Exploring user feedback in VR: the added value of qualitative evaluation methods

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Abstract

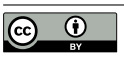
Evaluating immersive experiences, such as Virtual Reality (VR), is often done through User Experience (UX) and Quality of Experience (QoE) evaluations. Here, methodologies such as conducting experiments, the use of questionnaires or data logging can provide valuable insights into implicit user behaviour in their interactions with interactive media experiences (IMX). These quantitative methods can be combined with qualitative methods for user evaluation purposes, making it a mixed methods approach. Consulting literature, extensive research has been done to discover the various benefits and pitfalls of incorporating a mixed methods approach in evaluation studies. However, there is limited research on the added value of a qualitative research methodology in VR user evaluation studies and how these qualitative findings can provide novel insights. This paper presents a mixed-method user evaluation study of VR Planica, a novel VR experience developed by HSLU together with AFP, RTVSLO, Sparknews and VUB as part of the EU project TRANSMIXR. We begin by outlining the conceptual differences between QoE and UX, as well as the conceptual outline of mixed method approaches for user evaluation. Next, we describe our evaluation set-up, and our mixed methods approach applied in the VR Planica user evaluation study involving 33 participants. Drawing on the qualitative data, we reveal insights into how participants experienced and interpreted the experience, which helped deepen the interpretation of the quantitative results. We conclude by emphasizing the added value of a qualitative methodology in VR user evaluation studies and advocate for the use of mixed method approaches to better capture user perspectives.

CCS Concepts

• **Human-centered computing** → *User studies.*

Keywords

Virtual Reality, Evaluation methodology, Quality of Experience, User Experience



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1 Introduction

Over the past decade, research and development in Extended Reality (XR) have gained more interest, finding its way into diverse application areas, such as healthcare or education cite [11, 15] . XR serves as an umbrella term encompassing interactive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) [18]. As XR technologies grow, evaluating user experience becomes more challenging due to its diverse characteristics of these virtual environments and use across a wider field of applications [4]. This paper evaluates the mixed methods approach used in evaluating Planica, a novel VR experience developed by HSLU [10], designed for journalistic storytelling in the context of EU project TRANSMIXR. The VR experience immerses users in a 360-degree representation of a popular, annual ski jumping event in Slovenia. Users can explore the environment and teleport to different interactive scenes, such as interacting with a climate expert or inspecting the scenes in miniature scale. The aim of the paper is twofold: first, to present a set of qualitative findings from the user evaluation study of VR Planica; and second, to critically reflect on the methodological contribution of incorporating qualitative methods – such as interviews, observations and think-aloud – within these types of frameworks. Although quantitative methods, such as questionnaires, remain dominant in XR evaluations, recent research shows that qualitative approaches are underexposed in these evaluation contexts [4], despite their importance for contextualization and gaining a better understanding of underlying user needs [12]. Given the rapid development of XR applications today, this paper highlights the need for more nuanced and reflective methodological approaches where qualitative insights and the traditional quantitative metrics are combined to evaluate immersive experiences in a more substantiated way [11].

2 RELATED WORK

User experience (UX) and Quality of Experience (QoE) are related but conceptionally distinct terms, although they are sometimes used interchangeably in the literature [11, 16, 24],. Both terms concern the user's interaction with a technology or service [3], but they are focusing on different aspects of this interaction. UX originates from the Human-Computer Interaction (HCI) field and emphasizes the overall interaction a user has with the system, including their thoughts, emotions, and perceptions throughout the interaction [1, 25]. Here, open-ended questions such as "how did X make you feel?" are used to explore the user's perception of their experience. In contrast, QoE originates from the Telecommunications field and is more system-driven [23]. Here, quantitative measurements are more often used, focusing more on how users perceive the quality of the system and its performance, by indicating satisfaction and/or frustration [19]. Although QoE and UX often use similar evaluation methodologies, it is important to distinguish between them. There are several factors impacting both UX and QoE. A key impact factor on UX is the context of use. It is important to specify what we mean by context, something that has been defined and outlined in various ways. In a literature review by [13], they summarize the most common elements of context found in literature: the social (the presence, roles, and behaviour of other people around the user), physical (the surrounding environment, such as location, noise, lighting, etc), technical and informational (the technical setup, such as devices, network, system capabilities, etc), temporal (factors related to time, such as duration and urgency), task (the nature of the activity, such as multitasking or interruptions), and transitions (changes or shifts within the components) contexts. What is not part of these context dimensions identified is the user (including stable element such as social demographics, and dynamic elements such as mood and emotions), which [2] see as part of the social context. [17] developed the UX Context Scale (UXCS) which aims to provide a more comprehensive measurement of contextual factors when assessing UX. To control the influence of context, they mean that it is important to both measure objective (factual information) and subjective (value judgments) aspects of context, as these in combination can help to better understand what and why the user feels or thinks a certain way about a system. They argue that the more positive a context is evaluated, the more positive or highly rated the UX is as well. If the expectations of a system are favourable, the subjective usability rates have also been found to increase [20]. In the cases where users have previous experience with or knowledge of a system, the higher their expectations are of the system compared to users with less previous experience [17].

In terms of QoE, the influence factors are largely based on system-, context-, and human factors[21]. Here, the technical quality that a system or application produces, the physical environmental or economical context of the user, and physiological and psychological perceptions of the user on the experience are considered. Another crucial impact factor is the combination of the environment and user equipment [9]. Here, the performance of the equipment used has a great impact on system delivery, e.g., using a computer or a VR headset that do not meet the system requirements to run a VR experience might lead to rendering issues which evidently has an impact on the perceived QoE. Even though a user might have access to high-performance equipment, the environment may also have a huge impact, e.g., if the user is in a high-interference environment vs a low-interference environment they may perceive the QoE differently. In the XR context, there are some additional factors that can influence its use and acceptance among users, such as presence, cybersickness, ease of use, and usefulness [14]. These two prior factors are not included in traditional UX or QoE evaluation metrics as these are specifically linked to XR and should thus also be considered when evaluating UX and QoE in these contexts [22].

The use of a novel methodological approach, such as integrating a mixed methodology design, is crucial for the evaluation of emerging XR applications with users [11]. Mixed methods involve combining both quantitative and qualitative data approaches in a study design to deepen the understanding of a research question [7]. This methodological approach offers several design possibilities, for instance, in a sequential design, one method is applied after the other, allowing the findings from one study design to inform the next. In a concurrent design, both methods are applied simultaneously, and integration typically occur in the analysis and reporting phase. Here, the emphasis placed on each method can be different. Sometimes, one methodology is prioritized, while the other has a more supportive role (e.g. using open-ended survey questions alongside quantitative data). In other cases where both methods are given equal weight, they are considered both equally important [7]. As was the case in this study, a concurrent triangulation design was applied where both quantitative and qualitative data were collected and analysed with equal importance. There is also variation in when and how the integration occurs – whether during data collection, data analysis and/or data interpretation – and in how theory is used, which can be implicit or explicit. However, these approaches also receive criticism, as some scholars claim that since both originate from different ontological and epistemological foundations these cannot be combined. Qualitative research is generally characterized by a constructionist ontology that views social properties as the result of human interactions and an interpretivist epistemology that prioritizes understanding the reality through participants' perspectives. Often using a typical inductive approach (bottom-up) to theory development. Quantitative research, by contrast, adopts a natural science and positivist perspective, taking a more objective stance and using a deductive approach (top-down) to theory [6]. Despite these differences, many scholars see advantages in combining the strengths of both qualitative and quantitative methods [6, 7] . The proper alignment of methods is paramount to ensure coherence and purpose in the research[8]. When applied properly, a mixed method approach can facilitate the researcher to corroborate, elaborate, complement or contradict quantitative and qualitative findings [5]. Thus, when applying a mixed method approach, the strengths of both methods can potentially reinforce each other [7].

3 Case study description

3.1 VR Planica Experience

The VR case study used for this analysis is called the VR Planica experience, which was developed using Gaussian splat technology to photo-realistically represent real life environments and objects by HSLU. The VR experience enables users to visit an experience the setting of a popular, annual ski jumping event in the Planica

valley in Slovenia. In the VR experience, users can better explore the virtual environment by having a 360-degree view of the ski slope environment by entering a hot air balloon (Figure 1). In addition, users can teleport to different scenes: observation towers, a stage for the medalists and a camera area to have a detailed overview of the environment. As part of the experience, users can also navigate to two interactive scenes; a room where they can select and watch an interview with different climate experts and lastly, a room in which they can inspect miniature objects.

Figure 1: VR Planica Experience

3.2 Evaluation set-up

The evaluation technical set-up at HSLU was a 2x2m area to walk around, a Meta Quest 3 tethered to a PC with Windows 10, an Intel Core i7-9700K @ 3.60GHz, and a NVIDIA GeForce RTX 3080. At VUB, we used a 2x2m area, a Meta Quest 3, connected to a PC that features an AMD Ryzen 9 3900X (12 cores, 24 threads, 3.8–4.6 GHz) with 63.9GB RAM and multiple storage drives totaling over 10TB, supporting a DDR4 memory at 3200MT/s.

The evaluation study took place in two countries with a total of 33 participants in 33 individual sessions. The participants were mainly university students and employees, with a gender balance of 16 male and 17 female participants and an age range of 23-50 years old. In addition, 11 participants had prior experience with XR whereas two-thirds of the participants were not familiar with this technology. After filling in the informed consent form and explaining the experiment participants tried out the VR Planica for approximately 20 minutes. They were informed that they could stop the experiment if they experienced any discomfort. During the one-hour long experiment, participants were asked to think out loud during the experience. While in VR Planica, participants could freely navigate to the different static scenes (wooden tower, metal tower, slope, stage and press area) and explore the two interactive scenes (interaction with a climate expert and the inspector room). During the experiment, user activity in the virtual environment was directly logged via the head-mounted display (HMD) and participants were also observed by the researcher and were encouraged to think-aloud. During the observation, the researchers paid significant attention to how the participants interacted with the environment, navigated with controllers and their user experience in general throughout the whole VR Planica. Notes were taken simultaneously, and the observations in the form of thinking aloud were audio recorded for analysis afterwards. Immediately after the experience, participants were asked to complete a quantitative survey. The following scales were used to measure the following dimensions: User Experience was measured with the short version of the User Experience Questionnaire, the UEQ-S, which consists of 8 items on a 7-point scale. Second, we assessed Visual Quality with four questions ranging from “Bad” (=1) to “Excellent” (=5). We further measured the sense of “being inside the virtual environment”, also referred to as Presence, via the Igroup Presence questionnaire (IPQ). This questionnaire consists of 14 questions on a 7-point scale. Lastly, we used the “Cybersickness in Virtual Reality Questionnaire (CSQ-VR)” as a secondary measure to assess any potential adverse effects. After the quantitative survey, a 20- minute post-interview was conducted to contextualize their user experience and to gain an in-depth understanding of their motivations and sense making. The following themes in relation to their experience were discussed: overall impression, audiovisual QoE, navigation and interaction, social XR potential and future expectations (transferability to other sectors, willingness to pay and recommendations for improvement). This approach provided relevant quantitative metrics as well as detailed qualitative insights. In the remainder of this paper, we focus on the specific qualitative insights and reflect on the added value of a qualitative methodology in QoE and UX experiments.

4 RESULTS

4.1 Observations and think-aloud-method

The insights gathered through observations and the think-aloud method helped add depth to the evaluation, as we were able to observe in real-time the specific frustrations, nuanced experiences, and contextual challenges that the participants faced. For instance, although participants would describe the experience as immersive and visually engaging, their real-time commentary revealed issues with navigation, motion sickness, and interaction limitations.

A main limitation of the experience, according to the participants, was **learning how to move around** in the environment. Before entering the experience, participants were instructed on how to use the navigation controls, but participants with less to no previous experience with VR indicated difficulties with the movement in the environment. One participant with less previous experience for example found the movement to be unintuitive and restrictive: “And if it does not turn blue, I cannot do anything? Ah but then I’m back again in the same place. There is not much I can do.” (Participant 1, female). A minority of participants had also experienced **motion sickness or disorientation** in the hot air balloon, some needing to take a moment to localize and ground themselves before continuing. As this happened, a participant mentioned that they would prefer to be able to control the movement and direction of the hot air balloon, as that would help them feel less sick/dizzy. Having greater **agency** within the environment was a shared sentiment among participants, regardless of previous experience. Aside from greater navigation control, they also wished for more interactive elements, such as manipulation of objects or customization of the experience. This was especially the case for the inspector scene, in which participants

now could pick-up and investigate an object: "It would be cool [...] if you can let go it but it stays there, but right now it just falls down." (Participant 16, male). There was also common frustration with the **passive content**, e.g., in the climate expert scene, where they suggested improvements, such as being able to rewind or pause the videos instead of watching the expert speak.

Several participants had also reacted to the quality and stability of the experience, in which most had noted blurry areas, unfinished visuals, or inconsistencies in details. Some participants even experienced **technical issues**, such as freezing or crashing of the system. These issues impacted their overall immersion as the experience would get interrupted, but also due to the awareness or anticipation that it might happen again.

4.2 Interviews

The interviews provided further insights in the UX and QoE of VR Planica, while at the same time provided additional contextualization for the quantitative scales.

4.2.1 User experience. VR Planica which also served as an ice breaker to facilitate the conversation. Participants were mainly impressed by how novel VR Planica felt, especially for participants who were not familiar with VR to explore the possibilities of VR technology for the first time: "Yes, I was really impressed. I've never done anything like that before, that you really feel you are on location and you really feel you are exactly somewhere else in such a box. And I found that quite impressive." (Participant 12, male). While participants had initially mentioned difficulties in navigating the experience with the controllers, their comments during the interview highlighted that as they spent more time in the experience the difficulties cleared: "In the beginning I was struggling because on my part because I was not fully aware of how to use the joysticks. But then when I learned a little how to use them, it was easy. You could click and switch from one scene to the other easily, smoothly" (Participant 3, female). While basic controls and interaction were generally intuitive, participants also reported some issues with button sensitivity, which had caused frustration: "I have to be really precise with the controller to press them. That's the first time it didn't work and I didn't know why it didn't work [...]." (Participant 27, male).

Participants also indicated difficulties with navigating within the scenes themselves, one of them was the room of the climate expert. Here, they had to teleport themselves into a square to start the video, which some participants found strange: "Only with the interviews, I did feel like why do I have to teleport myself over there like that? I didn't necessarily find that added value or anything. Mainly because that's how it was. It really didn't seem like a real space there either." (Participant 5, female). Here, the main argument was that it did not feel like a realistic way of interacting and moving around in the environment, in real life they would have walked over there and pressed a button. To teleport between the different scenes, participants would navigate through portals via the control command in the hot air balloon. Although most participants reported that the portals worked well, some felt that the transitions between scenes felt disturbing as it broke the natural flow of the experience: "If I'm going through a portal and then kind of the next scene is basically me being dropped into another environment. The transition is lovely towards, but the transition is disorienting, you know, the load of the new scene. So that could cause a discomfort." (Participant 9, male). Another participant also argued that this caused them to feel motion sickness: "When the portal loads and the balloon changes direction and speed and acceleration? That's when I had balance issues. Like I had to step back one time to catch myself. That also increases the motion sickness." (Participant 27, male).

The hot air balloon was an enjoyed aspect by various participants, mainly due to its birds-eye view of Planica: "Apart from that, where you could look down from above and get a view of everything that was happening there, that was also cool and here, where you could operate the screens and the theme (Participant 15, female). Participants indicated that by having this overview of Planica, they felt that they had greater control of what was going on, and they could get a better idea of what Planica is about. Although the hot air balloon was generally appreciated by participants, some mentioned that the balloon transitions were odd: "The balloon ride was actually the least liked. That's the pace in between. I also found it funny that he flies through the mast there. Stuff like that." (Participant 16, male). Here, the quality of the experience would hinder their immersion and enjoyment, as these graphical aspects did not feel realistic. The two interactive scenes of the experience – the inspector and the climate expert room – were the favourite scenes among several participants. Due to its advanced visual quality and intractability, the inspector was a preferred scene: "I think that the miniatures, these visuals really felt like I was there, that I could see everywhere and I was just there and that I could take the miniatures or throw them." (Participant 16, female). Although the climate expert room generally received praise, there were some mixed opinions on its level of interactivity. Some participants found the interaction too static and suggested that this could be improved by displaying the climate expert as a volumetric avatar: "Of course, at this level I would understand that I cannot interact with the person because the person might not understand what I'm saying, but at least having the questions on top and then me being able to go to the question and then the expert answering in front of me, not in a video." (Participant 1, female).

4.2.2 Quality of Experience. The **visual quality** was an important, if not decisive, aspect of the experience according to the participants. A recurring point of feedback among the participants was the visual quality of the experience, and the opinions varied as it would depend on which scene they were in: "When I was on the stage, it felt much more realistic than the arena because there were weird things around me there" (Participant 1, female). Here, several participants found that the level of detail of some aspects of the scene created weird looking visuals, such as e.g., highly defined grass that otherwise would not be perceived that way. They found certain scenes to be fragmented, incomplete, spikey, or pixelated. "I think I already mentioned that the visual quality, it seems incomplete. It's a bit like fragmented. [...] the scenes in some part being incomplete and the trees growing out of air or just not being complete or fragmented." (Participant 28, female).

Another participant argued that the current state of the visual quality prevented him from feeling immersed in the experience: "I think it's also related to the visuals. You can have some non-realistic

visuals and be immersed into it if it's the whole thing is coherent and immersive" (Participant 3, male). Even though some scenes – such as the metal tower or the inspector – were visually more elaborated, participants' **feeling of immersion** was impacted when being exposed to scenes of lower visual quality. "I think the certain elements, like the especially when you're on the ground floor, looked incredibly realistic [...]. And then other elements like flat surfaces or like the snow because of the texture of the crosshatching looked very strange and it just it kind of takes you out of this, uh, virtual world." (Participant 14, male). Lastly, participants generally appreciated the **audio** in the experience, particularly the ambient sounds and narrations that accompanied the visuals, which improved their user experience: "Actually in terms of audio, it was already almost flawless" (Participant 10, male). However, some participants commented that the audio sometimes was too quiet and at times other choices of audio would have been more intuitive: "The wind noise drowned out the music, which made me think of it. Why is there music playing at all? Well, birds would have been more intuitive to hear. But there was actually relaxing music." (Participant 18, female).

4.2.3 Future expectations. What other sectors this type of experience can be applied. The sectors identified by participants were sports, marketing, urban planning, commercial real estate, training, professional collaboration, emergency exercise, tourism, education, entertainment, health and cultural heritage (museum), indicating a high potential for transferability. However, the three main sectors discussed were tourism, education, and entertainment. Participants argued that by having the possibility to get a glimpse of a destination before booking a trip, this type of experience could potentially broaden the scope of tourism: "Providing this kind of international experience without the means of transport, airplane costs or hotel ticket costs, them being immersed in something this photorealistic absolutely opens the scope for tourism." (Participant 12, male). Additionally, virtual experiences can concretize abstract concepts and contextualize unknown locations for educational purposes: "Education, people can have information beforehand about what the place is like." (Participant 2, female). These types of XR experiences can also serve as an alternative for different forms of entertainment such as film, concerts, and gaming. For example, one participant stated that these experiences could help prepare musicians for their performance: "For artists who are going to perform at a festival that it can be nice to be able to walk around on that stage in VR and that they can also get some idea of how many people are going to be there which could reduce stage fright". (Participant 7, male). Finally, there was a lack of willingness to pay for the current version of the VR Planica experience. Participants argued that the visual quality and interactivity needs to be improved to pay for the experience, some also referred to using Google Maps to access unknown places instead of using VR. Conversely, a minority of the participants would pay for the experience if you could try out the VR Planica at an exhibition: "I wouldn't mind paying, like 5 euros for the experience in in a museum or in an exhibition area." (Participant 12, male).

5 DISCUSSION

While quantitative methods generally provide a structured and measurable framework in assessing UX and QoE, they are not able to fully capture the nuance and complexity of user interactions in these immersive experiences [5,6]. By integrating qualitative methods, such as observations, think-aloud protocols, and interviews, it is possible to uncover user frustrations, emotional responses, and contextual barriers, which would not have been captured by the quantitative data alone. For instance, qualitative feedback was proven to be useful in this case as we were able to reveal why participants felt a certain way about certain parts of the experience. If they e.g., praised or disliked the visual quality in the quantitative feedback, they were able to tell us the 'what' and 'why' in the qualitative assessment. In our study, we were able to reveal underlying navigation issues, moments of disorientation, and technical and/or design limitations that broke the immersion. Here, we were also able to shed light on more contextual challenges between users, as some users with less previous experience with VR struggled more with navigation even though they received the same instructions [15,17]. As participants suggested improvements for the experience, which were revealed through the interview and spontaneous reactions during the experience, we were also able to explore and better understand user expectations and experiential gaps. Not only has the qualitative insights helped us contextualize and complement the quantitative insights, but we have also been able to identify areas in need of further iterations and development. In complex and immersive experiences where user feedback is highly subjective and context-dependent, it is essential to use a mixed-methods approach. As quantitative measures offer breadth to a study, qualitative input provides more depth to fully understand why and what needs to be improved, and therefore they should both be considered central components of UX and QoE evaluations in the VR context.

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