Evaluating User Experience in Tangible Augmented Reality

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ABSTRACT

In Virtual Reality (VR) applications, a lot of attention is already paid to how real a physical proxy object you interact with needs to feel in order to provide a good User Experience. However, when evaluating Augmented Reality (AR) applications, this is still strongly underrepresented. Especially in the area of Tangible Augmented Reality (TAR), however, the measurement of Presence is of great importance. Since virtual objects are integrated into the real world, it is important that the interaction with them feels as realistic as possible. Therefore, a possibility should be created to be able to determine User Experience in AR applications as well, in order to be able to compare applications with each other. The measurements carried out in the field of VR, such as the determination of Presence, should be used as a reference.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *Haptic devices.*

KEYWORDS

tangible augmented reality, optical see-through augmented reality, tangible interaction, haptic devices

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1 INTRODUCTION

When interacting with physical objects representing virtual objects, it plays a major role that the interaction with the physical object feels as if you are actually interacting with the virtual object you are being shown. To be able to measure quality in this respect in Virtual Reality (VR), a number of different questionnaires have been developed [9]. For the field of Tangible Augmented Reality (TAR) no comparable questionnaires could be identified in literature. In TAR, a real physical object is overlaid with a virtual representation, i.e., to move the virtual object, one has to interact with the corresponding physical object. The use of physical objects hereby creates a natural interaction in Augmented Reality (AR) [1]. This advantage can be exploited especially in optical see-through Augmented Reality using HMDs, where both hands are free to interact. An approach has to be established to also measure the experience in AR/TAR. Here, it is important to orient oneself on the experiences that have been made in the area of VR and to coordinate possible measurement methods with VR experts. Because of the similarities between VR and AR there is an intersection of measurement methods that can be used in both areas. In addition, further investigations will be necessary, each of which will only make sense in its specific area.

In this paper we will highlight the importance of measuring User Experience and especially Presence in AR and TAR. We also highlight the specifics of optical see-through Tangible Augmented Reality in contrast to Virtual Reality and describe why it is not possible to directly transfer existing VR methods to AR/TAR. Furthermore, we present a first approach for measuring Presence in Tangible Augmented Reality.

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2 EXISTING APPROACHES

There are a variety of ways to measure User Experience. In addition to behavioral and physiological measures, questionnaires are primarily used. Schwind et al. [9] provide an overview of questionnaires for measuring Presence in VR. The most prominent of these are the VR SUS Presence Questionnaire by Slater et al. [10], the PQ questionnaire by Witmer and Singer [11] and the IPQ questionnaire [4].

We are not aware of any questionnaire measuring Presence in an AR setting. The ARI (Augmented Reality Immersion) questionnaire by Georgiu and Kyza [3] was designed for location-based AR applications and assesses a definition of immersion from game-based research. It considers factors such as emotional attachment and interest, and thus differs significantly from immersion defined in VR, where it is closely related to Presence.

Nebeling et al. [6] developed the Mixed Reality Analytics Toolkit (MRAT) for analyzing the experiences of users in AR and VR applications. It is specifically designed for collection and visualization of quantitative or spatial data like task completion times or what users looked at. Therefore this toolkit is not suited for measuring Presence which is typically assessed via qualitative questionnaires.

In order to create a qualitative questionnaire for measuring Presence in Augmented Reality, it must be examined to what extent existing VR tools can be used for this purpose. Therefore, it must first be considered to what extent VR and AR/TAR differ from each other.

Figure 1: Comparison of a similar scene in VR and optical see-through AR. Left: VR environment with completely virtual object. Center: Photo of the real scene with physical object. Right: Real scene with physical object augmented by an optical see-through AR overlay.

3 SPECIAL FEATURES OF OPTICAL SEE-THROUGH AR COMPARED TO VR

Virtual Reality and Augmented Reality have similarities, but there are also a number of aspects in which the two areas differ from each other. The distinct feature of VR is that both, the environment you are in and the objects you see and interact with, are virtual (see figure 1 left). In contrast, AR blends virtual objects into the real environment, so you perceive a mix of reality and virtuality (see figure 1 right) [5]. If optical see-through augmented reality is used instead of video see-through augmented reality, the virtual objects are also slightly translucent due to technical limitations [8]. The physical element with which one interacts is therefore perceived to a certain extent, even if it is overlaid by a virtual object (see figure 1 right). Because of the differences mentioned above, it is not possible to transfer already existing evaluation methods without adaptations from VR to AR.

4 SUGGESTIONS FOR ASPECTS TO BE CONSIDERED IN AR QUESTIONNAIRES

To generate initial ideas for an AR questionnaire to measure Presence, we first analyzed the most widely used VR questionnaires, the IPQ [4] and the VR SUS Questionnaire [10], to see if they could be used in whole, or at least in part, for an AR questionnaire, or could be converted for AR through minor adaptations. We found that the IPQ is very VR-related and mainly deals with the sense of being present in the virtual reality. Only a very small amount of questions concerning sense of reality could be transferred to an AR questionnaire. Regarding the VR SUS, however, we identified the option to transform 4 of the 6 questions into an AR setting. Merely questions number 3 and 6 were too VR-related.

Our goal was to measure the tangible qualities of Tangible Augmented Reality applications. However, there are many AR applications that do not use tangible interaction and which would therefore be excluded when generating a TAR-specific questionnaire. Therefore we decided to generate two versions from the 4 identified VR SUS questions: One questionnaire for pure AR experiences with focus on the visual perception and one additional questionnaire incorporating tangible interaction. This allows to evaluate pure AR applications with the AR questionnaire and, in the case of TAR applications, to additionally test the interaction experience with the TAR questionnaire.

By transferring the VR SUS questions as closely as possible, we arrived at the following items for AR-Presence:

- Please rate on a scale of 1 to 7 how much you felt you were in a place without visual overlays, where 7 is your normal feeling of being in a place.
- To what extent were there times during the experience when the visual overlays were reality for you?
- During the time of the experience, which was the strongest on the whole, your sense of being in an unchanged reality or the feeling being in a changed reality?
- Consider your memory of being in the augmented environment. How similar are your visual memories of the displayed objects compared to memories of other objects you have seen today?

And for TAR-Presence:

- Please rate on a scale of 1 to 7 how much you felt you were interacting with the visual overlays, where 7 is the feeling of actually interacting with the digital visualizations.
- To what extent were there times during the experience when the visual overlays felt real during the interaction?
- During the time of the experience, which was the strongest on the whole, the feeling of interacting with the visual overlays or the feeling of interacting with the physical models below?
- Consider your time in the augmented environment. How similar are your memories of the interactions with the objects in the augmented environment compared to memories of interactions with other objects that you performed today?

Using two questionnaires with four items each can be a first step to measure the feeling of Presence but does definitely not serve as a measuring tool for the overall experience of users in the augmented environment. For a comprehensive assessment of the experience in (Tangible) Augmented Reality applications, a set of questions has to be determined collaboratively by VR and AR experts. Furthermore, the resulting questionnaires have to be evaluated extensively to ensure their validity.

Figure 2: Excerpt from the in-AR questionnaire: Selection with the help of the interactive pen (left) and selected option (right).

5 EXEMPLARY IMPLEMENTATION AS IN-AR QUESTIONNAIRE

In Virtual Reality research, the effect of leaving the VR environment for filling out questionnaires has already been investigated and the potential benefits of using in-VR questionnaires have been shown [7, 9]. Additionally, toolkits for enabling such questionnaires are available for VR [2]. Although research on the effects of leaving the augmented environment for a questionnaire is missing, there are very practical reasons to consider in-AR questionnaires. Even though optical see-through AR displays promise a more or less unobstructed view of reality in the absence of virtual overlays, the glasses prevent a completely clear view. Therefore, it is necessary to flip up the display (HoloLens 2) or even remove the entire HMD (HoloLens 1) to fill out questionnaires. This is not only a break from AR to reality, but the viewing angle is changed by the reorientation of the display, which would make a recalibration necessary. Especially in the case of intermediate questionnaires, which have to be filled out many times, this would lead to an unacceptable additional effort. For evaluating Presence in TAR applications, it is also possible to make use of the advantages of tangible interaction by providing users with a physical object representing a virtual pen. Considering the example of our presence questionnaires, these can be displayed directly onto the interaction area as virtual overlays (see figure 2). In a recent study in which we are making use of in-AR questionnaires, these are finding great acceptance.

6 CONCLUSION

In this position paper we explained why it is necessary to design questionnaires to measure the experience in (Tangible) Augmented Reality (TAR). We highlighted the importance of considering VR questionnaires as well as the experience with them when generating these questionnaires. In addition, we demonstrated that the intersection of AR and VR requires collaboration between AR and VR experts in generating standardized measurement methods to determine experience for both the VR and AR domains. We explained a first approach to transfer aspects from existing VR questionnaires to AR and TAR, but also showed that the resulting questionnaires are not sufficient to measure the experience, but have to be extended by further aspects and evaluated extensively at the end. Furthermore, we presented our approach to measure Presence in TAR, using a tangible in-AR questionnaire.

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