# Public HMDs: Modeling and Understanding User Behavior around Public Head-Mounted Displays

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**Figure 1. We explore the differences and similarities between public HMDs and public displays with the aim to transfer experiences between both research areas. Passersby transition from the viewing phase to the reaching phase similar to the audience funnel of public displays (A). Attention to public HMDs is also influenced by the honeypot effect (B) and (C). Figure (D) shows the setup in our field study.**

## ABSTRACT

Head-Mounted Displays (HMDs) are becoming ubiquitous; we are starting to see them deployed in public for different purposes. Museums, car companies and travel agencies use HMDs to promote their products. As a result, situations arise where users use them in public without experts supervision. This leads to challenges and opportunities, many of which are experienced in public display installations. For example, similar to public displays, public HMDs struggle to attract the passer-by's attention, but benefit from the honeypot effect that draws attention to them. Also passersby might be hesitant to wear a public HMD, due to the fear that its owner might not approve, or due to the perceived need for a prior permission. In this work, we discuss how public HMDs can benefit from research in public displays. In particular, based on the results of an in-the-wild deployment of a public HMD, we propose an adaptation of the audience funnel flow model of public display users to fit the context of public HMD usage. We discuss how public HMDs bring in challenges and opportunities, and create novel research directions that are relevant to both researchers in HMDs and researchers in public displays.

### ACM Classification Keywords

H.5.m. Information Interfaces and Presentation(e.g. HCI)

### Author Keywords

Head Mounted Displays; Virtual Reality; Field Study



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## INTRODUCTION

Advances in virtual reality (VR) technologies and dropping hardware prices have taken VR HMDs like the Oculus Rift to the consumer market. Several stakeholders are leveraging this opportunity for different purposes. For example, museums often use VR HMDs in their exhibitions to have their visitors experience immersive story telling [36]. Automotive companies market their cars by offering VR experiences that users can explore a car at a dealer or in public [1, 4]. Travel agencies advertise their holiday offers using HMDs [10]. Big shops sell kitchens by using HMDs at the point of sale to support the costumers imagination about the planned kitchen [38]. These developments drove the research community to establish new venues that focus on the use of VR HMDs in daily lives [40]. While we report on a preliminary investigation of this problem in our previous workshop paper [24], this work contributes significantly by reporting on the learned lessons from our deployment, as well as linking the findings to the audience funnel of public displays [3].

This increased use of HMDs in public leads to many opportunities. However, HMDs were not designed for unsupervised use in public resulting in unique challenges. We found that public HMDs, which we define as fully immersive HMDs staged in public without any supervision, are often unnoticed by passers-by, and users are often unaware of the possibility of wearing and interacting with it. These challenges do not only limit the opportunities of adopting public HMDs, but also affect the user's experience.

We argue that many of these challenges are common to those that have been addressed by public display researchers for decades; an HMD is essentially a display, with the difference that it is inside a black box. Therefore we expect that work in unsupervised public HMDs can benefit from the myriad

of public displays research concepts. This includes (1) mental models and (2) frameworks like the audience funnel flow model [3]. However, designing systems that attract attention and motivate users to move from one phase in the audience funnel to another one can be different in case of public HMDs compared to public displays. This might be due to HMDs having different design needs – being small, light and wearable on the user's head – to mostly big public displays that predominantly need to be visible from a long distance.

Thus in this work, we bridge the gap between research in public displays and public HMDs. We do so by reporting on a field study in which we studied the audience behavior when interacting with public HMDs. We then map this behavior to the "audience funnel" [3], which describes the phases that lead to interaction with public displays and the underlying models of attention and motivation. This allowed us to (1) adapt the model to public HMDs, with the aim to support designers of unsupervised public HMDs, (2) identify intersections between the fields of public displays and public HMDs, and (3) gain insights about the possible barriers preventing people from progressing from one stage of the audience funnel model to the following one. Based on our findings, we present novel research opportunities that are relevant to researchers and practitioners who (1) work in public displays and want to bring in their experiences to the novel area of public HMDs, as well as to those who (2) want to leverage the use of HMDs in public space. Our findings indicate that similar mental models exist for the public usage of HMDs across the phases of the audience funnel, but there are differences in the design needs for public HMDs. We discuss the novel research opportunities and challenges of public HMDs, and how existing research in public displays can be leveraged in this area.

## BACKGROUND AND RELATED WORK

In this section we give a brief introduction to the audience funnel concept and introduce the terms *attention* and *motivation*, as defined in the research on public displays.

### Modeling the Behavior of Public Display Users

Many models were proposed to model the behavior of public display users. Researchers proposed spatial models [42, 45] and temporal models [3, 30, 32] for the behavior of public display users. One of the most commonly used models is the audience funnel [3], which describes the different phases of interaction in front of public displays. It was first presented by Brignull and Rogers [3]. They investigated how people gather around a large public display and how they change from "onlookers" to "interaction with the display" and back again. This concept was adapted by the work of Michelis et al. [30], focusing on the observable behavior. They contributed to the model by introducing additional phases, as well as a mechanism to evaluate the conversion rate of a display, i.e., a threshold after which passers-by move from one phase to another. At the outset of interaction, a challenge for public displays is to draw attention. In a second step, the challenge is to motivate and maintain the user's motivation to interact (Figure 2). The conversation rate is determined by counting the people changing from one phase to the next. With this number, the quality of different systems can be compared [30]. In this work, we focus on the audience funnel; we study its applicability on public HMD users, and adapt it accordingly.

### Audience Attention

In public environments a display is not necessarily the central point of interest for humans. People have their own intrinsic goals, like getting to an appointment in time or looking for a certain shop. The challenge for designers is to find a balance between drawing the attention of the users [37] and not overexerting them by integrating into the surrounding environment [48]. A possible approach to attract attention is by behavioral urgency – signaling the need for immediate action [11] – and surprise. Also social effects take place, such as the so called Honeypot effect, which was observed and studied in a myriad of previous works [2, 3, 20, 27, 33, 49]. The honeypot effect refers to situations where the interaction/attention of one or more user motivates others to interact/attend to with the display [3]. A further effect is the landing effect, which describes situations where people pass by a public display, stop, and then return to the display [33]. A structured way of designing and reporting studies on display blindness in the wild is introduced by Memarovic and colleagues [28]. Compared to these works, our work is the first to investigate attention to public HMDs.

### Motivation to Interact

As previously mentioned, people in public environments are very likely not searching for a display to use, but will rather come across a display in a public place. Since the HMD does not have any meaning or function when not resting on a user's head, people need to be motivated to put the HMD on. Similarly, Michelis describes several building blocks that can be used to motivate people to interact with public displays. These are *Challenge and Control*, *Curiosity and Exploration*, *Choice*, *Fantasy and Metaphor* and *Collaboration* [29]. Similar to how the honeypot effect can influence attention to the display, it could also motivate users to interact with the public display. Another social aspect is the staging effect, which on one hand, some users interact solely to be noticed by others [7], while others resist interaction to avoid social embarrassment [6]. Motivation to interact with public HMDs was never studied before, our work attempts to close this gap in research.

### Interaction in Public

There is a large body of research that looks into how the presence of others influences a single persons actions. People have a certain role like being an instructor or security officer which implies a certain expected behavior and will foster or prevent certain types of actions. Furthermore, people in public environments might be related to each other, e.g., they might be friends or complete strangers [14]. Models that describe these effects are, to name but few, proxemics [17] – the study of how humans physical position to each other – or social facilitation – behavior change due to the mere presence of others – (see [43] for an overview). According to Mueller et al. [32], the important factors for motivating interaction in front of public displays are *The Presentation of Self*, *The Selective Control of Access to the Self*, *The Control over one's Personal Data*, *Social Behavior*, *The Public Nature of the Space*. In contrast to the use of public displays *The Selective*

*Control of Access to the Self* is more relevant for the usage of HMDs, as covering the eyes with the HMD means the loss of visual knowledge of the environment. The user might be uncomfortable if touched or might be worried about personal belongings, such as personal bags that could be left on the floor while using the HMD.

#### System Influence on the Behavior of Public Display Users

While we earlier discussed how *social aspects* influence the behavior of public display users, researchers also studied how the setup influences users' behavior. For example, Koppel et al. found an influence of the configuration of multiple displays on how users position themselves while interacting [22]. Gentile et al. found that the size of the audience around the display influences the distance from which users interact, and suggested placing/removing seats around the display to control this relationship [13]. Dalton et al. found that the building's architecture has a strong influence on the noticeability of displays [8]. Mueller et al. found that users were influenced by traffic lights [33]. Furthermore, the mere presence of displays could encourage communication among strangers [34, 44]. These effects were never investigated for public HMDs before, but the underlying psychological reasons behind them suggest that similar behavior could be expected with public HMDs. This presents a novel research opportunity.

## ADAPTING THE AUDIENCE FUNNEL TO PUBLIC HMD

The audience funnel for public displays gives a starting point for the design of unsupervised HMD systems in public environments. An HMD is a form of a display presented in public. Due to its form factor and functionality we expect different inhibition thresholds compared to traditional public displays. This is because it is much smaller than a public display, the display is hidden inside a black case, and it requires touching the HMD and putting it on one's head, which in turn results in not being able to visually perceive the surrounding environment.

In this section we will discuss each phase for interaction with public displays [32] adopted to HMDs (Figure 2). In our study we used a common setup consisting of the HMD itself, controllers, a second screen showing the experience of the HMD user and a sign promoting or describing the HMD and the experience.

*Passing By:* The main concern for the design of a public display is to attract the attention of the people passing by. Attention can be generated by abrupt appearance of objects, changes of luminance, contrast, moving or looming stimuli or user representation [19, 21, 47]. In contrast to a public display, HMDs are mostly black cases, with the display hidden inside and therefore unobtrusive. Some HMDs or controllers have glowing lights attached to it, e.g., the windows mixed reality headsets [31] or Sonys' Playstation VR [23]. HMDs in public are very likely to be presented with an additional public display that shows the HMD user's experience. However this means extra cost, need for space, maintenance and further.

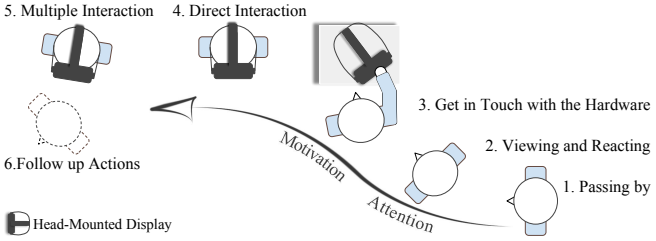


**Figure 2. We adapted the Audience Funnel for public displays [32]; we replaced "Subtle Interaction" with "Get in Touch with the Hardware".**

Therefore in our study we will focus on the question, if the passer-by's attention is aroused by recognizing the HMD or the public display accompanying the HMD?

*Viewing and Reacting:* When people react to a public display, e.g., by smiling or turning their head, they enter the viewer phase. The challenge in this phase is to keep the passer-bys' attention. This is difficult, as people do not expect anything useful from public displays [29]. To overcome this, several sources propose not to make the display look like a display, but integrating it into the environment or using physical objects placed next to the screen [46]. HMDs themselves own some of these attributes. They do not look like displays and the controllers are physical objects that invite to be touched. As mentioned before, they do not offer any visual stimuli or information that promises the passer-by an incentive to use. In contrast to public displays, the users mental model of an HMD in public spaces will change within the next years due to its pure novelty. This needs to be taken into account when researching on public HMDs but also gives the opportunity to influence this mental image in the next years.

In our field study we will focus on the question: what are the factors motivating passers-by to get closer to the HMD?

~~*Subtle Interaction*~~ $\rightarrow$ *Get in Touch with the Hardware:* If a user's motivation exceeds a certain threshold, s/he will start with subtle reactions to the interactive display; at this stage they are referred to as *subtle users*. These interactions mostly occur from several meters away [46]. During this phase the user performs different actions and needs to recognize the interactivity of the display. For HMDs, this phase might not take place with current systems. In order to interact with an HMD, the user needs to move closer and even touch the device, being in the center of interaction. Therefore, we propose to call this phase *Get in Touch with the Hardware*. This constitutes one of the adaptations of the audience funnel theory to fit the context of HMDs. In addition to explaining to users what can be done and how, they also need to be motivated to overcome the barrier of touching the HMD. Exemplary barriers might be hygienic reasons, the respect of others' property, the fear of damaging hardware, lack of interest in technology, or social embarrassment due to the "staging effect", i.e., attracting attention of surrounding people [6].

Therefore in our field study we will focus on the question if there is subtle interaction phase or if the user gets in touch immediately after reacting to the HMD.

*Direct Interaction:* The direct interaction with a public display starts when the user is standing central in front of the public display and/or performing a specific registration action [46]. In this phase users are called "direct users" and will attract significant attention of other people passing by, view-

ing or trying subtle interactions due to the honeypot effect. Furthermore, the experience needs to be challenging, but still the direct user needs to maintain control. The phase of direct interaction overlaps with the traditional research on interaction in VR systems; it is well documented how to design systems and experiences for direct interactions (e.g., [16, 18]). Also there is a lot of knowledge about how to build immersive system in order create presence, the feeling of being in the virtual world (e.g. [41]), and possible causes that break it. But there is still a gap in research on how to design these systems for public environments like fairs or shops or semi-public environments like households [15]. However there is a number of issues arising that need to be taken into account, like security of the user, enabling a high feeling of presence when being surrounded by strangers, communicating the functionalities in a running experience, which is not considered when designing an experience for the users home or a laboratory.

In this work we do not focus on exploring design parameters for VR in public space, but rather want to provide insights on issues that might arise when presenting VR experiences in public space without prior knowledge about the user.

*Multiple Interaction:* In the context of public displays, multiple interactions refer to cases where a user interacts with several displays after one another, or returns to interact with the same display again. The applicability on public HMDs requires longitudinal field studies to observe returning users.

*Follow up Actions:* A sample follow up action on a public display is to take a picture of a public display after the interaction due to the positive experience. We expect similar follow up actions with public HMDs. However, we also expect new types of follow up actions due to the different nature of public HMDs. For example, there could be consequences to aspects such as motion sickness, or being isolated from the real world.

## FIELD STUDY

We conducted a field study in order to find out if (1) we can identify the similarities and/or differences to the audience funnel, (2) to gain insights if the attention and motivation models hold in our setup, and (3) explore the threshold to transition between the phases in an HMD setup. The field study took place throughout an open university day, in which high school students and graduates visited our university.

Out of all the interactions throughout the study, we interviewed 19 different participants who were either passing by or interacted with the HMD. All of them were high school students or graduates aged between 16 and 20.

### Apparatus

A Lenovo Explorer Windows Mixed Reality Headset with the respective controller was used. The computer running the software was an HP Envy Computer with a Core i7-6500k Processor, GeForce-GTX 1080 graphics card, 16 GB RAM and Windows 10. The experience presented in the HMD was the Lab [12], an entertaining tech demonstration that introduces interaction metaphors for VR. The HMD was placed on a chair with an A4 poster next to it that said *"Put me on"*, with a picture of a man wearing the HMD and holding the

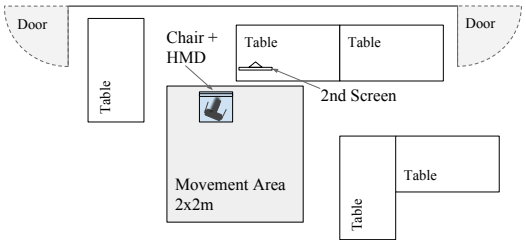


**Figure 3. Floor plan of the setup during the event.**

controllers in the hands (see Figure 1D). A display was placed next to the HMD that showed the current view of the HMD and respectively the users view during interaction. We did not use headphones since the Lenovo HMD does not come with mounted headphones; pilot tests showed that it can be very difficult for untrained users to handle the system with external headphones. The equipment was placed clearly visible on the side of a big room next to an entrance with a walkable area for the VR experience of minimum 2x2m. Next to it another VR Demo took place (Figure 3).

### Procedure

The demo was running all the time, therefore the starting point in the experience and the experience itself was different for each user. No official person or operator was standing nearby the demo. The experimenter watched the demo from a remote place in the room and observed people passing by. The experimenter measured the time the user wore the HMD, and logged the observations as people interacted with the HMD. We define interaction as every form of referencing oneself to the HMD,e.g., visually by looking at it, physically by touching it, or by positioning oneself close to the HMD, or by putting the HMD on. The experimenter did not reveal himself until a passer-by showed clear signs of leaving and unwillingness to interact with the HMD anymore. At this point the people were asked for an interview. The experimenter explained the goal of the study and introduced the audience funnel of public displays to the participant. Based on this, a semi-structured interview took place in which the participants were asked about their experiences in each of the phases and the issues they experienced or even prevented them from going through all the phases. The interview was kept simple; we used simple terms rather than technical ones associated with the audience funnel; for example, we did not ask “when did you transition from the viewing and reacting phase to interaction?” but rather “after noticing the HMD, how long did it take you to decide that you want to interact with it?”. The monitored events were reviewed during the interview. The recorded data was analyzed for each phase of the audience funnel separately. Similar events, like recognizing the screen or asking for help, were clustered in respective groups and counted.

## RESULTS

We discuss the results in the order of the phases of the audience funnel in the following.

### Passing By - Visual clutter conceal the HMD

From the 19 interviews we conducted, 5 people did not recognize the HMD at all. 4 out of these 5 realized the display on

the table next to the HMD, but not the HMD itself. For them the connection between the display and the HMD was not clear, therefore they did not look for a relationship between the two. 1 person said she is just not interested in technology.

14 people transitioned to the viewer phase. The attention of 8 of them was caught by the display first, 6 saw another person using the HMD and only 3 reported to have realized the HMD first, as they are interested in the technology. During the viewer phase we observed most people looking at the different parts of the demonstrator, namely the HMD, the poster and the display. 4 of the users looked around in the room searching for an official authority allowing them to interact with the HMD. This behavior was also reflected in the interviews. The major hindrance for the users was understanding the context (N=5) and the experience (N=5) in the demonstrator. Viewers mainly were interested to whom the demo belongs to. The viewers related everything happening around the display as belonging to the content presented on it. This includes another VR demo five meters away, and the booth of a different department next to our demo. This hindered 3 persons from putting on the HMD. 4 reported reading the poster with instructions.

Not understanding the experience in order to know what they could expect was a challenge. 3 users did not know what to do with the HMD and hence did not try it out.

#### Getting in Touch with the Hardware

One situation that could be interpreted as a *subtle interaction* was two persons approaching the HMD and lifting it up in order to see the effect on the display to create an understanding of the function of the HMD. But according to the original definition, this is not a subtle action since it forces the user to go into the central interaction zone, what makes him/her highly visible for others. This is contrary to subtle interactions, which are conducted inconspicuously in order to not draw the attention of others. A female participant reported to look for interaction possibilities with the public display itself. A child tried out several interaction metaphors with the second screen and even tried to use it as a touchscreen (Figure 1, A). This shows that the second screen could distract passers-by.

#### The Interaction Phase

*The Interaction Phase* was reached by 6 persons. We did not observe any hindrances at the transition into the interaction phase. People from one group helped each other to take on the HMD and controllers. All the subjects reported it was easy to go to the HMD and take it as the sign demonstrated, if there were others using the HMD before them (N=2), or if they asked bystanders if they can use the HMD (N=2).

We do not analyze the experience itself in this study, but want to point out the reasons why people quit their interaction after approximately two minutes. 3 users had trouble to hold the controller correctly, although it was shown on the poster. 1 user was pressured to stop interacting because his company wanted to leave the installation. The other 5 reported to have ended the interaction as there was nothing to do anymore, although they did not perform any interaction in the virtual environment. We suppose that this was due to the wrong usage of the controllers which made it impossible to press the buttons. Generally the passers-by had no prior experience in using HMD systems and therefore did not know anything about the interaction possibilities and the goal of the experience.

We made some additional observations that might be beneficial to know for future work. In 2 cases, couples were going through the HMD experience. In both situations, the partner who was in the real world did not talk to the HMD user. The real-world partners reported that they did not wish to disturb the HMD user, as they did not know anything about what the HMD user was doing. 1 direct user reported that she was happy to have her partner with her to take care of her bag. Only 1 participant used the chair for the experience.

#### The Follow-up Actions

showed situations like 1 user explaining her experience to others after she had taken off the HMD (see Figure 1, top right). In the interview she explained that she liked the experience very much, but could not imagine what she might experience in the VR beforehand. That is why she wanted to convince others that might have the similar reservations to try it out. This also attracted other people to have a look at the HMD, which is a variant of the honeypot effect [3]. In particular, a younger child using the HMD attracted a number of people gathering around the demo. Figure 1(A), shows the beginning of her interaction phase with people already gathering. In another case, a girl passed on the HMD to her partner while smiling and trying to convince him to try it out.

#### Limitations

The study was thoroughly designed and the data was carefully analyzed. However, there are limitations in our approach. Although we planned to have a lot of movement space around our demo, it got very crowded during the day. It was not reported as a problem in the interviews, however people lingering around in front of the HMD blocked the view on the HMD and/or hindered getting closer to the HMD, which is also reported as a challenge in the research on public displays [32]. Also, due to the nature of our study of creating first insights on the topic, we decided on our own what we think is a common used HMD system in public exhibitions, consisting of the HMD, with controllers and a second screen. In particular the second screen attracted more attention than the HMD with the controllers. This might have altered the results for the *Passing By* and *Viewing and Reacting Phase* compared to displaying the HMD on its own. However the motivation for the users mainly came from the HMD system. But as the display had such a important role in drawing attention future work should look into how the public HMD can integrate the purpose of the public display to draw the attention and communicate functionality to the user.

## DISCUSSION AND RESEARCH OPPORTUNITIES

We conducted a field study with an unsupervised HMD setup that was presented in public. In the following we discuss our observations on similarities to public displays and how public HMDs bring in challenges and opportunities, and create novel research directions that are relevant to both researchers in HMDs and researchers in public displays

#### Established Concepts are Applicable on Public HMDs

We were able to show that the phases of the audience funnel exist in the deployment of public HMDs, but still differ in the arising challenges. The field study supports our assumption that no subtle interaction phase exists for HMDs and therefore we suggest to call this phase *Get in Touch with the Hardware* which describes this part of the interaction better for public HMDs. In our discussion we will compare every step of the audience funnel to our observations.

#### Public Displays can help Attract Attention to Public HMDs

During the *passing by phase* 4 people saw the display but not the HMD. 2/3 of the passers-by initially saw the second screen and then the HMD. Despite the HMD's glowing controllers, they did not draw extra attention to it as reported by Ju et al. [19]. Further design considerations must be thought through to make the HMD draw attention on its own in order to avoid confusion for the user, as the relation between screen and HMD was not clear at the first point. One possibility to draw attention is to attach displays to the HMD directly in order to create attention or communicate functionality (e.g., [25, 35]). However the users' mental model about the value of a public HMD might change in the future, as today HMDs are very novel.

#### Public HMDs Need to Communicate the "Why"

When entering the *Viewing and Reacting* phase the attention is attracted and the users start to visually explore the system, they mainly look for meanings. The public HMD, like the public display, is a playful tool that therefore should address why to use it in order to stimulate the users inner motivation [39]. The viewers try to figure out whom the demo belongs to, what the experience is about and what their benefit would be if they would participate. This "why" is well known in the field of human computer interaction and is used in the design of public displays [9]. A conflict might arise for public HMDs between providing a second screen to foster the motivation of the users to participate in the demo and spending extra money for development, deployment and maintenance of a second screen. In order to safe these costs in the future, HMDs need a self-explanatory design. This creates a novel research opportunity. There is a need for systems that attract the attention of passers-by to public HMDs and further motivate the use of the HMD. Future solutions could investigate ways to communicate that passers-by are allowed to interact, without an authority present that allows the usage, explains the experience, and how to interact in it. For example, the suggested display could show an avatar inviting passers-by to try the HMD.

#### Public HMDs Require Interaction Instructions

We did not find any evidence for *subtle interactions* in our study. The challenge of communicating interactivity is also well known in public displays, but in contrast to HMDs, interaction with public displays is mostly remote (e.g., using mid-air gestures [26] or gaze [20]). However we see the importance of this phase to motivate the users and prepare them for using the HMD. As we could see, not giving proper instruction leads to trouble putting on the HMD, and holding the controllers correctly, which resulted in stopping the interaction. After putting on the HMD, it becomes even more difficult to provide instructions from outside the virtual world. Therefore we refer to this phase as *Get in Touch with the Hardware* and highlight the design needs contrasting to public displays.

A novel research opportunity is to investigate how to maintain interactions by instructing users how to interact. This could build upon work that investigated how to best instruct users in a way that achieves *immediate usability* [32]. The main design challenge will be how much information and instructions are given before putting the HMD on, and when wearing the HMD. Further HMDs enable a highly immersive and emotional experience which could be interrupted when users struggle to know its purpose or how to interact.

#### Direct Interaction is different in Public HMDs

The *Direct Interaction* phase is very different between the public display condition and the HMD condition. There is a lack in research on how to design these public environments, e.g., by following guidelines. There is a number of questions like how to handle the personal safety and security, e.g., from bumping into physical objects or worrying about personal belongings from theft. Participants of our study felt safer interacting in VR with other people around to, for example, "hold their bags". Altogether 6 of 19 users reached the interaction phase. All of them quit the demo as they did not know what to do anymore. This is due to the fact that the experience was running the whole time and therefore the participants get in the demo at any point, missing the tutorial. We also logged cases where the user's company left because of not sharing the same goal as that of the user, which is also reported in studies on the usage of public displays.

The issues related to the users' safety and security and the need to maintain communication create a novel research opportunity for the case of public HMDs, which is also recognised by other work looking into the aspect of making HMD experience social in mixed presence living room environments [15]. From this we learn that public HMDs should embrace and encourage group interactions by augmenting the whole room around the HMD user [15]. Additional ways that need less room are techniques that establish communication between HMD and non-HMD users by, for example, visualizing the user's eyes [5] or entire face [25] to non-HMD users. Achieving a trade off between feeling present in the virtual world and security is a challenge for future research in this area.

## CONCLUSION

In this work we presented a study that allowed us to gain insights on the applicability of research in public displays on the context of public HMDs. We discussed the similarities to findings from public display research, and underlined several novel research opportunities for future work. We found a high similarity between public displays and unsupervised presentation of HMDs in public spaces. Therefore we encourage the exchange of knowledge and experiences between the public displays and the HMD communities. A next step is to research on the presented opportunities, e.g., the design of the HMD, in more detail.

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