Working with XR in Public: Effects on Users and Bystanders

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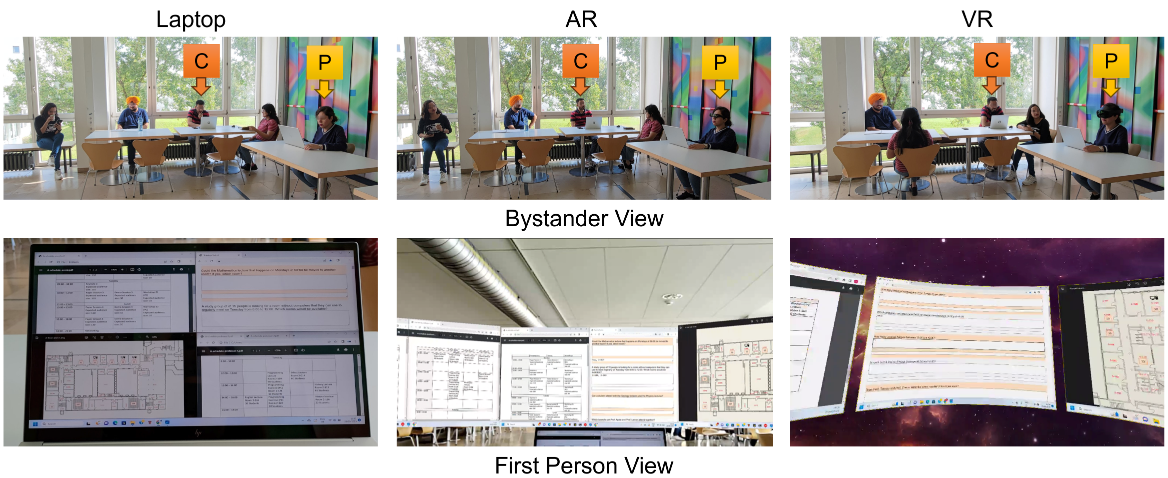

Figure 1: The top row shows the view of a bystander passing the area of the study for all three conditions (LAPTOP, AR, VR). C indicates the coordinator of the study and P indicates the participant. All other people are bystanders. The illustrations are reenactments of the actual situations. The bottom row shows the participant's views during the task for each condition.

Abstract

Recent commercial virtual and augmented reality (VR / AR) devices have been promoted as tools for knowledge work and research findings show that they can be beneficial. One benefit is the possibility to display virtual screens which could be especially helpful in mobile contexts, in which users might not have access to an optimal physical work setup. Such situations often occur in public settings, for example when working on a train while traveling to a business meeting. However, using such devices in public is still uncommon, which motivates our study to better understand the implications of using AR and VR for work in public on the user itself, and also on bystanders. Therefore, we present initial results of a study in a university cafeteria comparing three different systems: a laptop with a single screen; a laptop combined with an optical see-through AR headset; a laptop combined with an immersive VR headset.

Keywords: Virtual Reality, Augmented Reality, Extended Reality, Knowledge Work, Public Environment

1 Introduction

Using extended reality (XR) for knowledge work has recently gained popularity through the promotion of current commercial off-the-shelf devices as tools for work, such as the Meta Quest Pro and the Lenovo Think Reality glasses. With XR we refer to both augmented reality (AR) and virtual reality (VR) technologies. Prior research has also demonstrated the potential benefits of using XR for knowledge work, such as how VR can be used in open office spaces to reduce distractions [7] and how new interaction possibilities provided by VR can improve the performance for certain tasks [3, 2]. In addition, researchers have evaluated how the large display space provided by AR and VR can be used in the context of knowledge work [5, 6]. These properties of XR seem especially advantageous in mobile scenarios, where work environments can be less optimal, such as in crowded spaces with many distractions, or in confined spaces that limit the size of physical hardware [4], for example, in public transportation or in a café. However, prior studies on supporting knowledge work have focused on new technologies evaluated mainly through laboratory-based experiments which are typically not representative of public spaces. Therefore we see the need to explore how users of XR devices *experience* working with these devices in public spaces, and also to investigate how people around them react to the currently relatively rare sight of XR-users in public.

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2 Methodology

The study was conducted as a within-subjects design with one independent variable INTERFACE having three levels, LAPTOP, AR and VR. LAPTOP was chosen as the baseline, as it is commonly used for working in public spaces. For AR and VR, we chose commercially available headsets with current software that can connect to a laptop as an input device while displaying multiple virtual screens. Specifically, we used the Meta Quest Pro in combination with the application "Immersed" [1] for VR and the Lenovo Think Reality glasses A3 with its built-in display manager in AR. Both devices were designed and promoted by their respective manufacturers as tools for knowledge work. For all conditions we used a 16-inch HP Envy laptop and an external mouse. While participants could only use the laptop screen in the LAPTOP condition, they could use three virtual monitors in AR and VR (see Fig. 1).

The study was conducted in three sessions, one for each condition. All sessions started in a lab in which participants were introduced to the device and completed a 20 minute training task. Then, participant and coordinator moved to different places in the public cafeteria and the participant completed a task for 35 minutes while the coordinator was observing the situation (see Fig. 1). Afterwards participants answered various questionnaires and also several bystanders were asked to fill out a short online questionnaire. Then, participant and coordinator returned to the lab for a short interview. Three similar but different tasks were used for the three conditions which were counterbalanced along with the order of the conditions. Eighteen participants (all students or employees at our university) successfully completed the study (5 female). Their mean age was 25.67 years ($sd = 5.2$). The number of bystanders was counted at the beginning and end of each session resulting in a minimum of 7 and a maximum of 37. In total, we collected 231 responses from bystanders, given by 209 different people (104 female, 103 male, 2 others).

3 Results

In the following, we will present initial findings of our study. We used a repeated measures analysis of variance (RM-ANOVA) to analyze the data obtained through the study. For subjective data, we used aligned rank transform (ART) [8] and for post-hoc comparisons we applied Bonferroni adjustments at an initial significance level of $\alpha = 0.05$. In the following we use m to abbreviate the arithmetic mean and sd for standard deviation. We used axial coding to structure statements from free-text-fields and interviews.

Safety and Isolation We found a significant main effect of INTERFACE ($F(2,34) = 16.824, p < 0.001, \eta_p^2 = 0.497$) on participants' feeling of safety rated on an 11-point Likert scale (1 = threatened, 11 = safe). Post-hoc tests indicate that they felt significantly more safe in LAPTOP ($m = 8.44,\ sd = 2.2$) as compared to both AR ($m = 7.61,\ sd = 2.03$) ($p = 0.04$) and VR ($m = 5.94,\ sd = 2.67$) ($p =< 0.001$). In addition, participants felt significantly safer in AR than in VR ($p = 0.009$). Participants also stated that they liked that they could see the real environment in AR (P5, P15, P21, P22, P24) which made them feel more secure (P5) and some participants (P16, P18, P24) did not like being unaware of their physical environment in VR. These combined findings might indicate that participants' feeling of safety is related to how well they can perceive their physical environment.

Only P5 used full passthrough throughout the VR condition, and P9 switched to passthrough occasionally. All other participants chose one of the virtual environments, in which they felt comfortable or which they thought looked nice. Fourteen participants did not even use a passthrough window in VR, except for the keyboard, as they thought it was distracting (P4, P14, P16), was not needed (P7, P11, P17, P18, P19, P23), felt more focused and immersed without passthrough (P23, P24) or felt like they had less space for the task (P12). However, P6 regretted not using passthrough, as she wanted to see who was talking. Of the three participants who used a passthrough window, P8 moved it out of sight as it interfered with the task, and P9 and P22 had one on both sides but made little use of it during the task.

Standing out We also found a significant main effect of INTERFACE ($F(2,34) = 6.214, p = 0.005, \eta_p^2 = 0.268$) on participants' rating of feeling more observed (1) or unobserved (11). Post-hoc tests indicate that they felt significantly less observed in LAPTOP ($m = 7.22,\ sd = 2.76$) as compared to VR ($m = 4.78,\ sd = 2.67$) ($p = 0.004$). P23 also stated that he felt people were looking at him in VR. From observing the bystanders, we know that this feeling is valid. We observed that no bystander seemed to have any interest in the participants during the LAPTOP condition, as they were blending in well with other people working on their laptops. During the AR and VR conditions, individual bystanders stared at the participants for multiple seconds, some also stared repeatedly and some were obviously talking about the participant. However, the majority of bystanders either did not, or pretended not to notice the participants or only looked at them in a very subtle way. Some seemed to find excuses to look such as when they walked past the participant. In addition, while in the LAPTOP condition only 65% indicated that they noticed the participant, compared to 93% and 95% for AR and VR respectively. Fisher's exact test revealed that there is a significant effect of INTERFACE on whether bystanders noticed the participant or not ($p < 0.001$), with post-hoc tests showing that in the LAPTOP condition they noticed the participant significantly less often than in AR ($p < 0.001$) and VR ($p < 0.001$). These findings indicate that XR-users stand out, and that users are sensitive to that, especially in VR. However, the reactions of the bystanders remain mostly subtle and we did not observe any actions that could have been dangerous for the participants.

4 Conclusion

With the goal of observing how using XR devices in public affects the users and also the bystanders, we conducted a study in which participants used an AR and VR HMD as well as a LAPTOP in a university cafeteria. Initial findings indicate that, at the time of the study, using XR in public still makes users stand out, yet we observed mainly subtle reactions from bystanders and this behavior might change if XR becomes more widespread in the future. Our findings also suggest that seeing the physical surrounding can increase users' feeling of safety, yet, 14 out of 16 participants stated that passthrough windows in VR were unnecessary or distracting. Therefore, more research is required to integrate passthrough in a sensible way.

In future work, we will analyze the full data-set collected during our study, including a range of questionnaires and interviews from the XR users and more detailed descriptions of how bystanders experienced the situations. This will allow us to present a more complete picture of the current perception of XR use in public as well as possible challenges.

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