Social Acceptability of Virtual Reality in Public Spaces: Experiential Factors and Design Recommendations

Pouya Eghbali
Human-Centered Technology (IHTE)
Tampere University, Finland
p.eghbali@gmail.com

Kaisa Väänänen
Human-Centered Technology (IHTE)
Tampere University, Finland
kaisa.vaananen@tuni.fi

Tero Jokela
Nokia Bell Labs
Tampere, Finland
tero.jokela@nokia-bell-labs.com

ABSTRACT

With the latest advancements in Virtual Reality (VR), the possible use of VR devices in public and social contexts has increased. Since the use of VR typically requires wearing a Head-Mounted Display (HMD), the user is not able to see others – the spectators – present in the same context. This may lead to a decrease of social acceptability of VR by both the users and the spectators. We conducted a field experiment to explore what are the experiential factors of the users of VR (N=10) and spectators of VR use (N=30). We found experiential factors for the users to be ***adjustment of interaction, uninterruptable immersion, un-intrusive communication, freedom to switch between realities, sense of safety, physical privacy, shared experience,*** and ***sense of belonging***. For the spectators, the main factors are ***shared experience, enticing curiosity, feeling normal,*** and ***sense of safety***. We then run three sessions with user experience (UX) experts (N=9) to create a set of design recommendations for socially acceptable VR. The resulting ten recommendations provide a holistic view to designing acceptable experiences for VR in public spaces.

CCS CONCEPTS

• Human-centered computing → User studies; Human-centered computing → Virtual reality

KEYWORDS

Virtual reality, VR, Social acceptability, Public context, User experience, Spectators, Design recommendations

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1 INTRODUCTION

The origins of Virtual Reality (VR) go back to more than 100 years [34] and ever since then the technology has provided increasingly realistic experiences to the users. The development of VR devices has been growing over the last few years and VR can be expected to be part of people's everyday lives in the not-so-distant future [32]. VR systems consist of input, the application, rendering, and output – these main elements create the virtual world and provide an immersive experience to the user [14]. While VR input can be implemented with many different technological approaches, a major approach for immersive VR continues to be the use of the Head-Mounted Display (HMD). HMD requires the user to wear a device that covers their face, causing the users to be separated from the people around them.

With the wide range of available HMD models, ease of VR system setup, lowering costs and the variety of applications available, it is inevitable that VR will be used in public context where other people are present. Such contexts are, for example, fairs and exhibitions, company or university lobbies, schools, shopping malls and transportation vehicles. These places are inherently social to some degree, with variety of intensity in the involvement of other people beyond the user: Others may be merely passing by, spectating, or co-acting with the user in the situation [8].

While the VR user is enjoying their immersive experience by watching their screen, interacting with the virtual environment using their bodies and hands, and hearing the audio from the headphones, the others present in the context are typically unable to see what the user is experiencing. The ones spectating the VR user will only be seeing a person with their face covered, performing certain actions, and isolated from the rest of the people, unaware of their surroundings and happenings. The isolation of the user from the others can create a form of social gap that may affect the social acceptability of VR in public context.

As with any other interactive technology, the use of VR should provide its users positive user experience (UX). ISO 9241-210 defines user experience as ***"a person's perceptions and responses that result from the use or anticipated use of a product, system or service"*** [1]. UX is highly dependent on the context of use and social context is an essential element of the context of use (ibid). In public VR use the spectators are part of the social context and hence it is important to understand their experiences as well as their influence on the holistic UX of the VR users.

Earlier studies have focused on people's perceptions of the use of HMDs [31] and the use of AR by disabled people [27], but experiential factors related to social acceptability of immersive VR have not been in the focus. In this paper we explore the social gap between the users and the others present – we call them spectators – and identify the experiential factors affecting the acceptability of VR. Three research questions (RQ) to address this topic are: RQ1: ***What are the experiential factors in the social acceptability of VR use from the perspective of users?*** RQ2: ***What are the experiential factors from the perspective of spectators?*** RQ3: ***What are the interaction design recommendations of VR systems to enhance social acceptability?***

To answer the research questions, we conducted a field experiment in two phases – user tests and spectator surveys – and as the third phase, we run recommendation co-creation session with UX experts. The study was run in a university restaurant, with a participant sample of ten users and 30 spectators. We collected qualitative data by user tests and interviews, and quantitative data by surveys. Finally, three expert sessions were run to formulate design recommendations based on the first two phases.

The contributions of this paper are two-fold: On theoretical level, answering RQ1 and RQ2 provide a framework for experiential factors of social acceptability of VR, and on the practical level, the design recommendations (RQ3) provide support for HCI practitioners aiming to create positive VR experiences.

2 BACKGROUND AND RELATED WORK

First, we present the concept of social acceptability. Then, related research of acceptability of wearable technology is briefly reviewed. We then take a look at the earlier research on social acceptability of VR and interaction techniques that may support it. Lastly, we explain our definition of "others" in the public context – whom we will call spectators – based on related work.

2.1 Social Acceptability

Social acceptance refers to the judgment a technology after being used while ***social acceptability refers to the phenomenon of judging a technology introduced in the future*** [7]. Social acceptability can be disrupted if the use of a technology does not follow social norms or it disrupts the social flow [9]. Social acceptability can influence the inclusion or involvement of the user in certain groups [30]. The effect of social acceptability is so strong that even if it is only ***perceived*** disapproval of theh society, acceptability can be negatively influenced [16]. The importance of social acceptability lies partly in the fact that individuals pay attention and reflect themselves to their surroundings [25]. Furthermore, an interaction experience is affected by how the users believe they are perceived by other people present and hence interactions in public context may lead to discomfort and tension [16]. Factors affecting social acceptability go beyond the user feeling embarrassed to aspects such as social status, appearance, the cultural traditions regarding technology usage, and even ethical concerns [26][28].

2.2 Acceptability of Wearable Technology

While any technology can be affected by social acceptability, wearable technology can be more disposed to risks due to their visibility to the outside world. Wearable technology refers to electronic devices that are personal and worn on the body [15]. Wearable technologies face acceptability challenges that are affected by their form factor and physical design, their location on the body, people's familiarity with them, their interaction techniques, and privacy concerns [27].

To enhance social acceptability of wearable technologies, several creative solutions have been utilized. The use of jewelry such as rings, bracelets, earrings and necklaces [23] can be one approach of hiding wearable technology from plain sight. Another approach is integration of technology into everyday items that would go unnoticed such as eye glasses [23], shoes, hats, and even false finger nails [6]. Koelle et al. conducted a design study to investigate privacy notices for body-worn cameras, and give design recommendations for noticeability, understandability and trustworthiness of privacy indicators [17].

While there are many possible design solutions to tackle social acceptability of wearables, there have not been many efforts focused on measuring social acceptability of wearable technology. Technology Acceptance Model (TAM) [5] and Unified Theory of Acceptance and Use of Technology (UTAUT) [33] measure technology acceptance on a general level, social acceptability of wearables has been studied by Kelly with the WEAR scale [15]. The scale includes 14 items across two factors, ***fulfillment of aspirational desires*** and ***avoidance of social fears***.

2.3 Social Acceptability of VR and Techniques to Improve VR Interaction

While there is some related work aiming at understanding social acceptability of VR and the usage in public context, there have not been many studies that measure the social acceptability using field experiments in public context. Work by Profita et al. [27] explored social acceptability of HMDs in relation to disability of the user. The study explored the use of HMD by a user in public context and online questionnaires were used to answer surveys after watching video scenarios. The findings of the study suggest that observers considered HMD use more socially acceptable if the user had a disability.

In another study [31], online experiments were conducted to determine how VR glasses are perceived. The study had two independent variables with the first being the situation where the VR glasses were used such as a train, car, metro, living room, and bedroom and the second variable was the gender of the person using the VR glasses. The study concludes that the social acceptability of VR depends on the situation: The acceptability is lower when the user is assumed to interact with the others in the same context.

Regarding techniques that may improve social interaction in and around VR, several studies about VR interaction in public have been conducted. Mai and Khamis investigated people's behaviour around HMDs and suggest to combine knowledge of interaction with public displays to using HMDs in public, unsupervised settings [19]. In another study, Mai et al. [21] investigated the influence of the layout of the space to the user wearing a HMD and suggest implications such as ***"full separation [of users and bystanders] not mandatory"*** and ***"make users look good"***. Alallah et al. [2] studied social acceptability of non-VR HMD with the focus in input modalities. They present guidelines regarding e.g. subtleness of input modalities and conclude that perspectives of both performers (users) and observers should be considered when exploring social acceptability of emerging technologies.

Research prototypes have been developed to support communication between the VR user and people around them. TransparentHMD [20] reveals HMD user's face to others and creates an illusion of a transparent display to the user, allowing exploration of scenarios for collaborative VR use. FrontFace [3] aims at facilitating communication between HMD users and "outsiders" by providing a front-facing display displaying the VR scene or an image of the user's face, depending on if they are in or out of VR. Using a HMD-mounted cameras and depth sensors in the environment, JackIn Space system [18] integrates the first person view with the third person view and allows people to switch to a different virtual position during telepresence.

Considering safety of interaction, ShareSpace toolkit allows users to add "shields" in VR to help avoiding physical collisions and promote the shared use of the same physical space for activities of both HMD and external users [35].

2.4 Others in the Public Context

The actors involved in public context can be defined in different ways. Earlier work [8] defines participants in social gaming based on their level of participation with three constant roles of bystanders, audience, and players, with the audience divided into twelve distinct temporary roles. Another study [4] defines nine different personas of spectators as the bystanders, the curious, the inspired, the pupil, the unsatisfied spectators, the entertained, the assistants, the commentators, and the crowd. Finally, in a simpler and more general descriptive format by earlier research [11] the roles of those involved in a public display location are defined as the actors, spectators, and bystanders. Actors are those that interact actively with the system, while spectators are the ones who are observing the actors and trying to identify what the actors are doing by decoding their actions, and bystanders are those who show a short attention towards the display by glancing at it for a short period of time.

We adapt our definition of the VR actors from Finke's [11]. We use the term ***users*** for those actors using the VR device in a public context and the ***spectators*** for those actors who show interest in the actions of the user and try to understand what the users are doing.

3 OUR STUDY

Our study explores the social acceptability of VR with the goal of identifying the factors that influence the experience(s) of people (users) who interact with VR applications in public context and of those who spectate the user using the VR in public. The study was conducted in the public context of a university restaurant during busy week days. The restaurant is a relatively large open space in a recently opened building, and kind of a "central hub" of the university campus (See Figure 1). We chose field experiment [12] as the basis of the two phases because of the need to gain understanding of real-world contextual experiences. Both qualitative and quantitative data were gathered. The third phase consisted of expert workshops, with the aim of creating design recommendations for publicly used VR systems.

Figure 1. A user interacting in VR using a Head-Mounted Display in the public context of a university restaurant.

3.1 Research Phase 1: User Test Sessions

The aim of this phase was to identify the experiential factors affecting the social acceptability of VR from the perspective of users (Research Question 1).

Participants

Ten users participated in the user test sessions (seven male and three female, age range 18-41 years). We recruited the participants via social media. We asked about their familiarity with VR technology in our ad as suggested by [24]. In terms of interest in Virtual Reality, on Likert scale 1-7 the mean value to the statement "I am interested in Virtual Reality" was 6.6. Six participants had experienced public VR use a few times while three had no experiences and one user just once.

Methodology and Procedure

The user sessions lasted 50 minutes on average, consisting of introduction, approximately ten minutes of using a VR game, and the final interview and survey.

The users were introduced to the Samsung Galaxy S7 Edge device, wireless headphones, and Gear VR and motion controller (Figure

2). The users were informed about health and safety issues and informed to stop the test in case of any unwanted issues. They read and signed a consent form.

The VR experience was ***Tomb Raider VR: Lara's Escape*** mini game for the new Tomb Raider movie. This game was chosen due to its immersion factor, audio effects, and motion controller interaction requirements.

Figure 2. Samsung Gear VR, Galaxy S7 Edge, and Motion Controller used in the study.

The moderator explained the operation of the device followed by the users briefly exploring the gear VR universal menu to test the functionality of the motion controller before starting the VR experience in the public. During the VR experience, the moderator took notes and observed that the user was not in a dangerous situation.

The user test sessions were recorded both on audio and video while the interviews were audio recorded. The structured interviews had 14 questions that cover the viewpoint of the users about their experience with the VR in public context. The questions included ***participants' perceptions on head and body movements, how the presence of others affected their experiences, positives and negatives of their experiences, how their experience would be different in private,*** and ***the types of applications and public locations that could benefit from VR***.

Each user filled a survey after the test session. The survey consisted of 7-scale Likert questions adapted from an earlier study by Profita et al. [27] with 11 statements in six thematic groups including general statements about ***public VR use, statements about VR user, communication, interaction, isolation***, and privacy and ***safety***. (The statements are presented in Findings, in Table 1.)

3.2 Research Phase 2: Spectator Surveys

Phase 2 focused on factors affecting the social acceptability of VR from the perspective of spectators (RQ2). The study took place in the same context as in Phase 1, i.e. university restaurant.

Participants

The spectators were recruited amongst the bystanders and passers-by, while a research assistant was using the VR system. A total of 30 spectators were asked to participate (20 male and 10 female). 29 of whom were in the age range 18-41 years, and one was over 41 years. Their interest in VR, on a Likert scale (1-7, "I am interested in Virtual Reality") got the mean value 5.7. When asked about their VR experience in public, 12 mentioned a few times while 18 responded "never".

Methodology and Procedure

Similar to the user study, we ran the spectator study in the public context of a university restaurant. A VR user (a research assistant) interacted with the device being fully immersed in the virtual world while people were passing by. The moderator first identified potential participants who were people passing by and showed some interest in the VR user. The moderator then approached the spectators and engaged in a friendly conversation with them asking their opinion on VR use in public spaces and then asked if they would participate in the study.

We used surveys consisting of quantitative and qualitative questions. The surveys consisted of the same 7-scale Likert scale adapted from an earlier study [27] used in the user surveys. In the spectator survey, the questions were converted to the viewpoint of the spectator. For example, the question to the user "It felt rude to use the VR headset in a public place" was asked from the spectator in the form "It is rude for this person to use this VR headset in a public place". Additionally, there were open-ended questions for the spectators about ***how they felt about the person using VR in public, their perceptions of users' movements and gestures, their willingness to use the VR in public,*** and ***appropriate applications and public spaces for VR use***. The spectator sessions (discussion, observations, and filling in the survey) lasted approximately 7 minutes.

3.3 Research Phase 3: Co-Creation Sessions with UX Experts

In Phase 3 we conducted three co-creation sessions with UX experts. The aim was to create a set of design recommendations for socially acceptable VR (RQ3).

Participants

The participants of the co-creation sessions were UX experts familiar with interaction design. We invited participants from the UX-related research groups of our university. There were nine participants, six male and three females. Eight of them were UX researchers and one software developer.

Methodology and Procedure

We adapted the method for the co-creation sessions from the Participatory Design Framework [29]. There were three sessions, with three experts in each. Discussions were based on the main themes of the findings from the field experiments. Body storming was also encouraged to illustrate the recommendation ideas. The purpose of the sessions was creation (drafting) of the design recommendations. The sessions were audio and video recorded.

At the start of each session the moderator presented the key findings from the user test sessions and spectator surveys, i.e. the identified experiential factors (see Findings). The participants got a chance to get familiar with the VR application used in the research. The session then went on as a semi-structured discussion of the themes of the experiential factors and additional guiding questions about interaction, safety, and isolation. In the end of the session, ideas for design recommendations were drafted. Each session lasted approximately one hour.

3.4 Data Analysis

The qualitative data was analyzed using content analysis [10]. After transcribing the data, they were transferred into MS Excel where relevant responses were identified, and responses were iteratively grouped to main themes related to user experience and interaction. In the second round, the themes were mapped to experiential categories proposed by Hassenzahl [13]. One researcher worked through the whole analysis, while another researcher participated in discussing the categories and mappings during the process. The quantitative survey data was treated with basic statistical analysis for calculating means and standard deviations, in addition to two-tailed t-test for comparing the user and spectator survey results.

4 FINDINGS

We first present the findings of the surveys and a brief summary of public VR contexts and contents considered suitable by the participants (4.1). We then present the found experiential factors from the viewpoints of the users (4.2) and spectators (4.3). Finally, Section 4.4 presents the design recommendations created based on the UX expert sessions.

4.1 Social Acceptability Perceptions of Users and Spectators

Table 1 presents the responses for statements in the users and spectators surveys. While the statements in Table 1 are the user version of the surveys, the spectators had "mirroring" statements reflecting their viewpoints on public VR use. For example, statement 3 for the spectators is: ***"It felt uncomfortable to watch the user while s/he was using the VR in the public space"*** and statement 5 for spectators is ***"It would be useful for me if the VR user could communicate with me"***.

When comparing the results of the users and spectators, Statements 8 about ***isolation*** and Statement 10 about ***recording concern*** were the only ones of statistically significant difference. Users did not mind the isolation but spectators were more critical of not knowing what the user was seeing or doing. Regarding the recording of others, spectators were more critical compared to the users, but still this was not a major concern in this study context.

In general, the survey scores are rather positive and the study participants considered public VR use in this context to be appropriate. In addition to the appropriateness, two statements gained high scores from both users and spectators: Statement 5 scores about ***communication*** suggest that the communication between users and spectators would be useful for both and Statement 9 about ***shared screen*** indicates that it would be interesting that the spectators could see what users are seeing.

Overall, for both participant groups, public VR use seemed appropriate, did not feel rude or especially uncomfortable. They were quite neutral about the "coolness" or "awkwardness" of the use or perceived use.

Table 1. Mean values and standard deviations of user (N=10) and spectator (N=30) surveys. 7-point Likert scale was used (1=strongly disagree,7=strongly agree). The statements in the six themes are adapted from [15].

Statements	Users	Spectators
Statements about public VR		
S1. It felt appropriate to use the VR headset in a public place.	5.3 (0.8)	4.9 (1.1)
S2. It felt rude to use the VR headset in a public place.	2.1 (0.7)	2.8 (1.2)
S3, It felt uncomfortable being watched by others while using VR in a public place.	3.6 (1.4)	2.7 (1.2)
Statement about the user		
S4. I think the VR headset makes me look cool	4.6 (1.5)	4.3 (1.5)
Statement about public communication		
S5. It would be useful for me if the people around me could communicate with me.	5.4 (0.8)	4.7 (1.4)
Statements about interaction		
S6. It felt awkward doing head movements while using VR in public.	2.8 (1.5)	3.7 (1.2)
S7. It felt awkward performing body movements and hand gestures while using VR in public.	3.6 (1.7)	3.9 (1.2)
Statements about isolation		
S8. I did not like the fact that I was isolated from the rest of the people in a public space.	3.4 (1.6)	4.6 (1.6)
S9. It would be interesting if the other people could see what I was doing and seeing in the VR.	5.8 (1.5)	6.0 (3.5)
Statement about privacy		
S10. I was concerned about spectators recording me while using VR in public.	2.8 (1.5)	3.5 (1.0)
Statement about safety		
S11. I was concerned about bumping to objects and people while using the VR in public.	6.1 (0.7)	N/A

Suitable Public VR Contexts and Contents

Interview and survey results reveal that public contexts such as shopping malls, cinemas, educational institutes, conferences, parks, and museums are contexts that are considered as socially acceptable to use VR in. ***"I can imagine using VR in public, but it wouldn't be in a space like this but it will be in a place like a train where I will have a little bit of privacy – not a location with 360 degrees of people buzzing around"*** (F, 30-35 yrs). VR experiences such as VR explorations of new places, educational content, tours, and visiting historical places are considered suitable for public VR use. ***"Restricted places that you want to visit such as closed parts in museums and for tourism to visit places virtually. Also in tours the elderly that can't visit locations due to health can use VR in the bus."*** (M, 24-29 yrs)

4.2 Experiential Factors: Viewpoint of Users

The qualitative data related to user experiences of public VR interaction were thematically grouped from the statements of the user interviews. There were 139 relevant statements, from which ***eight experiential factors – i.e. themes that describe how user experience can be affected – were formed***. We then mapped the factors to Hassenzahl's experience categories [13]. Table 2 shows the identified eight experiential factors that can affect the social acceptability from the viewpoint of users. The main experience categories for VR users are ***autonomy, security, popularity,*** and ***relatedness***.

Table 2. Experiential factors affecting the social acceptability of VR from the viewpoint of users.

Experience Category	Experiential Factor
Autonomy	Adjustment of interaction
	Uninterruptable immersion
	Unintrusive communication
	Freedom to switch between realities
Security	Sense of safety
	Physical privacy
Popularity	Shared experience
Relatedness	Sense of belonging

Autonomy

Adjustment of interaction. A need for discreet forms of interaction was brought up by users. One user stated that "***If I was in an environment with lots of people walking past me I would choose VR experiences that do not require much movement like immersive story telling***" (M, 36-41 yrs). Another user brought up the need for minimizing the forms of interaction: ***"You had to minimize your movements since you don't know who is within your reach and you tend to do smaller movements and minimize your area of reach and workspace"*** (M, 18-23 yrs). User needs to be provided the option to choose a discrete public mode of interaction that would require less extensive movements. This would allow the user to enjoy their VR experience in public without the fear of hitting others around them or bumping into objects.

Uninterruptable immersion. An issue that came up several times during the test sessions was the excessive noise in 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. One user mentioned that that "***I was totally immersed until I heard someone talking loud"*** (M, 24-29 yrs). In an instance that the speaking got very loud, the user loudly stated ***"Guys, you are ruining my experience here***" (M, 30-35 yrs) and later mentioned background noise as one of the negatives to using VR in public. Users should be able to stay isolated in VR when they want and be able to enjoy the VR experience without being interrupted by outside noise. In case the outside noise is heard, the system could detect it and adjust the volume in the VR to prevent a break in immersion.

Unintrusive communication. On the opposite side of isolation, most of the users believe it would be useful if the people in the public context could communicate with them. User needs to have a communication channel with the outside without losing their sense of immersion. Communication should be to both directions: ***"I want it both ways whether it is me and people have the possibility of engaging in my experience or the other way around"*** (F, 30-35 yrs) Communication could happen either through the shared screen and showing some kind of signals in the user's view within the HMD, or there could be a chat channel or similar. The user should know that if anyone wants to communicate with them they can "show up" in the virtual world without the need to take the headsets off.

Freedom to switch between realities. One way to avoid the issues of bumping and hitting people or objects is to be aware of the surrounding and to know what is going on in the real world while using the VR. One user stated that ***"when you play in the public you should be aware the real world around you"*** (F, 30-35 yrs). The user needs the ability to switch between the virtual world and the real world at will. To be able to somehow see the real world without the need to taking off the VR device, some users suggested to provide a real-world view while using the VR. A user (M, 24-29 yrs) stated that "***in public space that you don't know, the surroundings obstacles should show in real time in the VR***". Another user (M,36-41 yrs) mentioned that ***"it would be beneficial to be able to change between the real world and VR***". By providing access to the real world through the VR device, the user can easily check their surroundings if they want to.

Security

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. In one instance a user mentioned ***"I was spinning around like a robot not trying to spin too fast and too far"*** (M, 18-23 yrs) while another user 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" (M, 36-41 yrs). In one instance a concrete security issue emerged: ***"I had this reflex and I noticed that I had my hand on my mobile unconsciously. In a train station someone might steal your things"*** (M, 36-41 yrs). Users need to feel safe during VR use in public context. The sense of safety can be provided to the user via physical barriers or virtually so that the user is always aware of obstacles and can take care of their belongings.

Physical privacy. Users mentioned that if they experienced the VR in **a private setting**, they would feel a better sense of freedom and be more relaxed in their body movements and actions: ***"if it is private I would like to make noises and scream but I didn't do this because of being in public. In a private room with more space I would be jumping and do more stupid behavior and it would be more fun"*** (M, 30-35 yrs). Users would also feel more focused since no outside stimuli such as noise would be present. Users need their own private space during VR use in public context. While it can be a very small space, it can ensure that others know the user is using VR and there will not be any unwanted contact with others. Most of the users were not concerned about being recorded by others while using the VR.

Popularity

Shared experience. Users did not mind being separated from the rest of the crowd and being immersed in a virtual environment. One user (F, 30-35 yrs) mentioned that ***"you are in the same place as others but basically you are 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. Sharing experiences could be done by sharing the screen or broadcasting VR screen to nearby devices. While many users believed that sharing their screens with the people around would be beneficial in creating a sense of shared experience, some users might feel judged or would not want to share private content while using VR. ***"It would not be your world anymore, in a game situation it would be fine, but in other things I wouldn't share."*** (M, 36-42 yrs) On the positive side users would know that those noticing the user interactions would understand their body movements and hand gestures.

Relatedness

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 and enjoy the sense of being in a virtual location while in the same place as others. The users enjoyed their VR experience in the public context of a university. Additionally, the users mentioned that if they saw other people using VR in a public space they would also be motivated to use it. The reasons mentioned were curiosity and the feeling of communality. ***"We are collective individuals and herd animals. It would be evident for the people not using VR that there is something special happening it will be easier psychologically [to join in]"*** (M, 36-41 yrs). If more people use VR devices in public, the usage will not feel out of place and the users can feel as being part of a community.

4.3 Experiential Factors: Viewpoint of Spectators

From the viewpoint of those spectating users of VR in a public context, there were 92 relevant comments from the user surveys. Based on the thematic content analysis we found four main experiential factors that can affect the social acceptability of VR (Table 3). The experiential factors of spectators were also mapped under Hassenzahl's experience categories [13]. The main experience categories for VR spectators are ***stimulation, relatedness,*** and ***security.*** Details are presented below the table.

Table 3. Experiential factors affecting the social acceptability of VR from the viewpoint of spectators.

Experience Category	Experiential Factor
Stimulation	Shared experience
	Enticing curiosity
Relatedness	Feeling normal
Security	Sense of safety

Stimulation

Shared experience. It came up that **sharing the user's screen** with the spectators can increase the acceptability. Spectators want to share the experience of the user and see the same as what the VR user is seeing to make sense of the movements and assimilate to what the user is interacting with. ***"It looks funny since I can't see anything [what the user is seeing]"*** (S30). 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. Additionally, seeing what the user is seeing can motivate VR use for spectators.

Enticing curiosity. 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 that ***"It is as comedy, 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 trying to use similar devices themselves in public spaces.

Relatedness

Feeling normal. The findings suggest that when more users start using VR in public, it will increase the social acceptability. Spectators need to be able to relate to the VR users. 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 could use it in public". Spectators should be able to feel that VR used in public context is as normal as using a smartphone or a mobile handsfree device in public.

Security

Sense of safety. Many spectators felt that safety and privacy are important. 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 use VR in public given that ***"they do not collide with 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 a major concern for the users only, the viewpoint of the spectators suggest that it is an important matter to them as well. Regarding privacy, the spectators did not have major concerns of being recorded by the VR users.

4.4 Design Recommendations for Public VR Use

After transcribing the data from the co-creation sessions with the UX experts, we compiled a list of all the possible items – the draft design recommendations – followed by identifying headings for each item, descriptive titles, and an explanation in addition to the experiential factors they address. Some of these items were not explicitly linked to the findings from Phases 1 and 2, but as they were suggested by UX experts, those items were included in the formation of the recommendations (in specific, PubVR_Rec1 and PubVR_Rec2). There were altogether 28 items or recommendation candidates that emerged from the three UX expert groups.

The resulting ten recommendations were categorised across six themes of ***content, movements and interaction, safety, communication, connectedness,*** and ***privacy***. The design recommendations address the experiential factors of both the users and the spectators. The recommendations can be used during the design process as inspiration guidance or as a list of heuristics when evaluating VR experiences for public contexts.

Content

PubVR_Rec1. Avoid unsuitable public VR content. VR systems 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 contents for public VR use are for example those that allow the users to explore locations, visit historical places, and going back in time virtually. Context-relevant content enhances ***sharing the experience*** with spectators.

PubVR_Rec2. 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. This recommendation enhances the ***uninterruptible immersion*** from the perspective of the users.

Movement and Interaction

PubVR_Rec3. Define a VR interaction zone. By defining the VR interaction zone physically allows the user 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 types of contexts, a virtual barrier can be set to show the physical zone of interaction in the virtual world (cf. [35]). This recommendation enhances the ***sense of safety*** factor of the users.

PubVR_Rec4. 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 be explicitly informed to the user every time the user choses the mode. This recommendation addresses the ***freedom of interaction*** for the users.

Safety

PubVR_Rec5. Define and present safety guidance virtually. Every time the user starts interacting in VR, basic safety guidance must be shown to the user, reminding her about the fact that the interaction is in public. Some items can be: 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. The ***sense of safety*** factor of the users can be enhanced by adhering to this recommendation.

PubVR_Rec6. 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 offered in a non-intrusive manner such as a view to the real world in the VR world. This recommendation adheres to the ***sense of safety*** factor for the users and ***sense of belonging*** with others.

PubVR_Rec7. Actively warn users of collision with objects. Warn the users in case they are going to bump to objects or people 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. ***Sense of safety*** is addressed by this recommendation for both users and spectators.

Communication

PubVR_Rec8. Allow communication with the real world. The spectators should be able to communicate with the user without breaking the user's sense of immersion and the need to take off the HMD. 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 of spectators to the VR chat. Alternatively, display solutions can help users to see spectators and vice versa (cf. [3][20]). The user experiential factor enhanced by this recommendation is the ***unintrusive communication***.

Connectedness

PubVR_Rec9. Allow the user to share their screen. The user needs to be able to share their view or their screen with those around for a shared experience (cf. [19]). 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. The recommendation addresses the experiential factor of ***sharing the experience*** from the perspective of users, while from the perspective of the spectators the factors affected are ***enticing curiosity*** and shared experience.

Privacy

PubVR_Rec10. Convey that the VR user's camera is not recording. To ensure the privacy of the spectators, the message that the user is not recording should be conveyed across (cf. [17]). One method could be using a well-known red recording sign on the VR headset that lights up if the user is recording the real-world environment. The ***sense of privacy*** factor of spectators is addressed by this recommendation.

5 DISCUSSION

Earlier work has addressed social acceptability of HMDs by studying a specific user group of disabled people [27] or respondents' perceptions of different contexts of use such as a train or a restaurant [31]. The method used in these studies was based on online surveys. Earlier research has also suggested several solutions to specific interaction challenges such as front facing HMD screens to improve connection between users and spectators [3] and virtual shields to help users avoid collision with others [35]. Commercial solutions for mirroring VR to other screens also exist, e.g. by Oculus Go. Our approach to study the social acceptability of VR was to gain holistic understanding of users' and spectators' experiences in public context. To this end we conducted empirical research in a public context and formulated a set of ten recommendations for design of VR for public use. The novelty of our research lies in bringing the holistic UX viewpoint to the study of social acceptability of VR.

Overall, we found that in a public context of a university, the use of HMD-based VR can go unnoticed by most people passing in the same area. Even if someone notices the user and feels awkward about the VR use in public, they will not get shocked, feel uncomfortable, or be annoyed by the VR use. Those using VR will also forget the presence of others after some moments of being immersed, even if there are lots of other people around. A finding that highlights the difference of opinion from the viewpoint of the users and spectators was how they experienced isolation: While the spectators did not like the fact that they were isolated from the user, most of the users enjoyed the sense of isolation and liked the fact that they were in the same context as the others but also somewhere else virtually.

Our findings suggest that from the perspective of VR users in public context, safety is a major concern and they constantly think about bumping into others, falling, or hitting others while interacting with the handheld controller. Having a sense of safety and even a private space within the public context would be beneficial to the users. Furthermore, the users would benefit from sharing their experience with the others in the same context. Being able to switch between realities without losing the sense of immersion is an important experiential factor for users. In addition, having the ability to communicate with the spectators while enjoying the virtual experience will enhance social acceptability.

From the viewpoint of spectators, the findings suggest that if users can share some aspects of VR use with the spectators in the public context, the chances of social acceptability will increase. By being able to share the experience of the VR user and seeing their screens, the spectators will understand the movements and gestures of the users in addition to being motivated to have the same experience. It is also important that those not using the VR feel safe and secure and at no point they should feel that the VR user is recording them without their knowledge. Finally, it is important to provide relevant experiences suitable for specific public contexts to motivate the spectators to experience the VR themselves.

Some of the recommendations are already supported by existing prototypical solutions. For example, ***PubVR_Rec3. Define a VR interaction zone*** can be addressed with the front facing screen of Chan et al. [3], Komiyama et al.'s [18] camera solution can support ***PubVR_Rec5. Define and present safety guidance virtually*** and Koelle et al.'s [17] study findings can be applied to follow ***PubVR_Rec10. Convey that the VR user's camera is not recording***. We find it very positive that such partial solutions already exist in the HCI research field – however, more are still needed.

The results of this research can be used to understand the experiential factors that influence both users and spectators when VR is used in public context. The proposed recommendations concretise the findings and offer practical support for designers and developers of VR systems.

5.1 Limitations and Future Work

The public context chosen for the user test sessions and the spectator surveys was located at a university in which students and staff may be already familiar with VR technology and more in favor of its use in public. With a participant sample that is less experienced with new technologies the acceptability scores would most likely be different. Still, we argue that the experiential factors are most likely applicable at least for similar contexts, since the themes are not dependent on specific participant types.

Future work in this research can be done by expanding the work and extending the research by conducing similar studies in multiple public context such as shopping malls, parks, and other public locations. Additionally, a larger number of users and spectators with a wider range of cultural and educational backgrounds, and age groups can shed light on the social acceptability of VR in specific public context.

Future work with the design recommendations can include involving VR professionals in design case studies and iterating and developing the recommendations towards validated design guidelines.

6 CONCLUSION

Virtual Reality systems and the associated devices such as HMDs have become more affordable, mobile and accessible in the past few years. It is very likely that VR will be broadly used in different contexts in the near future, including public contexts. However, wearing VR devices and interacting in VR in contexts where other people are present can cause negative experiences which need to be overcome to make VR use socially acceptable. We studied the social acceptability of VR by conducting a field experiment in a public context of a university and exploring the viewpoints of the users and the spectators and experiential factors that affects them. Following that, we developed the findings into design recommendations with groups of UX experts. The findings of our study offer a holistic set of insights into the social acceptability of VR for designers and researchers in the field.

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