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An Online Survey Assessing the Accessibility Barriers Encountered by Users of Virtual and Augmented Reality

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ABSTRACT

Given the nascent stage of virtual and augmented reality content design, there has been limited consideration of the unique requirements of disabled users. We present the results of an online survey ($n = 101$) that enables us to understand the obstacles and expectations of users with different types of access needs, long-term health conditions, impairments and/or disabilities as they relate to the consumption of immersive content. The results indicate that among those who have experienced some form of immersive content, almost three quarters encountered obstacles to their enjoyment.

1 INTRODUCTION

The social model of disability [14] stresses the role the physical environment plays in restricting one's access and capabilities. Immersive content can remove the barriers present in the physical world, as highlighted by one participant of our survey, "As my disability limits my mobility and changes the way and distance I can travel, using immersive content is a God send. And helps broaden my restricted world." By removing these barriers, users with a disability have access to new experiences and opportunities. An awareness among designers of the basic principles of accessibility for immersive content is therefore paramount in avoiding the needless erection of new access barriers within the virtual environment.

The main aim of this paper is to report on a survey that examined the experience and expectations of users with disabilities regarding virtual reality (VR) and augmented reality (AR). The online survey was completed by 101 individuals and specifically targeted users with one or more types of access needs, impairments, disabilities and/or long-term health conditions.

The study adopts the concept of enjoyment as the key criterion for the optimal (i.e. continuous, uninterrupted) flow of user experience (UX), as theorised by Csikszentmihalyi [6] and often used by the UX design community [11]. In this context, enjoyment comprises eight aspects of the UX journey: (1) tasks that stand a reasonable chance of completion; (2) ability to concentrate on the experience; (3) clear goals; (4) immediate feedback; (5) deep, but effortless involvement; (6) sense of control; (7) no concern; and (8) alteration of the sense of time. Targeting uninterrupted enjoyment in the experience of immersive content thus sets a challenging but worthwhile benchmark for what it means to be inclusive. There is a moral imperative to making VR and AR technologies more inclusive, but it is also generally accepted that improved inclusiveness leads to better usability for all, given the occurrence of situational impairments and varying levels of familiarity. Further, there are clear commercial advantages to reaching a wider user base. As one of the participants in our survey commented, "I have debated investing in gaming VR but chose not to because of fear of the games not being accessible." The work reported in this paper fits a broader vision for improving the inclusiveness of immersive technologies. This vision is founded on the principles of *inclusive design*, which seeks to ensure products and services are usable by as broad a population as possible through a better understanding of user diversity [3]. Raising awareness of accessibility needs in VR and AR is now increasingly important to avoid exclusionary design practices from taking root in the emerging realisations of the metaverse and spatial computing. The gap in guidance on how to deliver accessible VR and AR content is slowly being addressed thanks, in part, to industry associations and organisation like XR Access and XR Association (XRA)[1]. Improved developer guidance from device manufacturers is also emerging [12]. An informative survey of VR accessibility issues conducted by Wong et al. [15] echoes many of the same issues revealed in our investigation. Garaj et al. [8] also gathered the attitudes and perspectives of users with disabilities towards VR and AR. Our survey complements and extends these previous efforts thanks to its larger sample of users representing a broad range of encountered access barriers as well as a spectrum of prior familiarity with VR and AR.

2 RELATED WORK

The literature landscape indicates that improving the accessibility of VR and AR is a recognised problem demanding research attention [7]. Gerling and Spiel [9] observe that VR is an "inherently ableist technology" and suggest a paradigm shift from a reactive to a proactive approach to designing for accessibility. There remains, however, limited evidence-based generalisable guidance that is easily absorbed and utilised by developers. Indeed, Ashtari et al. [2] list the lack of concrete design guidelines as one of eight key barriers in developing applications more generally. We see our paper as being complementary to previous efforts [8, 15] in refining the broader picture of accessibility for VR and AR. The survey performed by Wong et al. [15] employed a recruitment strategy that chiefly gathered responses from users with an already established interest in VR. A risk exposed by this methodology is the potential exclusion of users who have experimented with the technology, but then encountered too many barriers to enjoyment to warrant continuation or interest in future use. Garaj et al. [8] collected expectations and attitudes regarding VR and AR from participants who had mostly (75.3 %) never before tried using an immersive headset. By contrast, 73.2 % of respondents to our survey have at least some prior exposure to VR and AR and also represent varied levels of interest and engagement: from users who engage with immersive experiences every month (14.9 %) to users who have only ever experienced immersive content once or twice in their life (48.6 %). The broader higher-level perspective brought by our survey is particularly important given the prevalence of co-occurring capability loss. This pursuit of breadth is consistent with a core tenet of inclusive design: capturing and learning from diverse perspectives [3].

Two recent papers [4, 5] in the area of VR and AR accessibility both come from a research project by Creed et al. The first paper [4] presents the outputs of two sandpits that involved a mix of VR/AR experts and disabled users in discussing the key challenges to the inclusiveness of VR and AR at present and accordingly lays out recommendations for future work in this space. The second paper [5] expands on the first and formulates a wider research agenda for improving the inclusiveness of VR and AR, calling for more research to address the accessibility requirements along the whole range of

[1] `https://xraccess.org/` and `https://xra.org/` respectively.

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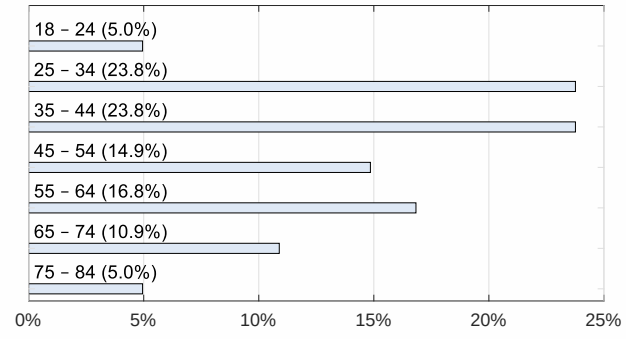

Figure 1: Distribution of survey participants across age groups.

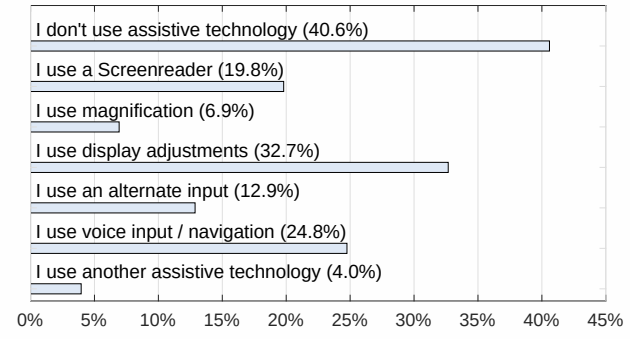

Figure 2: Categorical responses to question, "Do you use assistive technology to make digital experiences easier for you?"

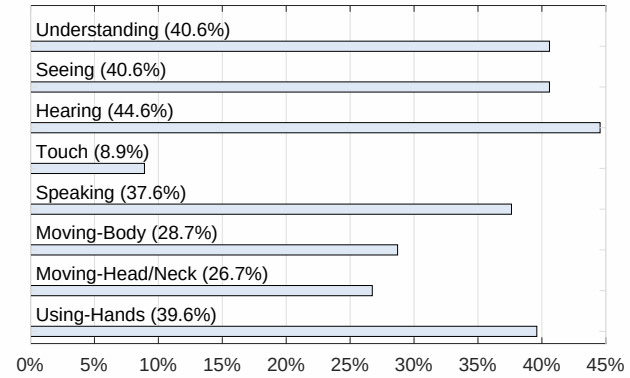

Figure 3: Percentage of participants who encounter different forms of access barriers in their daily life.

disability types. Our study provides a direct response to this call.

3 Survey Design

The online survey was divided into six sections: (1) demographics, (2) access barriers, (3) familiarity with immersive content, (4) barriers encountered in immersive experiences and self-initiated solutions to them, (5) expectations for the accessibility of immersive experiences and (6) perspectives on personalisation and adaptation.

We aimed to collect 100 responses and sought to ensure recruitment was as inclusive and representative as possible in terms of age, gender, access needs and familiarity with technology. Survey participants were recruited through a panel managed by a commercial agency specialising in disability and inclusion research. Most of these panel members are based in the United Kingdom and have diverse attributes in terms of gender, age, medical condition, education, digital literacy and socio-economic levels in addition to their varying access needs and adaption strategies. A secondary recruitment objective for the 100 participants was that at least two thirds of participants must have tried immersive reality using a headset at least once and up to a quarter of participants should have never tried any immersive content. This targeted recruitment strategy was facilitated by the custodians of the user panel who maintain records on the past exposure of participants to various technologies. Participants in the survey received a payment of £15 as compensation for their time. The study was approved by our institution's ethics committee.

4 Results

In total, 101 participants completed the survey. We report on the collected responses organised as follows: demographics, access barriers, familiarity with immersive content, barriers encountered, and attitudes and expectations of participants with no prior experience of immersive content.

4.1 Demographics

Of the 101 participants, 61 were female, 38 were male and one person indicated they prefer to self-describe (the one remaining participant provided no response to this question). The age distributions of the sample are summarised in Figure 1. From Figure 1, we can see that 25 - 34 and 35 - 44 were the most sampled age groups, together accounting for just less than half (47.6 %) of all participants. 98 of 101 participants answered yes to the question, "Do you consider yourself to have an impairment, disability or long-term health condition?" The main forms of access barriers encountered by participants are examined later in Section 4.2.

The majority of survey participants identified as being of white ethnicity (78.2 %). The proportion of other ethnicities sampled, in descending order, were Asian/Asian British (7.9 %), other not listed (5.9 %), Black/African/Caribbean/Black British (3.0 %), Arab (2.0 %) and Mixed/Multiple (2.0 %). This sampling shows good consistency with the general population statistics of England and Wales (White (86.0 %), Asian ethnic groups (7.5%) and Black ethnic groups (3.3 %)) [13].

Given this investigation's focus on the relatively novel technology of VR and AR, we saw value in contextualising later responses by capturing participants' general level of comfort with technology. Participants were asked to respond to the question, "How comfortable are you with personal technology such as smartphones, tablets or computers?" on the range from "I struggle using even basic technology and often need help" to "Very comfortable. I find technology easy to use and often help others." We found that 83.1 % of participants were either comfortable or very comfortable with technology, suggesting that the vast majority of participants are likely to have generally positive attitudes towards new technology.

It is common for users with a disability or impairment to use some form of assistive technology to reduce or remove barriers to interaction with a computer or smartphone. The survey asked participants to indicate what form of assistive technology they use. These responses are summarised in Figure 2. The results indicate that the majority of participants do use some form of assistive technology, although there is a large proportion of participants who do not (40.6 %). The most widely used assistive technologies among participants were display adjustments at 32.7 % (e.g. Dark Mode, inverted colours, larger font size), voice for input and/or navigation at 24.8 % (e.g. Dragon NaturallySpeaking, iOS Voice Control, Google Voice Assistant) and screenreaders at 19.8 % (e.g. VoiceOver, Talkback).

4.2 Access Barriers

Within the United Kingdom, the social model of disability [14] is the preferred perspective for viewing the consequence of living with some form of disability, impairment or long term health condition. The social model seeks to highlight how society and the physical environment impose barriers to accessibility. This contrasts with the

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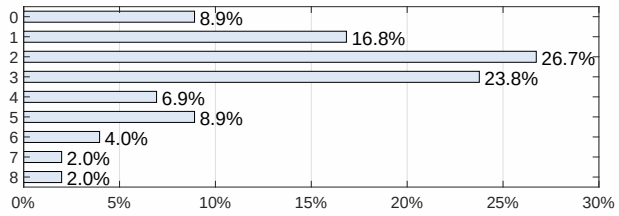

Figure 4: Co-occurrence of access barriers for the eight forms of access barrier queried in the survey.

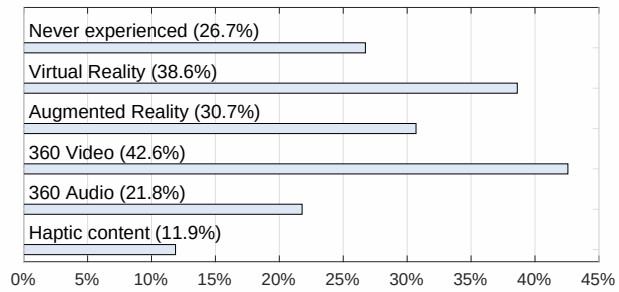

Figure 5: Categorical responses to question, "What immersive content do you have experience with?"

medical model of disability which highlights how the loss of access is a consequence of a physiological or psychological impairment. The value of the social model is that it stresses how a redesign or reconfiguration of the environment, that is, factors external to the individual, can improve accessibility. In line with the social model of disability, we asked survey participants to reflect on what forms of access barriers they face in daily life. Specific questions were presented covering the following eight forms of access barrier: i) understanding and problem solving; ii) perceiving or understanding visual content; iii) perceiving or understanding sound; iv) perceiving touch sensations; v) communicating with your voice; vi) moving your torso, arms or legs; vii) moving your head or neck; and viii) using your hands. Figure 3 summarises the percentage of participants who encounter the different forms of access barriers in their daily lives. Barriers to understanding, seeing, hearing, speaking and dexterity were encountered by more than one third of participants. Barriers to moving the body and head or neck were less common but still encountered by more than 25 % of participants.

Figure 4 plots the percentage of participants grouped according to how many different forms of access barriers they indicated, i.e. co-occurrence of access barriers. An important observation from this plot is the fact that it is common for users with a disability to encounter multiple forms of barriers in their daily life. 74.3 % of participants indicated that they encounter two or more different forms of access barrier and 47.5 % encounter three or more.

4.3 Familiarity with Immersive Content

In this portion of the survey we sought to examine the familiarity of the participant group with immersive content. Figure 5 summarises the forms of immersive content that participants had previously experienced. Note that one of the objectives of the survey was to capture attitudes and expectations of users without prior experience. Figure 5 shows that 26.7% of participants fall into this category. Those without prior experience were transitioned to a dedicated portion of the survey, which is examined later in Section 4.5. The remaining results in this section and the following Section 4.4 report on just the subset of participants *with* prior experience (n=74).

Those with prior experience were asked to comment on how frequently they used VR or AR. The distribution of responses is

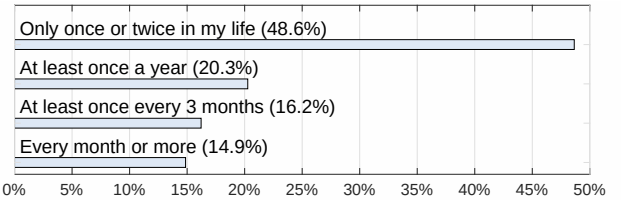

Figure 6: Categorical responses to question, "How often do you experience or use immersive content?"

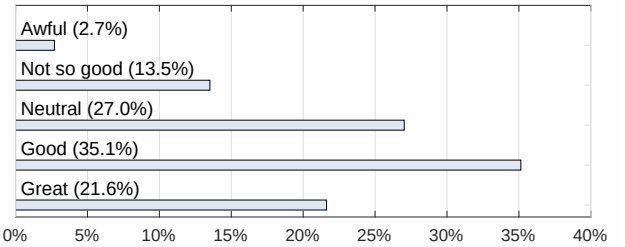

Figure 7: Responses to the question, "In general, when you experience immersive content, how do you feel?"

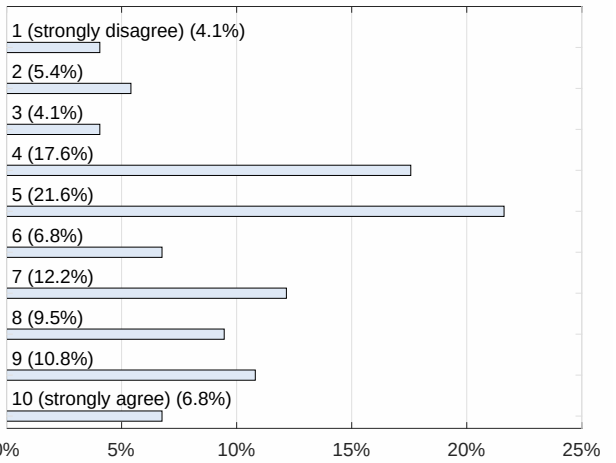

Figure 8: Response on a scale from 1 (strongly disagree) to 10 (strongly agree) to the statement, "In general, when I experience immersive content I feel safe."

summarised in Figure 6. The majority (48.6 %) of participants with prior experience had tried immersive content only once or twice before. 31.1 % indicated that they used VR or AR at least once every three months or more regularly. The remainder (20.3 %) experienced immersive content at least once a year. The subset of participants who indicated that they had tried immersive content only once before or only used it once a year, were asked a follow up question to gauge their interest in trying it again in the future. 64.7% of participants indicated they would like to experience immersive content again in the future. A further 25.5% indicated that they would maybe like to try it again. Only four participants indicated that they would not be interested in trying VR or AR again.

Participants were asked to reflect on their prior experience and rate how it made them feel on a five-point Likert scale from *Great!* to *Awful!*. The distribution of responses to this question is summarised in Figure 7. From Figure 7 we observe that although the experience of most participants was positive, there is still a relatively large group of users (16.2 %) whose experience was less than neutral.

Certain access barriers can manifest as anxiety or concern about one's personal safety. The use of VR and AR has the potential to exacerbate some of these concerns due to the risks introduced by

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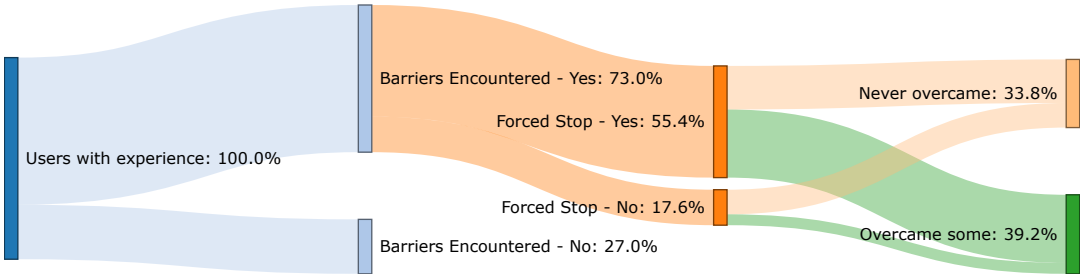

Figure 9: Sankey diagram illustrating the survey responses to the sequence of questions: 1) "Thinking back to the times you experienced immersive content, did you ever encounter barriers that affected how much you could enjoy that content?"; 2) "Did the barriers force you to stop experiencing the immersive content at any point?"; 3) "Did you overcome at least some of the barriers?"

the potential for disorientation, vertigo-like sensations and nausea. Indeed, research indicates that older adults and people with neurological disorders who have difficulty with balance may struggle to enjoy many forms of immersive content as per the design intent [1, 10]. We therefore asked participants with prior experience to respond to the statement, "In general, when I experience immersive content I feel safe." on a ten-point Likert scale from one (strongly disagree) to ten (strongly agree). Figure 8 summarises the responses to this survey question. A key point to observe in Figure 8 is that there are, very approximately, two modes to this distribution with some participants indicating general agreement with the statement (rating 7–9) and another subset indicating neutral or slight disagreement (rating 4–5). More generally we can observe that 31.2 % indicated some degree of disagreement with the statement (rating 1–4). This observation suggests that VR and AR technology and content could do more to address user concerns around safety.

4.4 Barriers Encountered by Users with Prior Experience of Immersive Content

The subset of participants (n=74) with prior experience of immersive content were probed as to whether they had encountered any barriers that affected their enjoyment levels. If barriers were encountered, follow-up questions were posed asking about what these barriers were, whether they forced a cessation of the experience and whether some of these barriers were overcome. Figure 9 shows a Sankey diagram illustrating the proportion of participants who had encountered barriers and whether these led to a cessation and/or were partially overcome. 73 % of participants had encountered barriers to their enjoyment of immersive content. These barriers forced the cessation of the experience for 55.4 % of participants and 33.8 % of barriers were never overcome, whether they forced a cessation or not. The subset of participants who were forced to stop their experience covered the full spectrum of access barriers encountered in daily life described in Section 4.2. In other words, there was no single form of access barrier faced by individuals that correlated with the need to halt their experience. These results indicate that there is significant scope for improvement in the accessibility of VR and AR to help reduce and eliminate these barriers to enjoyment.

4.5 Attitudes and Expectations of Users without Prior Experience of Immersive Content

In this section, we examine the attitudes and expectations of the subset of survey participants (n=27) who had no prior exposure to immersive content. As described in Section 3, we specifically sought to recruit a portion of participants without prior experience as a way to examine interest levels and to explore any reasons why users with a disability or impairment may be hesitant to try VR or AR.

In response to the question, "What interests you the most about immersive content?" participants mentioned the novelty, the reality and immersion of immersive content and 360-degree videos. Participants expressed particular interest in experiences that were impossible for them in the real world. For example, two participants wanted to try extreme sports, such as white-water rafting and skydiving. Other participants were interested in sharing immersive experiences with other people.

The survey asked participants without prior experience to indicate, "What type of immersive content in the home interest you the most?" as well as the same question relating to experiences outside the home. More than half of the participants in this group were interested in trying cultural, shopping, entertainment and educational experiences, as well as social activities and remote physical treatment from home in the future. One participant expressed interest in virtual training for daily tasks, such as writing, buttoning, carrying a tray and holding a mug. When outside the home, approximately 50% of participants believed immersive cultural and retail experiences would be most appealing. The general interest in gaming content was, by comparison, relatively low.

5 Discussion and Conclusions

Our goal in this research was to quantify the accessibility issues faced by users of immersive experiences. Various comments from participants highlight the potential benefits that VR and AR offer to users with a disability. By eliminating physical environment barriers, VR and AR offers a form of liberation to users. Developers should therefore consider how the experiences they are building could be more inclusive of those who might benefit most from the content.

We observed in written responses that users facing access barriers are willing to expend significant effort in trying to use content that was designed without thought for their needs. Consider the experience reported by one participant, "I was trying to use augmented reality apps on my iPhone SE 2 to play games and also for home decoration but as I'm blind and use voiceover screen-reading software on my iPhone SE 2020, I couldn't use the apps as they were completely inaccessible with voiceover, the developers hadn't made them compatible. I tried turning off voiceover and tapping around but didn't know what I was doing." This experience highlights the fact that users with a disability are interested and willing to engage with VR and AR but face many obstacles, some of which may be easily addressed by design if given sufficient attention.

Critically, our overall approach differs from much prior work in that our response group represents a board range of access difficulties rather than focusing on a single form of disability or impairment. This approach better reflects the frequent co-occurrence of disability and helps to surface the commonality and diversity in required accessibility solutions and features. We hope that our effort to quantify the accessibility issues encountered by users may offer initial guidance to developers at this critical point in time, given the nascent stage of VR and AR content design.

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