Evaluating the User Experience of Mobile VR

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ABSTRACT

For decades, Virtual Reality (VR) systems have provided unique user experiences, inspiring researchers to develop methods for assessing user experiences of VR. Until recently, VR was restricted to tethered configurations in indoor settings; now, portable systems such as Oculus Quest combine excellent immersion with mobility, allowing VR to move into public spaces and unpredictable contexts. Just as the emergence of mobile screen-based computing required the development of new methods of design and evaluation, so the emergence of mobile VR prompts us to consider whether existing evaluation methods need to be augmented. In this paper, we describe our method to evaluate the user experience of a VR application that replicates flooding in the city of Melbourne, Australia. We conducted an empirical study with this application and a mobile VR device, and we assess the user experience with a number of qualitative and quantitative methods that are suitable for field studies.

CCS CONCEPTS

•Human-centered computing~Human computer interaction (HCI)~HCI design and evaluation methods

KEYWORDS

Virtual Reality, Mobile VR, User Experience, Virtual Environments

1 Introduction

In the years after 2000, HCI researchers asked how we should evaluate the UX of mobile devices [1–4]. New methods were developed, including recreating outdoor contexts in laboratories, and doing field studies. Now VR, too, is going mobile in the form of systems such as Oculus Go and Quest. These provide novel features such as six degrees of freedom and a positional tracking system (Figure 1) that provide a greater sense of embodiment, more immersive experiences, higher sensory stimulation, more engagement and more behavioural actions than tethered VR platforms [5].

Figure 1: User testing the positional tracking system

Moreover, mobile VR platforms are becoming more affordable and accessible and they might be used in a broader range of contexts in the near future [6]. Recent research is exploring how users and spectators engage in the use of these devices in outdoor locations and proposed design recommendations [6,7]. This suggests that, as with mobile phones, HCI researchers should investigate how best to evaluate the UX of mobile VR and design for it. Unfortunately, there are only a few UX models in the literature that are used to evaluate virtual environments (VE). Each of these models propose different UX components that are difficult to evaluate (e.g., presence, usability, immersion, motion sickness, etc.) [8,9]. In the literature, we found several proposals to assess these components, but there is yet to be an established leading method [10–12].

This paper proposes a method that combines quantitative and qualitative UX techniques, a combination that can provide more valid results [13]. The techniques used are questionnaires, a semi-structured interview and two observation techniques: note-taking and interaction logging (screen recordings). To test our method, we used an Oculus Quest and a VR prototype that replicates flooding in a part of the CBD of Melbourne, Australia. The VR prototype was intended to provoke feelings of concern and anguish in the participants to enrich the virtual experience for its evaluation. By creating an application that replicated the city where participants live or work, and also giving them the ability to change the sea-level with a slider helped to accomplish this purpose (Figure 2) [14].

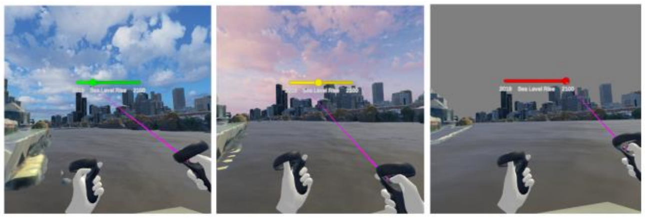

Figure 2: Sea Level Rise and Slider from the VR prototype

Also, we adopted the UXIVE model which includes 10 UX components (Table 1) since these are considered relevant in designing VR applications. With this research we did not want to propose a UX model for VR, but aimed to propose a new method to measure the user experience of applications using mobile VR devices in outdoor settings. We used the UX components presented in the UXIVE Model to categorise our findings. This was created based on four other models in the literature and the authors stated that it is simple and can be adapted to any virtual environment [15].

UX Component	Definition
Presence	Commonly defined as the sensation of "being there" in the VE [16].
Immersion	An objective description of aspects of the system such as field of view and display resolution [17].
Usability	Ease of learning and using the VE [13].
Emotion	Feelings of the user such as pleasure, satisfaction, frustration, disappointment, etc. [13].
Engagement	Connection between a person and an activity consisting of behavioural , emotional, and cognitive components [13].
Simulator Sickness	Feelings such as nausea, headache, dizziness, etc. that sometimes occur while using a VE [13].
Technology Adoption	Actions and decisions taken by the user for a future use or intention to use the VE [13].
Flow	Pleasant psychological state of sense of control, fun and joy that users feel with the VE [13].
Skill	Knowledge the user gain in mastering his activity in the VE [13].
Judgement	Overall opinion (e.g., positive, indifferent, or negative) of the experience in the VE [13].

2 Related Work

Prior work has discovered multiple components of UX in VR and used a range of techniques to study them. These components were listed previously in Table 1 and discussed here.

Table 1: UX Components in VR (UXIVE Model)

UX Component	Definition
Presence	Measured by post-questionnaires and interviews [18–20]. Also, behavioural, and physiological measures such as a change in heart rate, in skin conductance, or skin temperature [21–23].
Immersion	Subjectively through questionnaires and also objectively (task completion time, eye movement) [24]
Usability	Most studies measured this component with questionnaires and interviews [12,25,26].
Emotion	Measured through questionnaires [27,28] but also, through interviews and physiological measures such as heart rate, skin conductivity, breathing patterns, among others [29,30] .
Engagement	Several VR studies used questionnaires [15,31] as well as qualitative data from interviews [32].
Simulator Sickness	Many studies measure it with questionnaires and questions from interviews [28,33].
Skill	Measured with questionnaires [34,35] and by tasks performance or tasks completion [15,36,37].
Flow	Measured through questionnaires [28], but it also can be captured by qualitative data [38].
Technology Adoption	Mainly measured with questionnaires and interviews [28,39].
Judgement	As the previous component, questionnaires, and interviews [15,40].

Table 2: Techniques used to measure UX components in the literature.

Although many VR studies use these techniques, it is not clear if they are reliable and effective for any VR application in terms of scalability. Also, some of these techniques were criticized by authors. Slater argues that the use of questionnaires cannot measure presence in a VE. His argument is simple, "after-the-event questionnaire-based measures cannot in principle rule out the possibility that the reported presence was called into being simply by its having been asked about" [41]. This argument is supported by another from Schwind et al.; they stated that questionnaire results are incomplete and inconsistent since they rely on the participant memory [18]. Slater even stated that "presence researchers must move away

from heavy reliance on questionnaires in order to make any progress in this area" [41]. He proposed that presence should be studied based on virtual sensory data and the context of the VE. Also, the use of physiological and behavioural data with subjective and questionnaire data [42].
Objective measures such as behavioural and physiological are reliable to measure presence [21]. However, they are expensive in hardware and they required more time for analysis [21–23]. Furthermore, behavioural measures can provide biased results since the researcher could act consciously or unconsciously in favour of a desired outcome [21]. On the other hand, physiological measures such as a change in heart rate, in skin conductance, or skin temperature can be caused by several different stimuli [21], and therefore lead to uncertain measurement.

3 Proposed Method

We proposed a method to evaluate UX of mobile VR which is suitable for studies in outdoor locations (Table 3). Table 2 from the literature has focused on post-experience measures using questionnaires and interviews, and not expressions and actions performed by the user during the experience. A Mobile VR device allows such behavioural patterns thanks to its positional tracking system, the degrees of freedom and its wireless connection; and all of them can be captured through observation techniques such as video recordings and note-taking. These would be convenient for apps with a lot of free movement and hand gestures like Beat Saber or FitXR.

UX Component	Definition
1. Semi-structured Interview	Conducted before and after the user tested the virtual experience.
2. Questionnaires	A set of UX scales that measured presence, immersion, and usability.
3. Direct Observation of participants and note-taking	Directly observe participants during their VR experience and take notes of their use of the VR prototype. As well as, observation through the screen-casting in our laptop in real-time.
4. Interaction logging using a 3rd party software	Video Recordings that captured user's screen output wirelessly for later analysis. Monitoring user's view of virtual space in real-time through an external screen.

Table 3: Techniques of the proposed method

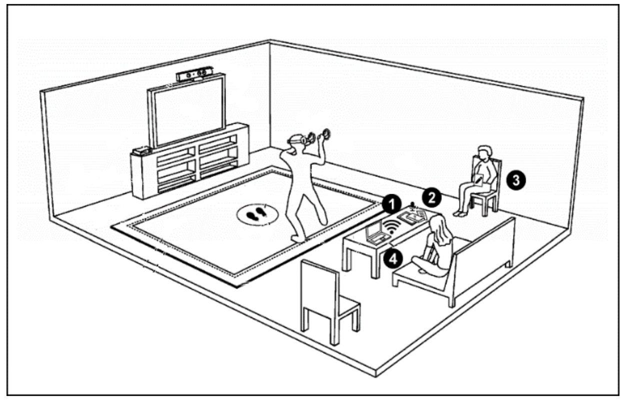

Figure 2: Proposed method to assess the UX of Mobile VR

Figure 3: User testing the app

Figure 4: Main Menu Scene of our app

Using our method, we were able to understand the UX problems and difficulties that participants had, and we discovered 19 UX problems. Table 4 shows how each technique contributed to the evaluation of each UX component.

UX Component	Technique
Presence	Both observation techniques provided useful information and they were consolidated with the qualitative data from the semi-structured interview and the questionnaire.
Immersion	In the same way as presence, we obtained information from both observation techniques and from the semi-structured interview based on comments from participants and the questionnaire.
Usability	Like presence and immersion, all techniques provided insightful information for this component.
Emotion	Comments from the semi-structure interview. Also, we could collect verbal and facial expressions of preoccupation (worry, fear, and anxiety), and body movements with the note-taking approach.
Engagement	Data from the semi-structured interview. Moreover, we took observation notes about verbal expressions and states of happiness, concentration, fun and joy.
Simulator Sickness	We relied on the semi-structured interview and the video recordings from the interaction logging.
Skill	We gathered information with the video-recordings and watched how users interacted. Also, we obtained some comments about this component from the semi-structured interview.
Flow	Interaction logging and comments from the semi-structured interview.
Technology Adoption	Mostly qualitative data from the semi-structured interview.
Judgement	Like technology adoption, qualitative data from the semi-structured interview.

Table 4 Evaluation of UX components with our method

Overall, questionnaires only provided a general overview of the UX. Both observation techniques provided us with insightful behavioural information which helped us to assess UX in detail. Then, data from the semi-structured interview complemented questionnaires and the observation techniques. It should be noted that these techniques can validate or contradict each other for each component. For instance, we matched usability issues with the recordings and note-taking, but we had a low score for the presence questionnaire and great user comments from the interview. Our method detected UX issues and improvements for the app**.** It is worth to mention that we wanted to consider the positional tracking for behavioural analysis. However, users did not use that much, we believe they were afraid of colliding with real objects of the real world. Due to COVID19 pandemic we decided to pilot-test the method in the lab and we aim to use it in the field in the future which can deal with this issue

4 Conclusion and Future Work

This paper presented a method for evaluating UX in mobile VR devices in the field. Our work addresses a lack of established evaluation methods for these emerging platforms. We were inspired by early mobile HCI research in which new usability methods were devised and tested that were attuned to mobile use. We validated our method through using it in an empirical study of a VR experience on Oculus Quest. We aimed to explore and use existing and novel techniques and take advantage of features of the hardware platform. We conclude that the method worked well as it led us to identify multiple UX issues related to the components of the UXIVE Model. We advise against the use of questionnaires alone and encourage the use of observation and interviews.

Using a mobile VR device outdoors can impact the UX of VR app due to the contextual factors that may interrupt or enhance the UX of the app and the device. These are open research questions that we plan to explore further by conducting online research with users in their home. We will use software tools that can ease the problems of running a remote study due to impediments of COVID19 pandemic. We also plan to recruit users from MTurk or Facebook that can provide us sample diversity with different contexts in various settings at users' homes.

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