiple answers into separate responses in order to have clear themes and responses in each theme. We also retracted the answers deemed irrelevant or out of the scope of the question. We then noted the frequency of each theme and transferred it into percentages. In the final step we created graphs for each question using the percentage values. The content analysis method provides us with adequate results that can transfer qualitative data into quantifiable data that can be clear and easy to understand. We primarily chose content analysis over affinity diagram as its nature of being in electronic format helps working efficiently and from different locations. Additionally, at any given point we can change the content on the spot and without the need of printing. Additionally, the content analysis can be easily backed up and stored and shared with external parties. Finally, all the calculations, graphs, and data visualizations can be made in the same space and altered at a later time if needed.

Ethical conduct

Before any of the audio and video recording sessions, the participants filled a consent form in addition to informing their participation is voluntary and they can stop at any time without providing reasons. Additionally, data anonymity was addressed by removing any identifying factor such as the names and personal details of the users, spectators, and UX experts. Each participant in our research was given a unique code instead which we refer to as U for users, E for experts, and S for spectators.

All the figures and images used throughout this thesis are given appropriate credits to the original authors and permission has been asked to use the work of authors. Those figures contenting the words *courtesy of* have already received a permission confirmation to use the work. The icons used in section 5 are by the artist Korawan_m (https://www.iconfinder.com/korawan_m)

4. RESEARCH STUDIES

This chapter describes the details of the research studies conducted. It includes the description of the methodologies, procedures, participant information, and findings from each study.

4.1 Study 1: User Test Sessions

This study is the user test sessions conducted in the public context of university. The aim of the study was identifying the factors that affect the social acceptability of VR from the perspective of the users.

4.1.1 Methodology

In order to understand the viewpoint of the users in terms of the social acceptability of VR, we chose field experiments as the base of the study (Goodman et al., 2004). The main reasons for choosing to study VR in the field was the opportunity to put the users in a true public context with by real people in the same place rather than laboratory setting and the imagination of the user. Secondly, the field experiment can provide a realistic overall viewpoint to the moderator observing the behavior of the spectators and others in the context. Finally, in the field experiment the moderator can get instant feedback form the user and get reliable answers from the users.

The tools of evaluation were structured interviews immediately after the user VR experience was over. Additionally a survey consisting of a 7 scale Likert scale was also used adapted from earlier studies (Profita et al., 2016)(Appendix A). The user session with the VR was recorded on video and audio with audio recording for the interview sessions. Photos were taken during the test sessions s artefacts (Appendix J).

The interviews are structured interviews (Appendix D) and took place after the test session was completed. The moderator asked a series of open-ended questions from the user to get a better understanding from the viewpoint of the user, in addition to a survey. The aim of the interview was getting a clear understanding of the user's perspective after using VR in a public space and identifying major issues or problematic areas.

The user survey statements (Appendix B) seek the VR user's point of view and influential factors from their perspective on social acceptability of VR. The aim of the user surveys was to answer RQ1 and to provide statistical data in support of the interviews.

4.1.2 Procedure

After the users arrived location, the moderator explained the nature of the research followed by filling a consent form and a brief introduction to the VR device and explaining the motion controller functions, display buttons, and how to adjust and wear the device. During the test sessions, the user wore the VR HMD and headphones and started an immersive experience. We chose to use Samsung Galaxy S7 Edge along with Samsung Gear VR and motion controller (Figure 4.1).

Figure 4.1 Samsung Gear VR, Galaxy S7 Edge and Motion Controller

The experience chosen was *Tomb Raider VR: Lara's Escape*[1] which was a mini game demo for the for new Tomb Raider movie. The adventure game enables the user becomes the famous character Lara Croft who has to descent into an ancient tomb to escape from soldiers. During the gameplay, the user is expected to interact with the VR using the motion controller representing a climbing axe, a bow, and a flash light (Figure 4.2) at different stages of the game. The game requires hand movements and head movements in addition to body movements such as turning in different direction. The game experience was chosen due to its immersion factor, audio effects, and motion controller interaction requirements.

Figure 4.2 Using a flashlight as Lara Croft (https://vrscout.com/news/tomb-raider-vr-free-movie/)

[1] https://www.oculus.com/experiences/gear-vr/1759965414055326/

After each test session, the user was interviewed followed by a survey and a movie ticket as a reward. Test sessions featured 10 users aiming to identify the social acceptability factors of VR from the perspective of users. For the most realistic results, the user testing sessions took place in a public context where there were many people present. The user testing took place in Reaktori restaurant in TUT campus (Figure 4.3) during weekday’s lunchtime between 11:30 AM and 2:00 PM where there were the most amount of people around. The test sessions ran for five days with two test sessions every day.

Figure 4.3 User test session in public context

In all the tests the moderator was available to ensure the safety of the VR user and the public. There was no instance of mishap or issues in 9 out of the 10 tests. In one test session however, due to an unusual large number of crowds in the restaurant que the passersby had to walk around the VR user which the moderator had to ensure no one bumped into the user and that there was no physical contact between the user and the passersby.

The users were recruited via social media after posting an advertisement on the Facebook group Tampere Foreigners and Not which has more than 6500 members. The target group was those users familiar with VR and who have had some past interaction with VR earlier. The reason for the familiarity was to increase the chances of successful user test sessions. In order to assure a smooth operation of the tests, and based on previous work (2017) we aimed mainly at recruiting qualified participants who were familiar with VR technology as recommended by earlier work (Mottelson & Hornbæk, 2017).

Ten users participated in the study, and their age ranged from 18 to 41 with most of them male and students. All the users had interest in VR but only two users indicated they owned own a VR device, and everyone mentioned they used VR for gaming and six users mentioned they played VR games alone. Half of the users mentioned they sometimes had experience with VR devices while only one never used any VR device and one had weekly experience and three of the users experienced VR just once. In terms of using VR in public, six users mentioned they had experienced it a few times while three mentioned they never had public VR experiences and only one user mentioned just once.

4.1.3 Findings

The findings presented in this section provide an overview of the findings after analysis of the surveys, interviews, and observations of the user test sessions. From the perspective of the users, the findings suggest **freedom of interaction, uninterruptable immersion, un-intrusive communication, freedom to switch between realities, sense of safety, sense of privacy, sharing the experience, and sense of belonging** as influential experiential factors and each factor is described in section 5. The survey results and a comparison between the user and spectator surveys are shown in section 4.2.3.

During the user test sessions, we observed that the majority of the passersby simply **glanced at the VR user for a second or two** and even at times, it seemed that the VR user was **invisible** as if not wearing a device immersed in another world and making hand gestures and other body movements. There were also some cases that passersby glanced for a second or two before continuing what they were doing. However, there were a **few cases of spectatorship** whereby the by passers started to pay attention to what the VR user was doing. This was seen by their **facial expressions** and gestures such as smiling, frowning, and stopping to decode the VR users' movements. In some particular instances there was discussion about the user with friends who were sitting on the same table or waiting in que to get lunch. In one instance the VR user U10 (M, 24-29 yrs) got excited and loudly said *"Oh, wow"* while looking around in the VR world, at the same time a few students sitting in a nearby table started looking at the user and laughing in addition to paying attention to the VR user for a few minutes before continuing their discussion.

Even though there is a high level of interest form the user towards VR in general, only a few have ever used it in public which was either once or for short periods and the user test sessions was their first experience of using VR in public context. While a majority of the users felt either negative or neutral on using VR in public prior to the test sessions, their opinions shifted to positive after their experience. Almost all the users found their experience joyful even though some would prefer some form of privacy due to their concerns.

Freedom of interaction, sense of safety

A major concern amongst the users was the **safety factor** and most of the users felt that they were going **to hit other people, bump into objects near them, or trip on something and fall down**. The presence of others and fear of contact with people can affect the interaction. In some cases, this fear led to a reduced movement and a more careful VR interaction by users. In one instance user U9 (M, 18-23 yrs) mentioned *"I was spinning around like a robot not trying to spin to fast and too far"* while another user U7 (M, 36-

41 yrs) mentioned *"At times when I was in the game I forgot that other people existed because it was hectic, and I needed to fully focus on the game, eventually I remembered there were others and I needed to be careful"*. He added that "*if I was in an environment with lots of people walking past me I would play VR experiences that does not require much movement like immersive story telling*". In addition to the hitting and bumping, one safety perspective that showed up in a single instance was the safety of the belongings of the user. After the test session, U7 (M, 36-41 yrs) mentioned that "*I had this reflex and I noticed that for some reason I had my hand on my mobile unconsciously"* adding *"in a train station someone might steal your thing"*.

Sense of privacy

Safety can affect the performance of the user in VR both physically and mentally as the users mentioned that if they experienced the VR in **a private setting**, they would feel a better sense of freedom and bee loose in their body movements and actions in addition to being more focused since no outside stimuli such as noise would be present. This private area can be in the. An interesting finding was that most of the users were not concerned about being recorded by others while using the VR.

Sharing the experience

Additionally, the users **did not mind** the fact **of being separated from the rest of the crowd** and being immersed in a virtual environment. One user U8 (F, 30-35 yrs) mentioned *"you are in the same place and others but basically you are not and in a different world"*. The sense of immersion gave the users **a new experience** and the users noted that they completely forgot about the presence of other people after a few minutes of starting their VR experience. While some users might feel judged or would not want to share private content while using VR, others believed that **sharing their screens** with the people around would be beneficial in creating a sense of **shared experience** in addition to knowing those noticing the user interactions would **understand** the body movements and hand gestures. In addition, majority of the VR users agreed that it would be interesting if the other people could see what they were doing and seeing while using the device.

Sense of belonging

While using VR in the presence of others may feel a little **out of place and awkward at first**, once a user starts the VR experience, they will forget about the others enjoy the sense of being in a virtual location while in the same place as others and that the users enjoyed their VR experience in a public context of a university. Additionally, the users mentioned that if they saw other people using VR in a public space the would also be motivated to use it. The reasons mentioned was curiosity and the feeling of commonality. U9 (M, 36-41 yrs) mentioned "*we are collective individuals and moving herds, it would be obvious for the people not using VR that there is something special happening and they may not be bothered and it will be easier psychologically*" .

Freedom to switch between realities

One way to avoid the issues of bumping and hitting other including objects would be aware of the surrounding and know what it going on in the real world while using the VR. U4 (F, 30-35 yrs) stated that *"when you play in public you should be aware the real world around you".* To be able to somehow be able to see the real world without the need to taking off the VR device, some users suggested a form of real world view while suing the VR. U5 (M, 24-29 yrs) stated "*in public space that you don't know the surroundings obstacles should show in real time in the VR*". U7 (M,36-41 yrs) mentioned that *"it would be beneficial to be able to change between the real world and VR like the AR and VR device coming from apple in the future*"

Uninterruptable immersion, un-intrusive communication

An issue that came of several times during the test sessions was the excessive noise of the public context. When the speaking noise got louder in the real world, the users could easily hear them, and it made them **lose their sense of immersion** and it distracted them from their VR experience momentarily. U5 (M, 24-29 yrs) mentioned that for a "*moment I was totally immersed unless I heard someone talking loud".* In an instance that the speaking got very loud U3 (M, 30-35 yrs) loudly stated *"Guys, you are ruining my experience here*" and later mentioned background noise as one of the negatives to using VR in public. Additionally, most of the users believe it would be useful if the people in the public context could communicate with them.

The findings suggest it is socially acceptable to use VR devices in a public context such as **shopping malls, cinemas, educational institutes, conferences, parks, and museums** While some users and spectators find using VR in public as awkward, they don't find it rude to use the technology and the head movements and body gestures are somewhat acceptable when using VR. The users had split opinions on being watched by others in the public context while using VR in public with half not minding it while the other half did mind it. Another finding was that most of the users believed that using VR in public made them **look cool**.

4.2 Study 2: Spectator Surveys

This study is the user test sessions conducted in the public context of university. The aim of the study is identifying factors that affect the social acceptability of VR from the perspective of the spectators.

4.2.1 Methodology

In order to understand the viewpoint of the spectators in terms of the social acceptability of VR and similar to the user test sessions, we chose field experiments as the base of our study (Goodman et al., 2004). The main reasons for choosing to study VR in the field was the opportunity to get the feedback of authentic spectators who are interested in VR user in a public context. Secondly, the field experiment can provide a realistic overall viewpoint to the moderator observing the behavior of the spectators, their body language, and facial expressions. Finally, in the field experiment the moderator can get instant feedback form the spectators and get reliable survey answers from the spectators directly after viewing the VR user.

The tools of evaluation were surveys consisting of short answers and 7-scale Likert scale adapted from earlier studies (Profita et al., 2016) similar to the user surveys.

The user surveys seek the viewpoint of the users after the user test sessions and interviews (Appendix B) while the spectator survey (Appendix C) concentrate on the spectator viewpoints and how they look at the social acceptability of VR after viewing someone using the VR in a public space. The spectator surveys also feature some open-ended questions for a more in-depth look into the matter.

4.2.2 Procedure

While we originally planned conducting the spectator surveys at the same time as the user test sessions, we decided to take the viewpoints of the spectators in a different occasion. This decision was taken due to lack of human resources and in order for the moderator to be able to devote the time required to identify spectators, engage in a conversation with them and attend to their questions. The context was a public context situated at the main entrance of the Tietotalo building in front of Hertsi restaurant in TUT (Figure 4.4). While there was a user immersed in VR and interacting using the motion controller, the moderator stayed in proximity and identified spectators as those who clearly had an interest in the VR user. Spectators were those who had a clear interest in the VR user and took time to stand and try to understand what the user was doing. The moderator approached them and engaged with them by asking them their thoughts on using VR in public. Once the spectators became interested, the moderator asked if they would be willing to fill a survey to share their ideas and thoughts on the subject. The spectators were given a chocolate bar and a coffee ticket as a token of appreciation for their time.

Figure 4.4 Using VR in public with spectators around

A total of 30 spectators were identified and asked to fill the questionnaires. Two thirds of the spectators were male and a majority of those showing interest in the VR user were also male. Almost all the respondents were students and majority of them fell between 24 to 29 years age group. Most of the participants had interest in VR and almost half of them had a single use time with VR and only a few owned VR devices and from those who owned VR the most usage was for gaming purposes and half of them played VR games alone. Finally, most of the spectators had never experienced VR in public.

4.2.3 Findings

The findings presented in this section provide an overview of the results after analysis of the surveys and observations of the spectator surveys. From the perspective of the spectators, the findings suggest **shared experience, enticing curiosity, relevant experiences, being a norm, and a sense of privacy** described further in section 5.

The findings suggest that in a technical location such as a university, **VR users do not easily distract passersby**. Some of the spectators believed that seeing someone using VR in public and interacting using head movements, body gestures, and hand movements was normal while others thought it was awkward. However, those walking in the context who notice someone using VR, **do not get shocked** by it and do not feel it is rude of the person to user the device. Even those who consider the VR user as awkward can **change their perspective** after a few moments of getting used to the scene.

Being a norm

The findings suggest that as more users start using VR in public, it will increase the socially acceptability. One spectator S9 (M, 24-29 yrs) noted that "*the first time you see it, it looks kind of stupid, but now it doesn't feel weird*" while another spectator S14 (F, 30-35 yrs) noted the movements as "*awkward in the beginning and then natural".* While half of the spectators mentioned they would be willing to use VR in public, the other half mentioned that it would depend on the context and the experience. S20 (F, 30-35 yrs) mentioned *"Yes, it is something cool and interesting and I do not care to use it in public"*

Shared experience, enticing curiosity

Moreover, it was found that **sharing the user's screen** with the spectators can increase the chances of acceptability in addition to motivating VR use for spectators. Almost all the spectators were **curious** to see what the VR user is doing in the virtual world. S20 (F, 30-35 yrs) stated that *"it's interesting for me to know what the user is doing".* When giving viewpoint into using VR in public, S24 (M, 24-29 yrs) mentioned *"it is comedy gold, because one does not have any idea of what the user is looking at"* Additionally getting to see what experience the user is having in the VR can make the spectator curious and interested. In addition, the spectators **did not like** the fact that the **user was separated** from the rest of the people in the public context. The spectators also believed being able to **communicate with the user** would be useful.

Sense of privacy

Additionally, some spectators felt that **safety** and **privacy** are important. When the issues of privacy arise**,** the opinions can vary from one person to the next and some might not care while others are afraid that the user is recording them without their concern. **Safety** was important to a few users and they believed the user can cause some harm. S6 (F, 18-23 yrs) said *"they seem crazy and it could be dangerous because you don't see the real life"* S24 (M, 24-29 yrs) mentioned that they would be willing to user VR in public "*given that I don't bump into things or people*". Additionally, S13 (M, 18-23 yrs) mentioned *"it is the responsibility of the VR user not to bump into others in crowded spaces.* While we originally hypothesized that safety would be the main concerns of the users only, the viewpoint of the spectators suggest that it is an important matter to them as well.

Relevant experiences

Furthermore, the spectators find **suitable** public VR locations as museums, cinemas, educational institutes, parks, tourist attractions, malls, and event and seminars. Additionally, socially acceptable VR experiences are explorations, educational content, tours, movies, and visiting of historical places.

User and spectator viewpoints compared

In order to find out if there are any differences between the perspective of the users and the spectators, we compared the results of the quantitative data. We used two a tailed t test (Sakai & Tetsuya, 2016) for each statement and compared the common user statement with the mirroring spectator statement. We used the mean, standard deviation, and the population for each question using online software GraphPad. The two tail t tests revealed that **there are no statistically significant differences between the results in all the statements aside from statement 8, which is about the user isolation**.

Statement 8 is "I do not like the fact that the VR user is isolated from the rest of us" on a 7 scale liker scale. While half of the users disagreed with the statement and four were neutral, majority of the spectators either somewhat agreed or agreed to the statement. The results (Figure 4.5) suggest that while the users enjoy being isolated from the rest of the people, the spectators do not share the opinion and do not like the isolation created by the VR. This fact was also seen in the user test sessions as described earlier and some users mentioned that they enjoyed the fact of being physically in the same place but completely in a different world.

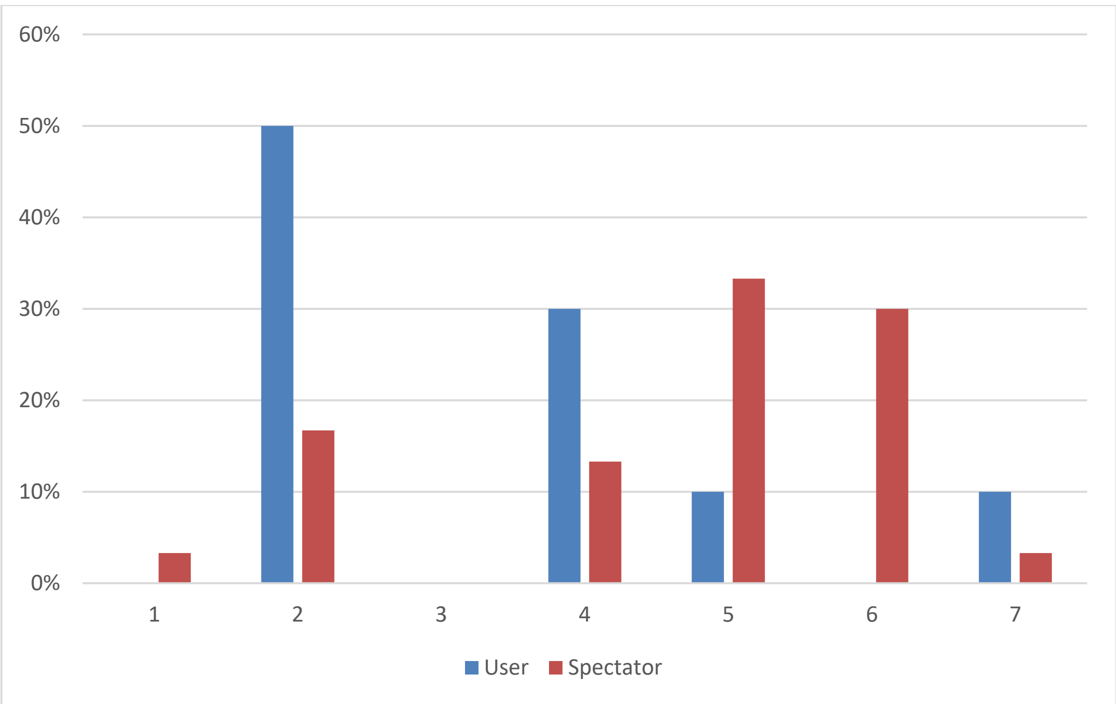


Figure 4.5 User vs Spectator response: I do not like the fact that VR user is isolated from the rest of us. (1=strongly disagree, 7=strongly agree)

Figure 4.6 is a summary of the comparison of the quantitative data of users and spectators.

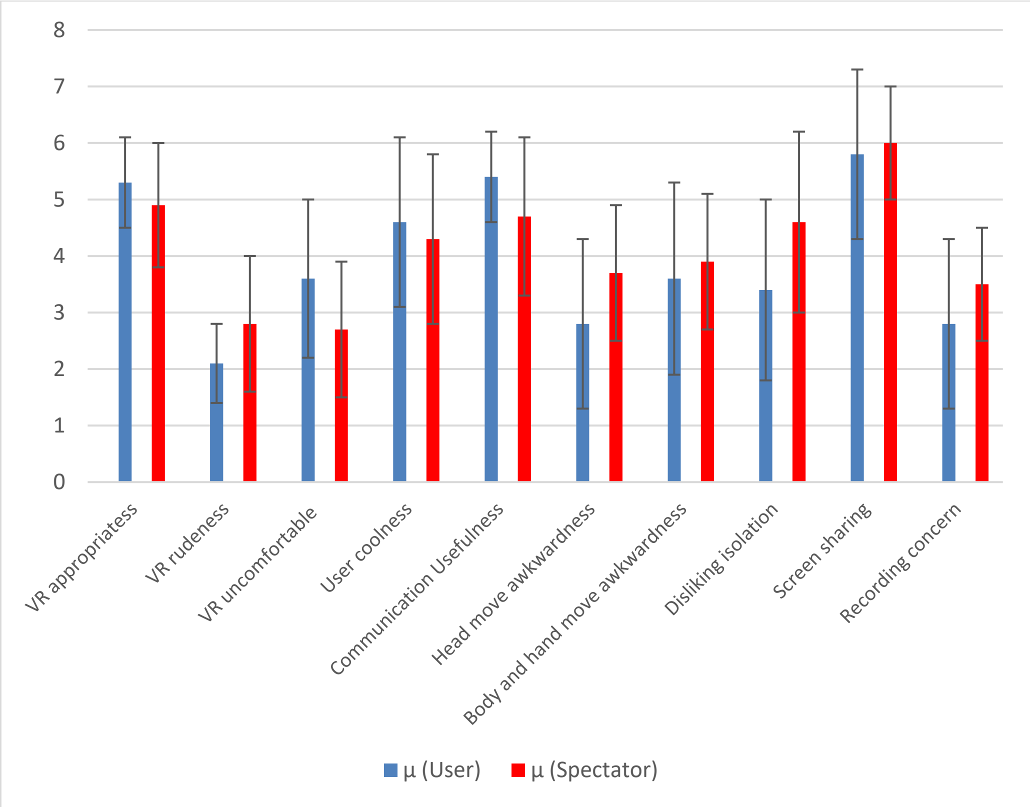


Figure 4.6 User (N=10) and spectator (N=30) survey result comparison

Statements:

1. It is appropriate for this person to use the VR headset in a public place.

2. It is rude for this person to use this VR headset in a public place.

3. I feel uncomfortable watching this person use the VR headset a public place.

4. The person using the VR headset looks cool.

5. It would be useful for me to communicate with the VR user.

6. I find the head movements of the VR user awkward.

7. I find the body movements and hand gestures of the VR user awkward.

8. I do not like the fact that VR user is isolated from the rest of us.

9. I am curious to see what the VR user is seeing and doing in the virtual world.

10. I am concerned the VR device camera is recording me.

4.3 Study 3: Co-Creation Sessions

In this section we present the details regarding the research study 3 which is the co-creation sessions. The aim of the study was identifying important design guidelines for socially acceptable VR experiences with the help of UX experts.

4.3.1 Methodology

The Co-creation sessions adapted the Participatory Design Framework (Sanders, Brandt, & Binder, 2010) with the following details.

Form: The main actions to taken in the sessions were discussions based on main themes and questions, body storming, and play acting was used to show examples of interactions to complement the discussion in addition to providing participants with a more concrete method of showing their thoughts. The participants got the chance to wear the HMD in addition to participate in the discussion.

Purpose: The goal of the sessions was idea generation for the creation of the design guidelines and getting a better understating of the guidelines of VR use in public context.

Group size: There were 3 sessions in total, each session hosting 3 expert participants.

Setting: The sessions were held face to face rather than online to provide the opportunity to try the HMD in addition to engage in active discussions

Venue: The sessions were held in pre-booked rooms in the Tietotalo building of TUT.

Iteration: Each session was held once with no iteration session due to time constraints. The participants were informed of the main topic in advanced to help formulate ideas for the sessions.

The target participant for the discussion sessions were experts, researchers, scholars, and those active in the fields of HCI, UX and VR. The reason for this limitation was to be able to stay focused on topic and use the experience in the field to contribute to the creation of the design guideline. The participants were recruited by approaching them in the Pervasive Department of TUT and at the of the sessions they were rewarded with a movie ticket.

The participants of the co-creation sessions were those experts in the field of UX and familiar with interaction. The participants were rewarded with a movie ticket for the session. We invited participants from the Unit of Human-Centered Technology (IHTE), part of the Department of Pervasive Computing at Tampere University of Technology.

The discussion topics consisted of 4 main themes (Appendix F) of *interaction*, *safety*, *isolation*, and *design guidelines*. Interaction theme included questions that asked the unacceptable forms of interaction in public places and type of input devices. Safety theme looked at the privacy matters of spectators and providing a safe zone of interaction. Isolation theme discussed the shared experience of the VR user in addition to communication between users and spectators. Design guidelines theme asked about the appropriate guidelines that could be used in drafting a set of design principles.

4.3.2 Procedure

For the purpose of the co-creation session, we invited experts in field of UX or those previously involved with VR. The purpose was to discuss the design guidelines of public VR interaction and compile guidelines for socially acceptable VR designs. Three sessions were held with each session having three participants and a moderator. The sessions each lasted for one hour and discussed four main themes of *interaction*, *safety*, *isolation*, and *design guidelines*. Each theme was discussed for 10 minutes and the sessions were recorded on video and audio and transcribed at a later time. In the beginning of the sessions, the moderator explained the topic of the thesis briefly including a quick overview of the data gathering and discussed the main findings form the earlier user and spectator surveys and findings. The session then started based with 10 minutes allocated to each theme. Before the discussion of the design guideline theme, the moderator went through a quick summary of the session to remind everyone of the topics discussed. The most important discussions of the sessions were transcribed and analyzed using content analysis with Microsoft Excel.

Each Co-creation session included 3 participants and a moderator. Each participant had the chance to use the VR device while we discussed the guidelines and important aspects following a set of themes referring to the original hypothesized factors earlier. The aim of the sessions was to answer the RQ3.

Code	Field	Focus area	Working role	Session
E1	User Experience	Human centered robotics	Research assistant	1
E2	Human Technology Interaction	Interaction design	Doctoral student	1
E3	User Experience	Human centered robotics	Research assistant	1
E4	Human Technology Interaction	UX Research	Research assistant	2

E5	User Experience	Human centered robotics	Research assistant	2
E6	User Experience	UX research	Doctoral student	2
E7	Human Technology Interaction	UX design	Research assistant	3
E8	Software Engineering	IoT platforms	Project researcher	3
E9	Software Engineering	360-degree videos	Doctoral student	3

Table 4.1 Expert participant summary

Table 4.1 is a summary of the experts who participated in the co-creation sessions along with a unique code given to each participant, their field of study, their focus area, working role, and the session they participated in.

4.3.3 Findings

The findings of interaction theme of the discussion topics suggest that socially acceptable interaction depends mostly on the context it is used in addition to the type of VR experience. However, any form of interaction that is socially unacceptable in general should be avoided when designing VR experiences. Some examples of socially unaccepted forms of interaction are waving the hands too much, unintentional punching and touching, dancing, funny movements, jumping, weird hand gestures and screaming. Additionally, there is no single input device that is considered socially acceptable but rather a variety of input devices that mostly target minimizing movements such as the user's tongue, straws similar to the ones used in wheelchairs, eye gaze, hip trackers, step trackers, wristbands, and gloves.

An important aspect discussed was the conveyance of privacy to the others. E7 mentioned that *"psychologically, it would be better if I knew that I was not being recorded, even if it was not true"*. The conveyance of the non-recoding message could be as simple as covering the device camera or sharing the screen of the user with the spectators or other methods. For instance, E8 suggested *"if the VR devices or mobiles had some form of old-school type of red light that signifies recording"*. In terms of safety, the VR user must have some form system in place for avoiding bumping into people and objects around. One method could be in the form of sensors. E3 mentioned *"the first thing that came to my mind is a proximity sensor like the ones you get in cars that beep when you get close to obstacles"*. Some of the other methods discussed were an MR style of scanning the environment, a 360-camera showing the surrounding to the user, projecting the zone of interaction on the floor, or even using a chair as a zone of interaction.

The finding of the topic of user being isolated from the others in the context suggest sharing the user screen either on external screens or viewing it directly from their own devices by scanning a QR code. Similarly, in order to communicate with the user, the spectators could use the same QR code and a standalone chat service on their devices. The user will also have the same chat session showing in the virtual world without breaking their sense of immersion. Some other suggestions for communication between spectators and VR users were a form of walkie-talkie, a form of Like Button similar to Facebook, and a way of inducing adjustable electric shock to the user similar to those on some smart watches. Alternatively, the presence of a pre-determined moderator such as a friend can be an easy solution for using VR in the presence of others to facilitate communication and avoiding unwanted situations.

When discussing the design guidelines of socially acceptable VR, there was a total of 26 items discussed that cover the themes of *movements and interaction, safety, communication, and privacy.* After categorization and retraction of repeated and out of scope items of the items the design guidelines presented in the results section of this thesis were formed.

5. RESULTS

This chapter presents the main results of the research in this thesis. This chapter has two sections. The first section presents the influential experiential factors in social acceptability of VR from the perspective of the users and spectators. The factors are presented based on earlier work and from the main findings of the user and spectator interviews, surveys, and observations. The second section presents design guidelines in designing for social acceptability of VR. The design guidelines presented are based on the insights and understandings gained throughout the co creation sessions with the experts.

5.1 Experiential Factors

The experiential factors presented are divided based to previous work done by Hassenzahl et al. (2013) that defines six set of needs that are suitable to be used in experience design as follows. *Autonomy* refers to a feeling of being in control and causing your own actions rather than outside influence. *Competence* is the feeling of capability and being able to effectively do your actions. *Relatedness* is the way you feel about people caring for you and having contact with them. *Popularity* is the feeling of being liked and respected in addition to being influential. *Stimulation* is about enjoying the moment and getting a pleasurable experience. Finally, *security* is the feeling of safety and being in control of the situation (Hassenzahl et al., 2013). We look at the perspective of both users and spectators in the below subsections.

5.1.1 User

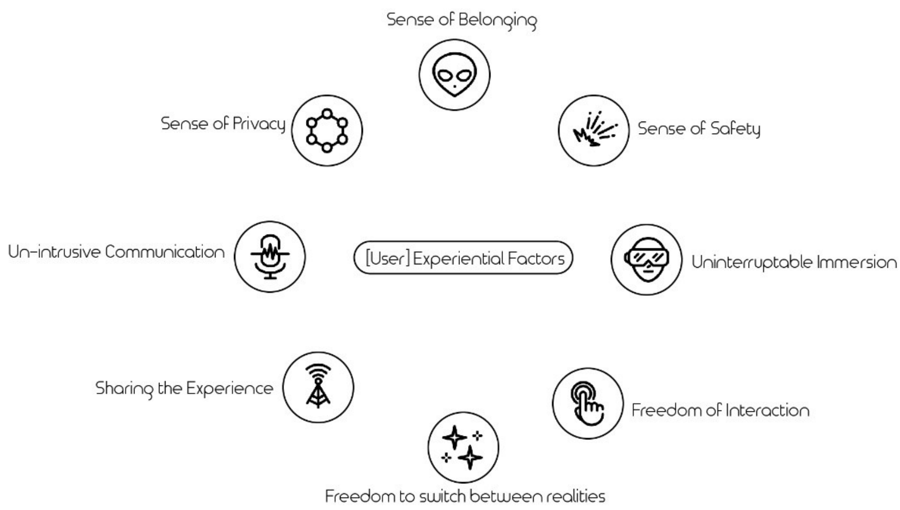


Figure 5.1 User experiential factors

From the perspective of the users of VR devices in public context of a university, we have found that the following are the influential experiential factors that can affect the social acceptability. The factors were the result of the interviews, surveys, and observations of the users after the user test sessions. The following experiential factors have been dvided according to earlier work by Hassenzahl (2013) described in the beginning of section 5.

Autonomy

Freedom of interaction - User needs to be able to have freedom to choose a more discrete method for their interaction. VR users should be given the freedom to choose between normal interaction mode and a more public friendly interaction mode that would require smaller movements or alternative interaction method that would be less obvious to the spectators around.

Uninterruptable Immersion - User needs to enjoy the VR experience without being interrupted by outside noise. When the user is immersed using the VR, one of the factors that can break the experience is noise coming from the real world. The user has to be isolated from the outside world and not thinking about stimuli that is generated from outside the virtual world.

Un-intrusive communication - User needs to be able to have a communication channel with the outside while not losing their sense of immersion. The users must be aware that during their VR experience, anyone can approach them and start a discussion without being intrusive and breaking their immersion which affects their VR experience.

Freedom to switch between realities - User needs to switch between the real world and the virtual world at will. By providing the users with the opportunity to leave the VR world shortly and peek at the outside world, the users can ensure of their surroundings at will and have a better VR experience in public context.

Security

Sense of safety - User needs to feel safe during VR use in public context. Perhaps the most important factor that can make or break the experience of any VR user is the feeling of safety. The moment the VR user feels unsafe such as hitting people or objects while using the VR they can have doubts and interrupt their experience to ensure that won't happen.

Sense of privacy - User needs to have a private space during VR use in public context. Even being in the most public places, we need our private area, no matter how limited or small it may be. Privacy is a particularly important aspect to the VR user to ensure that they have enough of it to be able to use their VR device with no hesitation. This includes both situations of seated or standing VR use.

Popularity

Sharing the experience - User needs to be able to share their VR experience with the others present in the context. By providing the opportunity to the VR user to share their screen with the outside world, they can enjoy their VR experience more by knowing that the people around focus on the game play or visuals rather than focusing on the user.

Relatedness

Sense of belonging - User needs to have a sense of belonging to a group of VR users and not isolated. If VR users get to see other using VR devices, they will be motivated to use their devices as well and will not feel that they would stand out since the people around will not be concentrating on looking at one person but rather the group. If there are designated VR spaces that provides the required necessities to users, it would make public VR use a more enjoyable experience.

5.1.2 Spectator

From the perspective of those spectating others using VR devices in public context of a university, we have found that the following are the influential factors that can affect the social acceptability. The following experiential factors have been divided according to earlier work by Hassenzahl (2013) described in the beginning of section 5.

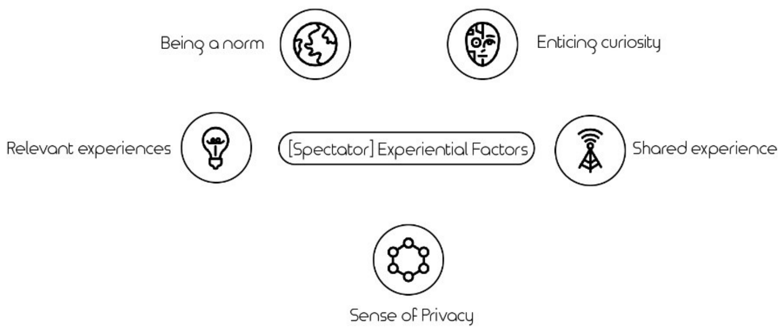


Figure 5.2 Spectator experiential factors

Stimulation

Shared experience – Spectators need to see the same screen of the VR user to make sense of the movements and share the experience with the user. By providing the opportunity to see the VR user's screen, the spectators can get a sense of sharing the same experience as the user and be able to make sense of movements that the user makes.

Enticing curiosity – People get curious when they see another person using VR, which can be extremely helpful in motivating them to try to use similar devices themselves if offered in public spaces. This effect can be enhanced by being able to see what the user is seeing.

Relevant experiences – If the experiences offered in the public context are relevant to the context and can be beneficial to the spectators, they would be more willing to user it and accept it. For instance, a historical site that transfers the user back in history while they are situated there.

Relatedness

Being a norm – Once people start seeing VR devices used in public context and it becomes the equivalent of using a smartphone, using VR can feel natural and the feeling of awkwardness can slowly fade away.

Security

Sense of privacy – Those not using the VR should not feel their privacy is jeopardized at any time; they need to be aware that they are not recorded by the device and ensure their privacy.

5.2 Design Guidelines

The following design guidelines were compiled after reviewing the co-creation sessions in addition to the field test observations and findings from the users and spectators. The guidelines are in line with standards of Interaction Design Foundation (Interaction Design Foundation, n.d.).

The design guideline intended to be used as a reference at any point by designers during the design process or to evaluate their VR experiences. In total there are 11 items across six themes of *content*, *movement and interaction, safety, communication, connectedness, and privacy*. Other than content which are the general of VR content, the guidelines reflect the central factors descried in section 2 and address the experiential factors of the users and spectators described earlier in section 5 (Table 5.1). By adhering to these guidelines, the social acceptability of VR is increased, and both the users and spectators can have a positive experience.

Design Guideline	**User Experiential Factor**	**Spectator Experiential Factor**
Movement and interaction	Freedom of interaction	Relevant experiences
Safety	Sense of safety Freedom to switch between realities	
Communication	Un-intrusive communication	
Connectedness	Sharing the experience Sense of belonging Un-interruptible immersion	Enticing curiosity Shared experience
Privacy	Sense of privacy	Sense of privacy

Table 5.1 Design guidelines addressing experiential factors

5.2.1 Content

1. *Check for public suitability of VR experience features* - An most important element to remember is that the experience is going to be used in public. By referring to the simple question of "*is it suitable for public context?*" every little feature, element, and detail of the experience can be evaluated individually and based on the answer is it can either be accepted, iterated, or rejected.
2. *Avoid unsuitable public VR content* – VR experiences targeted to be used in public context should not contain inappropriate images and scenery such as gore, violence, and nudity since there will be others available in the context and a possibility of sharing the screen. Suitable content for VR are those that allow the users to explore locations, visit historical places, and going back in time virtually.

5.2.2 Movement and Interaction

3. *Define a VR interaction zone* – By defining the VR interaction zone physically, it would allow the users to use the device in those specific locations. This form of zone can be defined in areas such as shopping malls, museums, exhibitions, universities, and parks that have VR experiences specific to that place. In other public context, a virtual barrier can be set to show the physical zone of interaction in the virtual world.
4. *Allow a public interaction mode* – The user needs to be able to choose a mode of interaction that is specific to public context and would allow a more discrete form of interaction. This can include minimizing the movements and scaling down the interaction or having an alternative form of interaction such as single button pressing on the controller and gaze tracking that would enable the user to stand or sit still in a public context. The public interaction mode needs to explicitly explained to the user every time the user choses the mode.

5.2.3 Safety

5. *Define and present safety guidelines virtually* – Every time the user starts the experience, basic safety guidelines must be shown to the user and reminding her about the fact that the interaction is in public. Some items can be as: ensure the environment is safe to use, the floor is flat with no obstacles in the vicinity, the user has her carry-ons safely placed on her, and the availability of public interaction mode.
6. *Allow user to freely switch between realities* – The user needs to be able to freely switch the VR view to the real world to see the surroundings and be able to re adjust her location as needed. This reality can be in a non-intrusive manner such as a screen to the real world in the VR world.

7. *Actively warn users of collision with objects* – Warn the users in case they are going to bump the users or objects that they are unable to see. Using methods such as camera detection, sensors or others means warn the users if there is an object or a person in the vicinity.

5.2.4 Communication

8. *Allow un-intrusive communication from the real world* – The spectators should be able to communicate with the user without breaking their sense of immersion and the need to take the HMD off. There can be an active chat application running in the VR that would allow those spectating to call the user virtually and appear in their world as a form of an avatar and communicate with them. A QR code can be displayed on the front of the device to allow access from outsiders to the VR chat.

5.2.5 Connectedness

9. *Allow the user to share their screen* – The user needs to be able to share their screen with those around for a shared experience. This can be achieved using techniques such as casting or streaming the experience on platforms and website such as YouTube and Twitch and printing a QR code that will direct the spectators to the link to watch the experience on their own devices.
10. *Allow auto volume adjusting* – The user should be provided with an option that allows them to set an auto volume adjusting which increases the volume as the environment noise increases, this can be extremely helpful as loud outside noise can cause a break in the sense of immersion.

5.2.6 Privacy

11. *Convey that the camera is not recording* – To ensure that the privacy of the others in the context, the message that the user is not recording should somehow be conveyed across. One method could be using a red recording sign that lights on the VR headset that lights up if the user is recording the real-world environment.

6. DISCUSSION AND CONCLUSIONS

This chapter summarizes the thesis and studies conducted, how the research questions were answered, discussion of novelty, lessons learned, and possible future work on the subject.

6.1 Summary of Findings

By conducting a field study consisting of 10 VR users in a public context of a university, we identified what the users considered as influencing factors in their experience. In addition of interviews post the user test sessions and observations, the users gave their input to a survey adapted from earlier studies. After analysis, the findings suggest that from the perspective of VR users, the influential factors of social acceptability of VR are f*reedom of interaction*, *uninterruptable immersion*, *un-intrusive communication, freedom to switch between realities, sense of safety, sense of privacy, sharing the experience* and *sense of belonging*. (RQ1)

By conducting a second field study consisting of 30 spectators of a VR users in a public context of a university, we identified what the spectators considered as influencing factors in their experience. The spectators gave their input to a mirroring survey of the users from their own perspectives. After analyzing the data, we have come to the conclusion that from the perspective those spectating VR users, the influential factors of social acceptability of VR are *shared experience*, *enticing curiosity*, *relevant experiences, being a norm*, *sense of privacy.* (RQ2)

From a standpoint of designing for socially acceptable VR experiences, we have identified a set of design principles that can be used as a reference point. By adhering to the guidelines, the social acceptability of VR can be enhanced and the users as well as others in the same context can mutually benefit. The guideline includes 11 items across six categories of *content*, *movement and interaction, safety, communication, connectedness, and privacy.* The list includes items as follow. *Check for public suitability of features, define a VR interaction zone, allow public interaction mode, avoid unsuitable content, define safety guidelines virtually, allow user to freely switch realities, actively warn users of collision with objects, allow un-intrusive outside communication, allow user to share their screen, allow auto volume adjust,* and *convey that the camera is not recording.* (RQ3)

6.2 Discussion

With the rapid expansion of VR into various fields and the greater sense of immersion created with the latest VR devices, along with the lowered cost for buyers and availability in mobile forms, the use of VR in public context in the future seems inevitable. The lack of clear guidelines for public VR provides a gap that needs to be filled to create pleasing VR experiences that are acceptable in the public context.

Earlier research (Profita et al., 2016) and (Schwind et al., 2018b) evaluated social acceptability of VR based on the person wearing the device and the context the device was used by conducting online questionnaires. Our approach to the social acceptability of VR was conducting field research based on those earlier work in a public context with a real VR user interacting with the device and real spectators in the context giving their feedback. While we adapted from the earlier studies, our study extends the earlier research and we have shown the influencing factors of social acceptability of VR from the perspective of those using the it and the others spectating.

Furthermore, as of the time of the writing of this thesis, there are no clear design guidelines or principles that focus on designing for social acceptability of VR. Our goal was to present a set of guidelines that can be used as an aiding tool for those aiming to create VR experiences that are going to be used in public context.

The results of the research provide a set of guidelines that can be used as a reference point when designing public VR experiences to avoid issues that were already discovered. Referring to the guidelines can help designers save time, money, and avoid potential mishaps in the future. As of the writing of this thesis there has not been any such guidelines written and to our knowledge this is the first research that has approached social acceptability of VR in this manner. Additionally, researchers can benefit from the results of this thesis to conduct their own field studies and evaluate their concepts and work.

While the results of this thesis have managed to reach the goals set earlier, we can identify some limitations to this work. The public context chosen for our study was a technical university with students who are familiar with VR technology, and his could have affected the results and skew them to one side of the spectrum. Another limitation is the limited number of contexts, users, and spectators involved in the research study. Ideally, the study needs to be conducted in multiple public context such as shopping malls, parks, and other public locations and each context needs to be individually evaluated for social acceptability. A larger number of users and spectators also can ensure that the results are valid, and the results can be applied to the general population. Finally, due to the limited qualitative data from the spectators, the spectator factors defined are not as complete as the user factors and the insights are not as in-depth or detailed.

6.3 Lessons Learned

Throughout this thesis, we faced some challenges. Below are some of the challenges we faced, and some of the lessons that could help in future research process.

Iteration - The first version of the work is only followed by the second version, followed by the third, and so on and so forth. You may need to iterate your work repeatedly and keep changing details in the process. Sometimes you may need to revamp your work entirely and reshape the way the information is presented. Sometimes you need to redo a step from scratch. At some point after getting the first set of spectator surveys, we found out that there was not enough qualitative data and hence we repeated the process by updating the surveys and redoing the entire test session for the 30 spectators again including the data entry.

Research into the research – It is crucial to do comprehensive research before taking your next step. While it may seem obvious, it will be forgotten at times. In order to conduct our field surveys, we found out that simply approaching and asking people to fill surveys was not enough and a lot of people would simply say they have no time. Therefore, after doing some research into conducting street surveys, we figured that the best method was to actually engage with them and ask their opinion on the matter. Once we had a short conversation and they felt they could contribute, filling the surveys was easy.

Ask the experienced – At some point you may start to ask questions from yourself and wonder if you are even on the right path. This is where showing your work to a colleague who has some experience in the field goes a long way. They can give you their impressions and let you know if anything is out of place.

6.4 Future Work

While our research findings suggest positively towards social acceptability of VR, it is somewhat limited to technical context such as a university. An extension of this research is to take the field tests into other public context that contains a wider array of spectators, which may even include those not familiar with VR technology at all. For this purpose, we suggest a few public contexts that were suggested by our respondents and conduct test sessions with more users in each scenario. The VR experiences should also match the context. The following context are some suggestions that include the relevant experiences as well.

Museum – Creating a VR experience in a museum that allows the visitors to virtually be present in the scene and interact with the different elements.

Historical Site – At a historical site such as an old factory, the visitors can travel back in time and experience the same location decades ago.

Cinema – The cinema lobby provides a perfect opportunity to setup VR for movie trailers where visitors can watch short trailers of movies before purchasing their tickets.

Shopping Mall - When promoting an experience such as a vacation package to Hawaii in a shopping mall, a VR experience to allow the visitor to virtually visit the beaches and hear the waves before making their purchase decision.

In addition, the public VR guidelines discussed in this thesis can be refined by involving professionals in the field. To achieve this, we suggest approaching startups and companies active the field of VR for detailed discussion and iterating the guideline items after receiving input from multiple VR experts. Furthermore, we can test the ideas of the design guidelines by implementing them and identifying the validity of each item.

6.5 Conclusions

The findings of the studies in this thesis suggest that it is socially acceptable to use VR devices in a public context such as a university and a majority of users and spectators do not find it as awkward or rude to use the technology. Furthermore, we found out that while it may feel a little out of place and awkward at first, once a user starts the VR experience, he or she will forget about the others present and will start to enjoy the sense of being in a virtual location while in the same place as others. The findings also suggest that users will feel safe even in a public space provided they have a zone of interaction that is predefined and helps avoiding contact with other people present.

In terms of the spectators, we found out that in a technical location such as a university, VR users do not easily distract passersby. Even if those walking in the context notice someone using VR, they do not get shocked and do not feel it is rude of the person to user the device. Even those who consider the VR user as awkward can change their perspective after a few moments and getting used to the scene. Additionally, we believe that sharing the user's screen with the spectators will increase the chances of acceptability in addition to motivating VR use as well and be beneficial to both the users and the other people around.

Finally, the results suggest that both the users and spectators find using VR devices in public places such as cinemas, educational institutes, parks, tourist attraction, shopping malls, and conferences interesting and thus it may be more socially acceptable to use VR devices in these types of context.

The research conducted in this thesis, the findings, and the design guidelines can help future designers and researchers create public VR experiences that take into account the viewpoints of those using the VR in public as well as to those observing the users. Furthermore, the designers and researchers can have a better idea of experiential factors from the perspective of VR users and the other people around them and ensure that they can match those factors.

REFERECES

ABI Research. (2017). ABI Research's First VR and 360-Degree Video Tracker Identifies More than 460 Companies in the Markets. Retrieved June 12, 2018, from https://www.abiresearch.com/press/abi-researchs-first-vr-and-360-degree-video-tracke/

Anthes, C., Garcia-Hernandez, R. J., Wiedemann, M., & Kranzlmuller, D. (2016). State of the art of virtual reality technology. In *2016 IEEE Aerospace Conference* (pp. 1–19). IEEE. https://doi.org/10.1109/AERO.2016.7500674

Benbouriche, M., Nolet, K., Trottier, D., & Renaud, P. (2014). Virtual reality applications in forensic psychiatry. *Proceedings of the 2014 Virtual Reality International Conference on - VRIC '14*, 1–4. https://doi.org/10.1145/2617841.2620692

Buenaflor, C., & Kim, H.-C. (2013). Six Human Factors to Acceptability of Wearable Computers. *International Journal of Multimedia and Ubiquitous Engineering*, *8*(3).

Canalys. (2017). Media alert: Virtual reality headset shipments top 1 million for the first time | Canalys. *Canalys Newsroom*, (November). Retrieved from https://www.canalys.com/newsroom/media-alert-virtual-reality-headset-shipments-top-1-million-first-time

CB Insight. (2017). Beyond Gaming: 13 Industries AR/VR Is Poised To Transform. Retrieved June 26, 2018, from https://www.cbinsights.com/research/ar-vr-industries-disrupted-beyond-gaming/

Chan, L., & Minamizawa, K. (2017). FrontFace. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services - MobileHCI '17* (pp. 1–5). ACM Press. https://doi.org/10.1145/3098279.3098548

Chavan, S. R. (2016). Augmented Reality vs. Virtual Reality: Differences and similarities. *International Journal of Advanced Research in Computer Engineering & Technology*, *5*(6), 2278–1323.

Cheung, G., & Huang, J. (2011). Starcraft from the stands. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11* (p. 763). https://doi.org/10.1145/1978942.1979053

De La Peña, N., Weil, P., Llobera, J., Giannopoulos, E., Pomes, A., Spanlang, B., … Slater, M. (2010). Immersive Journalism: Immersive Virtual Reality for the First Person Experience of News. *Presence: Teleoperators and Virtual Environments*, *19*(4), 291–301. https://doi.org/doi: 10.1162/PRES_a_00005

Denning, T., Dehlawi, Z., & Kohno, T. (2014). In situ with bystanders of augmented reality glasses. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14* (pp. 2377–2386). ACM Press. https://doi.org/10.1145/2556288.2557352

Dierk, C., & Paulos, E. (2018). Wearables Should Transcend Cultural Norms and Practices. *Chi 2018*.

Distler, V., Lallemand, C., & Bellet, T. (2018). Acceptability and Acceptance of Autonomous Mobility on Demandd: The Impact of an Immersive Experience. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, 1–10. https://doi.org/10.1145/3173574.3174186

Donalek, C., Djorgovski, S. G., Cioc, A., Wang, A., Zhang, J., Lawler, E., … Longo, G. (2014). Immersive and collaborative data visualization using virtual reality platforms. In *2014 IEEE International Conference on Big Data (Big Data)* (pp. 609–614). IEEE. https://doi.org/10.1109/BigData.2014.7004282

Downs, J., Vetere, F., & Smith, W. (2015). Differentiated Participation in Social Videogaming. *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI '15*, 92–100. https://doi.org/10.1145/2838739.2838777

Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y. L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction. In *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC 2014* (pp. 4159–4162). IEEE. https://doi.org/10.1109/EMBC.2014.6944540

Earnshaw, R. . (1993). *Virtual Reality Systems*. Academic Press.

Edwards, C. (2003). Wearable Computing Struggles for Acceptance. Technology: the ultimate fashion item? *IEE Review*, 24–25.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Finke, M., Tang, A., Leung, R., & Blackstock, M. A. (2008). Lessons Learned: Game Design for Large Public Displays. In *International Conference on Digital Interactive Media in Entertainment and Arts* (pp. 26–33). New York, New York, USA: ACM Press. https://doi.org/10.1145/1413634.1413644

Goodman, J., Brewster, S., & Gray, P. (2004). Using field experiments to evaluate mobile guides. *Proceedings of HCI in Mobile Guides, Workshop at Mobile HCI 2004*, *44*(September).

Gugenheimer, J., Stemasov, E., Frommel, J., & Rukzio, E. (2017). ShareVR. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17* (pp. 4021–4033). ACM Press. https://doi.org/10.1145/3025453.3025683

Hassenzahl, M., Eckoldt, K., Diefenbach, S., Laschke, M., Lenz, E., & Kim, J. (2013). Designing moments of meaning and pleasure. Experience design and happiness. *International Journal of Design*, *7*(3), 21–31.

Hsieh, Y.-T., Jylhä, A., Orso, V., Gamberini, L., & Jacucci, G. (2016). Designing a Willing-to-Use-in-Public Hand Gestural Interaction Technique for Smart Glasses.

Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16, 4203–4215. https://doi.org/10.1145/2858036.2858436

Interaction Design Foundation. (n.d.). Design Guidelines. Retrieved November 10, 2018, from https://www.interaction-design.org/literature/topics/design-guidelines

Ishii, A., Tsuruta, M., Suzuki, I., Nakamae, S., Minagawa, T., Suzuki, J., & Ochiai, Y. (2017). ReverseCAVE experience. In *SIGGRAPH Asia 2017 VR Showcase on - SA '17* (pp. 1–2). ACM Press. https://doi.org/10.1145/3139468.3139482

ISO. (2010). ISO 9241-2010. Ergonomics of human-system interaction. Human-centred design for interactive systems. Retrieved June 18, 2018, from https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-1:v1:en

Jdid, F., Richir, S., & Lioret, A. (2013). Virtual stage sets in live performing arts (from the spectator to the spect-actor). *Proceedings of the Virtual Reality International Conference on Laval Virtual - VRIC '13*, 1. https://doi.org/10.1145/2466816.2466840

Jerald, J. (2016). *The VR Book: Human-Centered Design for Virtual Reality*. *ASA Refresher Courses in Anesthesiology*. Association for Computing Machinery and Morgan & Claypool.

Keylly, N. (2018). My Device, My Self: Wearables as a Specific Case of the Social Acceptability of Technology. *Chi 2018*.

Koelle, M., Kane, S., Olsson, T., Mitchell, R., & Williamson, J. (2018). (Un)Acceptable !?! – Re-thinking the Social Acceptability of Emerging Technologies. *Chi 2018*. https://doi.org/10.1145/3170427.3170620

Law, E., Roto, V., Vermeeren, A. P. O. S., Kort, J., & Hassenzahl, M. (2008). Towards a ahared definition of User Experience. *CHI 2008 Proceedings - Special Interest |Groups*, 2395–2398. https://doi.org/10.1145/1358628.1358693

McGrath, J. L., Taekman, J. M., Dev, P., Danforth, D. R., Mohan, D., Kman, N., Bond, W. F. (2018). Using Virtual Reality Simulation Environments to Assess Competence for Emergency Medicine Learners. *Academic Emergency Medicine*, *25*(2), 186–195. https://doi.org/10.1111/acem.13308

Merel, T. (2018). Record over $3B AR/VR investment in 2017 ($1.5B+ in Q4). Retrieved June 12, 2018, from http://www.digi-capital.com/news/2018/01/record-over-3b-ar-vr-investment-in-2017-1-5b-in-q4/

Miner, C., Chan, D., & Campbell, C. (2001). Digital jewelry: wearable technology for everyday life. *Extended Abstracts on Human Factors in Computing Systems*, 45–46. https://doi.org/10.1145/634067.634098

Mottelson, A., & Hornbæk, K. (2017). Virtual reality studies outside the laboratory. *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology - VRST '17*, *10*, 1–10. https://doi.org/10.1145/3139131.3139141

Murdoch, C. (2017). VR has finally found its place: porn. Retrieved June 28, 2018, from https://mashable.com/2017/10/06/vr-porn-statistics/?europe=true#WNddU_8cD5qU

Nah, F. F. H., Eschenbrenner, B., Zeng, Q., Telaprolu, V. R., & Sepehr, S. (2014). Flow in gaming: literature synthesis and framework development. *International Journal of Information Systems and Management*, *1*(1/2), 83–124. https://doi.org/10.1504/IJISAM.2014.062288

Naz, I., Bashir, R. S., & Alam, K. A. (2017). Measuring the Impact of Changing Technology in Mobile Phones on User Device Interaction Based on a Qualitative Survey. *ICEEG '17*. https://doi.org/10.1145/3108421.3108427

Norman, D., & Nielsen, J. (2016). The Definition of User Experience (UX). *Nielsen Norman Group Publication*. Retrieved from https://www.nngroup.com/articles/definition-user-experience/

Oculus. (n.d.). Health & Safety Before Using the Headset. Retrieved from https://www.oculus.com/legal/health-and-safety-warnings/

Olshannikova, E., Olsson, T., & Huhtamäki, J. (2018). Perspectives to Social Acceptability Issues in Professional Social Matching Systems Background and Motivation. *Chi 2018*.

Peter Morville. (2004). User Experience Design. Retrieved June 18, 2018, from http://semanticstudios.com/user_experience_design/

Pohl, D., & De Tejada Quemada, C. F. (2016). See what i see: Concepts to improve the social acceptance of HMDs. In *Proceedings - IEEE Virtual Reality* (Vol. 2016–July, pp. 267–268). IEEE. https://doi.org/10.1109/VR.2016.7504756

Profita, H., Albaghli, R., Findlater, L., Jaeger, P., & Kane, S. K. (2016). The AT Effect: How Disability Affects the Perceived Social Acceptability of Head-Mounted Display Use. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 4884–4895. https://doi.org/10.1145/2858036.2858130

Reddivari, S., Smith, J., & Pabalate, J. (2017). VRvisu: A Tool for Virtual Reality Based Visualization of Medical Data. *Proceedings - 2017 IEEE 2nd International Conference on Connected Health: Applications, Systems and Engineering Technologies, CHASE 2017*, 280–281. https://doi.org/10.1109/CHASE.2017.102

Reuters. (2018). Virtual Reality (VR) in Gaming Market 2018 Leaders: Electronic Arts, Google, HTC, Oculus VR, Kaneva, Samsung, Sony, Leap-Motion. Retrieved June 28, 2018, from https://www.reuters.com/brandfeatures/venture-capital/article?id=32714

Rico, J., & Brewster, S. (2010). Usable gestures for mobile interfaces. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10* (p. 887). New York, New York, USA: ACM Press. https://doi.org/10.1145/1753326.1753458

Ries, B., Interrante, V., Kaeding, M., & Anderson, L. (2008). The effect of self-embodiment on distance perception in immersive virtual environments. *Proceedings of the 2008 ACM Symposium on Virtual Reality Software and Technology - VRST '08*, 167–170. https://doi.org/10.1145/1450579.1450614

Rizzo, A., Cukor, J., Gerardi, M., Alley, S., Reist, C., Roy, M., … Difede, J. A. (2015). Virtual Reality Exposure for PTSD Due to Military Combat and Terrorist Attacks. *Journal of Contemporary Psychotherapy*, *45*(4), 255–264. https://doi.org/10.1007/s10879-015-9306-3

Sakai, T., & Tetsuya. (2016). Two Sample T-tests for IR Evaluation. In *Proceedings of the 39th International ACM SIGIR conference on Research and Development in Information Retrieval - SIGIR '16* (pp. 1045–1048). New York, New York, USA: ACM Press. https://doi.org/10.1145/2911451.2914684

Samsung. (n.d.). Gear VR Controller | VR Hand Controller | Samsung UK. Retrieved July 11, 2018, from https://www.samsung.com/uk/mobile-accessories/gear-vr-controller/

Sanders, E. B.-N., Brandt, E., & Binder, T. (2010). *A framework for organizing the tools and techniques of participatory design*. *Proceedings of the 11th Biennial Participatory Design Conference on - PDC '10*. https://doi.org/10.1145/1900441.1900476

Schwind, V., Reinhardt, J., Rzayev, R., Henze, N., & Wolf, K. (2018a). On the Need for Standardized Methods to Study the Social Acceptability of Emerging Technologies. *Chi 2018*.

Schwind, V., Reinhardt, J., Rzayev, R., Henze, N., & Wolf, K. (2018b). Virtual reality on the go? *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - MobileHCI '18*, 111–118. https://doi.org/10.1145/3236112.3236127

Shin, D. (2018). Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? *Computers in Human Behavior*, *78*, 64–73. https://doi.org/10.1016/j.chb.2017.09.012

Silver, C. (2017). How VR Porn Is Penetrating Our Minds, Erecting The Future Of Virtual Reality. Retrieved June 28, 2018, from https://www.forbes.com/sites/curtissilver/2017/05/11/how-vr-porn-is-penetrating-our-minds-erecting-the-future-of-virtual-reality/

Sirkkunen, E., Väätäjä, H., Uskali, T., & Rezaei, P. P. (2016). Journalism in virtual reality. *Proceedings of the 20th International Academic Mindtrek Conference on - AcademicMindtrek '16*, 297–303. https://doi.org/10.1145/2994310.2994353

Sony. (n.d.). PlayStation Move motion controller | More Ways to Play | PlayStation. Retrieved July 11, 2018, from https://www.playstation.com/en-ae/explore/accessories/playstation-move-motion-controller/

Sony Computer Entertainment Inc. (2016). Playstation®Vr Launches October 2016 Available Globally At 44,980 Yen, $399 Usd, €399 and £349. Retrieved June 27, 2018, from https://www.playstation.com/en-us/corporate/press-releases/2016/playstation-vr-launches-october-2016-available-globally-at-44980-yen-399-usd-399-and-349/

Sony Computer Entertainment Inc. (2017). Playstation 4 Sales Surpass 70.6 Million Units Worldwide. Retrieved June 27, 2018, from https://www.playstation.com/en-us/corporate/press-releases/2017/playstation-4-sales-surpass-70-million-units-worldwide/

Tham, J., Duin, A. H., Gee, L., Ernst, N., Abdelqader, B., & McGrath, M. (2018). Understanding Virtual Reality: Presence, Embodiment, and Professional Practice. *IEEE Transactions on Professional Communication*. https://doi.org/10.1109/TPC.2018.2804238

Van Wyk, E., & De Villiers, R. (2009). Virtual reality training applications for the mining industry. In *Proceedings of the 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa - AFRIGRAPH '09* (p. 53). New York, New York, USA: ACM Press. https://doi.org/10.1145/1503454.1503465

Vive. (n.d.). VIVE | Controller. Retrieved July 11, 2018, from https://www.vive.com/eu/accessory/controller/

William R. Sherman, A. B. C. (2002). *Understanding virtual reality: Interface, application, and design. Elsevier*. Elsevier.

Wobbrock, J. O., & Kientz, J. A. (2016). Research contribution in human-computer interaction. *Interactions*, *23*(3), 38–44. https://doi.org/10.1145/2907069

Zajtchuk, R., & Satava, R. M. (1997). Medical applications of virtual reality. https://doi.org/10.1145/260750.260768

APPENDICES

Appendix A – Survey Questions in Earlier Research

Statements about the interaction:

1. It looked awkward when this person was using the wearable computing device. (Awkward)
2. It looked normal when this person was using the wearable computing device. (Normal)
3. It was appropriate for this person to use the wearable computing device in this setting. (Appropriate)
4. It was rude for this person to use this wearable computing device. (Rude)
5. I felt uncomfortable watching this person use the wearable computing device. (Uncomfortable)
6. I would be distracted by this person if I were at the bus stop with them. (Distracting)

Statements about the user:

7. This person seemed independent. (Independent)
8. This person needed help. (Need Help)
9. This person needed the wearable computing device. (Need Device)
10. This person looked cool. (Cool)
11. This person looked nerdy. (Nerdy)

Statements about the device:

12. The wearable computing device seemed useful. (Useful)
13. The wearable computing device seemed unnecessary. (Unnecessary)

Source: **Profita et al., 2016**

Appendix B - User Survey Questions

Statements about public VR:

1. It felt appropriate to use the VR headset in a public place. (Appropriate)
2. It felt rude to use this VR headset in a public place. (Rude)
3. It felt uncomfortable being watched by others while using the VR in a public place. (Uncomfortable)

Statements about the user:

4. I think the VR headset makes me look cool. (Cool)

Statements about communication:

5. It would be useful for me if the people around me could communicate with me. (useful)

Statements about the interaction:

6. It felt awkward doing head movements while using VR in public. (awkward head movements)
7. It felt awkward performing body movements and hand gestures while using VR in public. (awkward body and hand movements)

Statements about isolation:

8. I did not like the fact that I was isolated from the rest of the people in a public space. (isolation)
9. It would be interesting if the other people could see what I was doing and seeing in the VR (screen sharing)

Statements about the privacy and safety:

10. I was concerned about spectators recording me while using VR in public. (privacy concern)
11. I was concerned about bumping to objects and people while using the VR in public. (safety concern)

Appendix C - Spectator Survey Questions

Statements about public VR:

1. It is appropriate for this person to use the VR headset in public places. (Appropriate)
2. It is rude for this person to use this VR headset. (Rude)
3. I feel uncomfortable watching this person use the VR headset in a public place. (Uncomfortable)

Statements about the user:

4. The person using the VR headset looks cool. (Cool)

Statements about communication:

5. It would be useful for me to communicate with the VR user. (Useful)

Statements about the interaction:

6. I find the head movements of the VR user Awkward. (head movements)
7. I find the body movements and hand gestures of the VR user awkward (body and hand movements)

Statements about isolation:

8. I do not like the fact that VR user is isolated from the rest of us. (isolation)
9. I am curious to see what the VR user is seeing and doing in the virtual world. (scree Sharing)

Statements about the privacy:

10. I am concerned the VR device camera is recording video. (Concerned)

Open Ended Questions:

1. How do you feel about the person using VR in a public space?
2. What do you think of the VR user head movements, body movements, and hand gestures?
3. What kind of applications or experiences would be interesting for VR in a public space?
4. Are you willing to use VR in a public space? Please elaborate
5. What kind of public spaces could benefit from VR experiences? How?

Appendix D – User Interview Questions

1. Have you ever experienced VR in a public space before today's test session?
2. What was your opinion on using VR in public before using it?
3. Did your opinion about using VR in a public space change after the test session?
4. How would you describe your overall experience of VR in public?
5. Can you describe what was positive about your VR experience in public?
6. Can you describe what was negative about your VR experience in public?
7. Would you use VR in a public setting again? Why?
8. What is your opinion on moving your head, body and hands in public while using VR?
9. What kind of applications or experiences would be interesting for VR in a public?
10. What kind of public spaces could benefit from VR experiences?
11. How did the presence of other people affect your VR experience in public space?
12. Would your experience with VR be different in a private space? How?
13. Would you be motivated to use VR in public if you saw others using it?
14. Would sharing your screen with people around make any difference to you? How?

Appendix E – Background Questions

Age (18-23) (24-29) (30-35) (36-41) (41+)

Gender (M/F/Other)

Current Occupation (choose 1) (student / employed / unemployed)

Field of study if student ( ) OR Profession if not a student ( )

I am interested in Virtual Reality (Head Mounted Display devices worn on the head creating a virtual environment): (scale:1-Strongly Disagree to 7-Strongly Agree)

Please circle your choice below

I have experience with VR devices (daily, weekly, sometimes, just once, never)

I have used VR devices in a public space (many times, a few times, never)

I have owned/own a VR device (Y/N)

I use VR for (gaming, non-gaming)

I user VR mostly (alone, with friends, with family)

Email (if you are interested in getting the **results, in capital letters**)

Appendix F – Co-Creation Session Discussion Topics

Theme 1: Interaction (10 mins)

What forms of VR interactions are unacceptable in public context? How could we solve them?

What type of input devices would best suit VR device in public spaces?

Theme 2: Safety (10 mins)

How could those spectating VR use in public spaces feel that their privacy is not violated?

What would be some useful ways to provide a zone of interaction for the VR users ?

Theme 3: Isolation(10 mins)

How would spectators see the VR experience of the user?

How would spectators communicate with VR users?

Theme 4: Design guideline (10 mins)

What would be some design guideline elements based on the above discussions ?

Appendix G – User Test Session Script

INTRODUCTION

Welcome!

My name is Pouya. I am a TUT master student in Information Technology and major is User Experience. Today we are here to do a user testing on a Virtual Reality use in public spaces. It is part of my master thesis work. I will be here from beginning to the end of the test with you with my colleague here as well to assist you during the test sessions.

If you don't mind, I would ask you to put your mobile on silent mode with no vibration for the duration of the test.

PERMISSION TO RECORD THE TEST

Before we move on, please note that test will be recorded on audio and video. This will help us evaluate the system better, and the purpose is to test the system and not your performance.

The recorded video material will be used only to analyze the at a later time if required. The recording maybe used for making video demo purposes at a later time. However, your information will not be shared with anyone.

➔ ***Hand the consent form***

THE PURPOSE OF THE TEST

Have you ever participated in a user testing before?

I will briefly explain it to you, so that you become more familiar with the procedure. I would appreciate your honest, direct, and unbiased feedback. Your contribution will be directly helping in contributing to improvement of similar systems in the future.

Today, we will test using Virtual Reality in a public space.

We are testing the system and not you. Your role is important, as you are here to help us test the system and get your valuable feedback from it.

If you encounter some difficulties during the test, you can stop at any moment and you do not need to provide reasons. You are the priority here and we want to you to be comfortable.

TEST PROCEDURE

Firstly, you will get some time to examine the system during which you may explore and ask questions.

Then you can go ahead and dive into the VR world. After your session, we will have a short discussion and I will get your impressions. My colleague will be with you at all times in case you encounter any issues.

As a reminder, you can stop participating in the test at any time and for any reason, and you don't need to explain the reasons why you quit

Do you have some questions at this point?

BEGIN THE USER TEST

START RECORDING – The recording will start now

VR EXPLORE – *Familiarize the user with the VR headset, Motion Controller, and the VR experience*. You are going to play an interactive game Tomb Raider VR: Lara's Escape. The game is interactive and the controller (**show controller**) will be used as your main interaction point, you will need to use the trigger on the motion controller in points of interest. You may hold down the home button at any time to realign your controller. You can adjust the focus using the ring in front of the VR (**show focus ring**)

START VR EXPERIENCE – Insert Galaxy into VR Device, connect headphones, connect motion controller, hand to the user and after some time looking around the VR home, ask to start the Tomb Raider Application.

SPECTATOR SURVEYS - Identify **spectators (3 – 5 per session)** and approach them in a friendly manner. Spectators are those that take time to look at the VR user and seem amused or have a curious look, they spend more than just a glance.

- Hi, what do you think of VR use in public spaces? (start a short conversation about the topic and engage them in the topic)
- Would you be willing to spend a few minutes in writing your answers down?
- You would be contributing to improvements in public VR devices in the future
- My name is Pouya and I am doing research on the social acceptability of Virtual Reality Devices in public spaces as part of my master thesis.
- I would appreciate your feedback on the matter in filling my short surveys. As a token of appreciation, you can help yourself to a warm cup of coffee and some chocolates.
- You contribution is highly appreciated and will greatly help in improving systems in the future.

➔ Hand in Background Questionnaire and survey – Hand in coffee ticket and chocolate bar and thank them for their time

USER INTERVIEW

Thank you for taking part in testing VR in public spaces. I would like to get your perspective now on your experience to help improve the system design in the future.

➔ ***Interview Paper and write down answers.***
➔ ***User Survey and background questions***

DEBRIEF – END OF INTERVIEW
Do you have some other thoughts or comments that you would like to share?

Thank you very much for participating and I hope you enjoy the movie!

→ ***Hand Movie Ticket***

STOP RECORDING

Appendix H – Co-creation Session Script

INTRODUCTION

Welcome!

My name is Pouya. I am a TUT master student in Information Technology and my major is User Experience. This session is to help my Master's thesis work with the title social acceptability of virtual reality interaction: experiential factors and design implications. Your personal opinions and views are very important and we value your honest feedback. The session is expected to take 75 minutes and you are welcome to have the refreshments here.

If you don't mind, I would ask you to put your mobile on silent mode with no vibration for the duration of the test.

PERMISSION TO RECORD THE TEST

Before we move on, please note that the session will be recorded on audio and video. This will help us evaluate the system better, and the purpose is to test the system and not your performance.

The recorded video material will be used only to analyze the at a later time if required. The recording maybe used for making video demo purposes at a later time. However, your information will not be shared with anyone.

➔ ***Hand the consent form***

THE PURPOSE OF THE CO-CREATION SESSION

The purpose of today's session is to identify important factors in VR usage in public spaces and create a set of guidelines to be used in the future for VR experience designers. You are free to use the device, give feedback or show us what you mean by acting it out. There also paper and pens here that you can use to draw, write, or express your thoughts.

Let's start the discussion, you can start using the VR headset as well and tell us what you think and discuss the implications as well.

- **Theme 1: Interaction**
  - *Q1 What forms of VR interactions are unacceptable in public context? How could we solve them?*
  - *Q2 What type of input devices would best suit VR device in public spaces?*
- **Theme 2: Safety**
  - *Q1 How could those spectating VR use in public spaces feel that their privacy is not violated?*
  - *Q2 What would be some useful ways to provide a zone of interaction for the VR users ?*
- **Theme 3: Isolation**
  - *Q1 How would spectators see the VR experience of the user?*
  - *Q2 How would spectators communicate with VR users?*
- **Theme 4: Design guidelines**
  - Q1 What would be some design guideline elements based on the above discussions?

Do you have some other thoughts or comments that you would like to share?

Thank you all very much for participating and I hope you enjoy the movie!

→ ***Hand Movie Tickets***

STOP RECORDING

Appendix I – Consent Form

Please tick the box in each section indicating that you have read and understood the statements in that section. All data will be anonymized and your identity will not be revealed at any point.

☐ **Participation:**

I agree to participate in the user study conducted by Tampere University of Technology as part of the research process of Pouya Eghbali for master thesis in the field of user experience. The supervising faculty for this project is Professor Kaisa Väänänen (kaisa.vaananen@tut.fi)

I understand that participation in this user study is voluntary and I agree to stop immediately raise any concerns or areas of discomfort during the session with the moderator.

☐ **Video Recording:**

I understand and consent to the use of the video recording. I understand that my personal information and identity will not be shared with anyone. I give my permission for the video recording.

☐ **Use of Video Material:**

I relinquish any rights to the video recording and understand that Tampere University of Technology may use the recording. I understand that parts of the recording maybe used for creating video material and published online at a later time.

☐ **Use of Data:**

I understand that data gathered during this study will be used for analysis at a later stage and that my words may be quoted in published papers.

☐ **Health Caution:**

I understand that using a VR device can be physically challenging and intensive. I understand that the VR device may cause nausea or discomfort to me. I am responsible for my own physical safe being and I will stop if I feel any discomfort or difficulty while performing the study. Tampere University of Technology or the moderators are not responsible in case of any injuries.

Please sign below to indicate that you have read and you understand the information on this form and that any questions you might have about the session have been answered.

Date: _________

Participant Unique ID: (   )

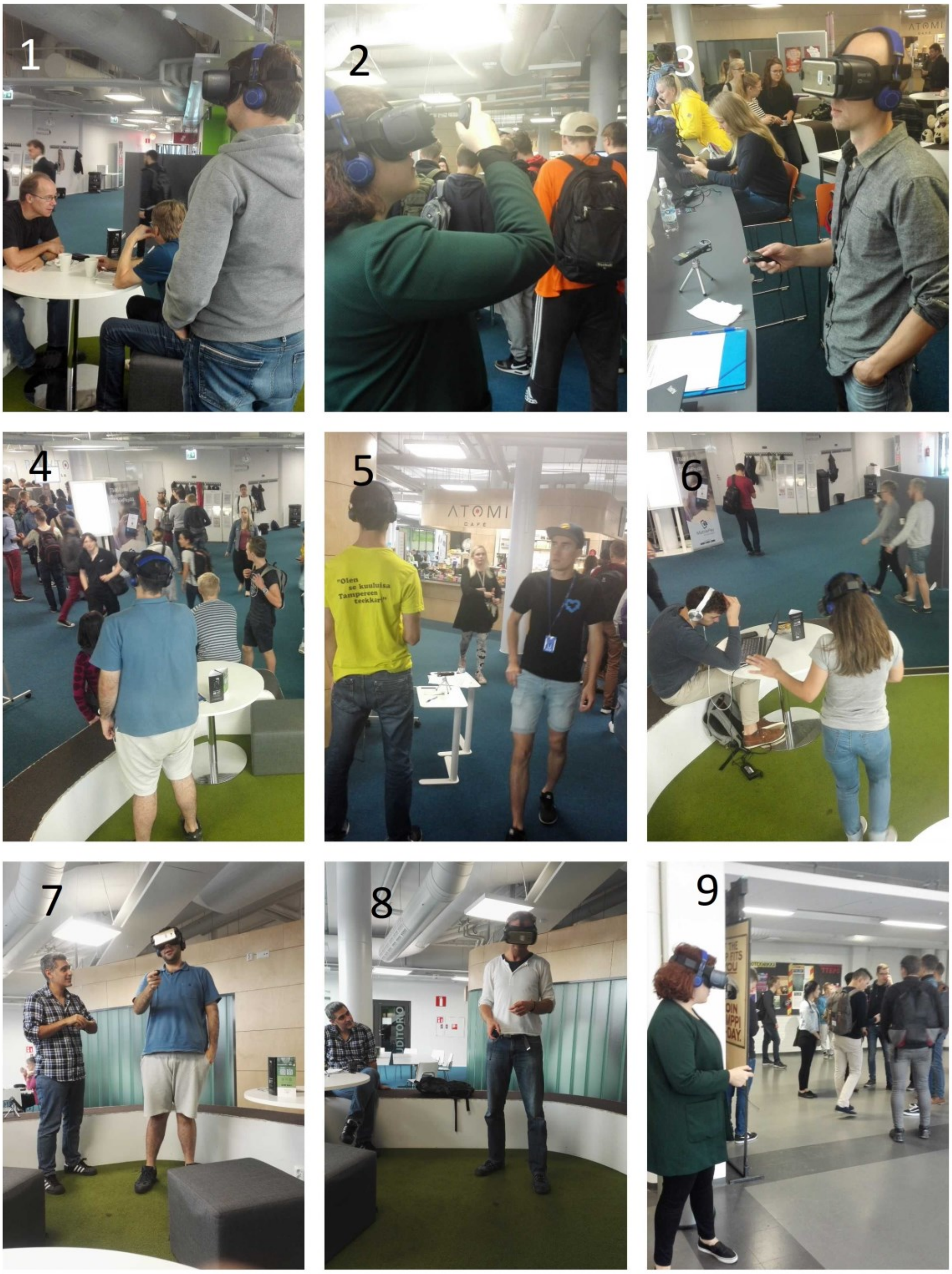
Participant name: ____

Participant signature: ____

Thank you

We appreciate your participation.

Appendix J – VR use in Public Context



Appendix K – User Survey Results

Question	Mean Value	Standard Deviation	Mode
1. It felt appropriate to use the VR headset in a public place.	5.3	0.8	5
2. It felt rude to use the VR headset in a public place.	2.1	0.7	2
3. I felt uncomfortable being watched by others while using the VR headset a public place.	3.6	1.4	5
4. The VR device in public space made me look cool.	4.6	1.5	5
5. It would be useful for me if the people around me could communicate with me.	5.4	0.8	5
6. It felt awkward doing head movements while using VR in public.	2.8	1.5	2
7. It felt awkward performing body movements and hand gestures while using VR in public.	3.6	1.7	3
8. I did not like the fact that I was isolated from the rest of the people in a public space.	3.4	1.6	2
9. It would be interesting if the other people could see what I was doing and seeing in the VR.	5.8	1.5	7
10. I was concerned that people would record me while using the VR in public.	2.8	1.5	2
11. I was concerned about bumping to objects and people while using the VR in public.	6.1	0.7	6

Appendix L – Spectator Survey Results

Question	Mean Value	Standard Deviation	Mode
1. It is appropriate for this person to use the VR headset in a public place.	4.9	1.1	5
2. It is rude for this person to use this VR headset in a public place.	2.8	1.2	2
3. I feel uncomfortable watching this person use the VR headset a public place.	2.7	1.2	2
4. The person using the VR headset looks cool.	4.3	1.5	3
5. It would be useful for me to communicate with the VR user.	4.7	1.4	5
6. I find the head movements of the VR user awkward.	3.7	1.2	5
7. I find the body movements and hand gestures of the VR user awkward.	3.9	1.2	5
8. I do not like the fact that VR user is isolated from the rest of us.	4.6	1.6	5
9. I am curious to see what the VR user is seeing and doing in the virtual world.	6.0	3.5	6
10. I am concerned the VR device camera is recording me.	3.5	1.0	5

Appendix M – Two sample t-test

Q	P value and statistical significance	Confidence interval	Intermediate values used in calculations
1	The two-tailed P value equals 0.2974 By conventional criteria, this difference is considered to be **not** statistically significant.	The mean of Group One minus Group Two equals 0.400 95% confidence interval of this difference: From -0.366 to 1.166	t = 1.0565 df = 38 standard error of difference = 0.379
2	The two-tailed P value equals 0.0901 By conventional criteria, this difference is considered to be **not quite statistically significant**.	The mean of Group One minus Group Two equals -0.700 95% confidence interval of this difference: From -1.515 to 0.115	t = 1.7392 df = 38 standard error of difference = 0.402
3	The two-tailed P value equals 0.0560 By conventional criteria, this difference is considered to **be not quite statistically significant**.	The mean of Group One minus Group Two equals 0.900 95% confidence interval of this difference: From -0.024 to 1.824	t = 1.9714 df = 38 standard error of difference = 0.457
4	The two-tailed P value equals 0.5871 By conventional criteria, this difference is considered to be **not statistically significant**.	The mean of Group One minus Group Two equals 0.300 95% confidence interval of this difference: From -0.809 to 1.409	t = 0.5477 df = 38 standard error of difference = 0.548
5	he two-tailed P value equals 0.1435 By conventional criteria, this difference is considered to be **not statistically significant**.	The mean of Group One minus Group Two equals 0.700 95% confidence interval of this difference: From -0.249 to 1.649	t = 1.4936 df = 38 standard error of difference = 0.469
6	The two-tailed P value equals 0.0612 By conventional criteria, this difference is considered to **be not quite statistically significant**.	The mean of Group One minus Group Two equals -0.900 95% confidence interval of this difference: From -1.844 to 0.044	t = 1.9295 df = 38 standard error of difference = 0.466
7	The two-tailed P value equals 0.5421 By conventional criteria, this difference is considered to be **not statistically significant**.	The mean of Group One minus Group Two equals -0.300 95% confidence interval of this difference: From -1.287 to 0.687	t = 0.6152 df = 38 standard error of difference = 0.488
8	The two-tailed P value equals 0.0469 By conventional criteria, this difference is considered to be **statistically significant**.	The mean of Group One minus Group Two equals -1.200 95% confidence interval of this difference: From -2.383 to -0.017	t = 2.0540 df = 38 standard error of difference = 0.584

9	The two-tailed P value equals 0.8626 By conventional criteria, this difference is considered to be **not statistically significant**	The mean of Group One minus Group Two equals -0.200 95% confidence interval of this difference: From -2.524 to 2.124	t = 0.1742 df = 38 standard error of difference = 1.148
10	The two-tailed P value equals 0.1004 By conventional criteria, this difference is considered to be **not statistically significant.**	he mean of Group One minus Group Two equals -0.700 95% confidence interval of this difference: From -1.542 to 0.142	t = 1.6839 df = 38 standard error of difference = 0.416