Inclusivity Requirements for Immersive Content Consumption in Virtual and Augmented Reality

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Abstract. Immersive technologies, such as virtual reality (VR) and augmented reality (AR), enable many new possibilities for audio-visual content consumption, in particular as a means of allowing for various new experiences that either mimic or surpass what can be experienced in real life. Since immersive experiences can add variety to a daily routine and thus improve quality of life, VR and AR content may be especially attractive to individuals with disabilities and older people who are often home-bound due to limited mobility. However, for VR and AR to be able to reach their full potential, it is important to ensure the design of such systems is inclusive. As an initial step in this direction, this paper provides a set of high-level user requirements from eight focus groups that involved users with a range of disabilities/capability loss types and consequent access barriers to the full enjoyment of VR and AR content and experiences. We clustered the user requirements around the participants' prioritised strategies for overcoming access barriers. These strategies are customisation, interaction, information, and adaptation for VR; and customisation, interaction, and awareness for AR. Overall, we identify several common high-level user requirements across both VR and AR, including the need to support users in fine-tuning settings and to have available a rich number of modalities to support flexible interaction.

1 Introduction

Recent hardware and software developments have resulted in an ever-expanding range of virtual reality (VR) and augmented reality (AR) headsets offering increasingly advanced capabilities to engage in immersive audio-visual content, including movies, games, and interactive remote experiences, such as virtual attendance of a guided museum tour and participation in a music concert.

Such forms of content consumption open up new possibilities for a wide range of immersive environments. However, for immersive content to be accessible to a wide range of user groups, it is necessary for system designers and developers to have an accurate understanding of users, including user groups of people with different disabilities/types of capability loss, and older people.

To address this gap in the literature, this paper reports the results of a user requirements elicitation study that consisted of eight focus groups involving users across the

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disability/capability loss spectrum. Our aim is to elicit high-level user requirements for inclusive content consumption that can serve as a starting point for a more refined and nuanced elicitation of requirements to cover the functions specifically related to VR and AR content consumption.

A central approach in this work is the concept of inclusive design (Clarkson et al. 2003; Keates and Clarkson 2010), which suggests we can reach much broader and more diverse user populations by specifically attempting to better understand user diversity. The consideration of inclusive content consumption in VR and AR is perhaps particularly important given the potential that such immersive experiences have to contribute to the quality of life for people with disabilities and older people (Garaj et al. 2022). As rationalised by the social model of disability (Shakespeare 2006), real-world social and physical environments can form profound constraints on disabled and older people's access to daily life by limiting their physical mobility. VR and AR environments, on the other hand, facilitate virtual mobility, and may be able to substitute for the lack of real-world access and thus improve levels of engagement with life and its quality. Recently proclaimed visions of the Metaverse (Ravenscraft 2022) and the role it may play in complementing everyday interactions in society highlight a time critical need to make immersive technologies inclusive.

So it is unsurprising that industry has formed initiatives to tackle the broader accessibility issues. Two examples of these initiatives include XR Access Initiative (2022) and XR Association (2022). Targeted academic research still remains rather limited, but initial efforts include the survey by Wong et al. (2017) of attitudes and sentiments held by users with disabilities towards AR and VR and also the work by Garaj et al. (2019) on the inclusive design of immersive reality.

2 User Requirements Study

To elicit high-level inclusivity user requirements for content consumption in VR and AR, we carried out eight focus groups (FGs), four exploring VR (FG1-4), and a further four exploring AR (FG5-8), as summarised in the table below. The focus groups were carried out remotely on Zoom and participants were asked to reflect jointly on any past experiences with VR or AR and on specific videos displayed during the session showcasing representative experiences of VR and AR content.

Participants: Focus group participants were recruited from a user panel managed by an external inclusive research and innovation consultancy. This user panel enabled efficient recruitment and facilitated stratified sampling of a wide range of capability loss types. Where possible, participants were assigned to focus groups based on their dominant capability loss. This assignment was imperfect due to scheduling constraints, and so there was some mixing of capability loss types within groups to ensure a reasonable number of participants per group. The assignment of participants to focus groups is summarised in Table 1. Some participants participated in both the VR and AR focus groups. Otherwise, all focus groups on a particular technology were unique.

Method: The focus group structure had four parts. Part 1 served as a warm-up and probed the group's general reflections on their overall prior experiences with VR or AR.

Table 1. Focus group participants summary

Technology	Group	Disability/Capability loss type							Total	Female:Male
		Sight	Hearing	Touch	Speech	Cognition	Mobility	Multiple		
VR	FG1	3	1	–	–	1	1	–	**6**	4:2
	FG2	–	–	–	–	1	3	1	**5**	5:0
	FG3	–	–	–	–	4	1	–	**5**	2:3
	FG4	1	1	–	–	–	1	1	**4**	2:2
AR	FG5	3	–	–	1	–	4	–	**8**	6:2
	FG6	–	3	–	–	2	–	–	**5**	2:3
	FG7	–	–	1	–	1	4	–	**6**	4:2
	FG8	–	–	–	–	1	5	–	**6**	5:1
Overall Total		**7**	**5**	**1**	**1**	**10**	**20**	**2**	**45**	30:15

Part 2 involved a more detailed exploration of the group's experiences in VR or AR through review of the user experience (UX) journey. The group reflected on past experiences and specific videos showcasing scenarios of (1) putting on and using relevant hardware (i.e. headsets and hand controllers for VR and tablets and smartphones for AR); (2) interacting with menus and other user interface elements; (3) the virtual content, environments and experiences themselves; and (4) the interaction techniques demanded by the operating systems and content.

Part 3 was a co-design exercise with the aim of understanding high-level user requirements in order to design more inclusive VR or AR experiences. This part involved a card sorting exercise in which participants were presented with a range of strategies that might help make immersive interfaces and content more usable and enjoyable for everyone. Participants were asked to reflect on which ideas they felt were the most important for them and then specify the two or three solutions that were most relevant to them individually. The frequency of these individual selections was used as the basis for subsequent discussion in the group to arrive at a final ranking of the most relevant solution.

Part 4 was an open discussion.

For the card sorting exercise, we asked participants to consider the following high-level accessibility strategies and choose the two most important to them. These were distilled from an online survey ($n = 101$) we had previously carried out and included the following ways to overcome access barriers:

- **Customisation:** Allows users to customise accessibility settings, for example, placement and styling of captions, scene contrast, and pacing of narratives.
- **Assistive Technology:** Allows users to benefit from their own assistive technologies, such as screen readers and switches.
- **Familiarisation:** Provides users with more tutorials and means of familiarisation, for example, offers greater assistance in learning about the technology and access to virtual environments that are familiar to users and thereby less confronting.
- **Adaptation:** Automatically adapts features to users' abilities, for example, by letting the content or system adjust itself, such as by adjusting the difficulty of a game or by making objects easier to reach, or more visible.

- **Awareness:** Allows users to maintain better awareness of the physical environment in which they engage with the immersive experience, for example, by making users aware of the physical world while not distracting them from virtual content.
- **Information:** Makes more information available to users, for example, provides hints and warnings, as well as presents the same information in multiple forms, such as captions or vibrations.
- **Interaction:** Supports more ways to interact, for example, by allowing users to select different modes of physical interaction, such as enabling interaction via hand tracking, head movement, controllers, etc.

3 Results

In this section we report on the results of the card sorting exercise as this was the primary focus of the workshop, and also generated the mostly lively and considered discussion among focus group participants. We group-elicited requirements by the common strategies listed above.

3.1 Virtual Reality

The most popular solution strategies among the focus groups (FGs) are Customisation (FG1, FG3, FG4) and Interaction (FG1, FG2, FG3). The next most prioritised is Information (FG2, FG4). In addition, one focus group also prioritises Adaptation (FG2).

Customisation: A priority area that emerged from the focus groups is enabling fine-grained adjustments of the visual appearance of the virtual world and any virtual controls, including brightness, contrast, inverted colour schemes, and other overall visual aspects (FG1, FG3, FG4). This area also includes the ability to adjust any text in terms of size and colour (FG1, FG3, FG4). Related, another highly preferred requirement is support for varying the speed of any animations, including scrolling text and video streams (FG1, FG3, FG4).

Other prioritised elements involve support for captions, subtitles, and audio descriptions of settings and surroundings (FG1, FG4). There was a desire for automatic transcripts (FG1), ideally coupled with the option to mix text and British Sign Language at various points (FG4).

One focus group (FG1) suggestion is to fine-tune interactions by allowing the user to control the speed of the pointer and click in the visual scene to access different areas (as opposed to having to navigate to reach them). Another suggestion is to include an option for an audio or vibration trigger to signal a request for user engagement.

One focus group (FG3) request is an ability to manually configure support for users with variable dexterity by, for example, allowing users to adjust the amount of movement required to reach virtual objects, in order to reduce fatigue.

In addition, we observe a range of other elicited user requirements: however, they are not as consistently prioritised across all focus groups.

Interaction: There is a desire to support multiple means of interacting. Eye gaze is identified as one such modality (FG1, FG3), as one switch-based accessibility systems, such as an eyebrow switch and gaming controllers (FG3).

Another prioritised group of requirements is voice control support, such as permitting users to use voice commands for positioning within VR and for navigating menus and interacting in general (FG2, FG3).

In terms of mixing and matching modalities, one focus group (FG2) explicitly suggests support for varying modalities according to current conditions, providing users with choices, but taking care not to force users to choose every single time the conditions change (FG2).

The remaining elicited requirements are largely in the area of ergonomics. We identify an area of high-level requirements relating to the ergonomics of the headset, such as supporting shoulder braces for the headset to assist the user in holding the head up and ease, or eliminate, neck strain (FG1). A related requirement is to reduce the weight of the headset (FG1) and to eliminate the need to strap the headset to the head (FG1). Headsets should also be untethered and thus not require wired connections (FG1). Last, ideally headsets would either provide an ergonomic experience for users needing to wear glasses or eliminate the need to wear glasses with the headsets (FG3).

In terms of hand control, headsets should work for users wearing gloves (FG1) and reduce neck and body movement by further hand controls, including gesture control (FG2, FG3). In terms of physical controllers, it is desirable to adopt the inclusive design approach and consequently implement light modifications to existing controllers to make them more accessible, as this may be more affordable for users than having to purchase expensive bespoke solutions (FG3).

Finally, ideally there should be no requirement to install sensors in a room, and if there is such a requirement, the systems should make it easier to instal such sensors (FG1).

Information: There is a desire to receive help spoken with a clear, pleasant voice and to avoid jargon (FG2). If it is necessary to introduce new concepts, then these should be clearly explained (FG2). Systems should provide a written and spoken tutorial on how to use them, suitable for first-time users (FG4). Another suggestion is to provide tutorials for each individual skill or task (FG2).

To encourage exploration, systems should have ways of allowing users to explore different options and settings (FG2).

Finally, systems should provide a way for users to assess their motion sickness in VR (FG2).

Adaptation: One focus group (FG2) reflects on the solution focusing on adaptation. One important aspect of such adaptation is enabling user control by providing mechanisms that allow the user to regulate the level of automatic adaptation and turn it off. In conjunction, it is suggested that it may be useful to have the option for users to provide data of their interactions and behaviours to improve system adaptation. Finally, users should be prompted when automatic adaptation may be useful and they should be allowed enough time to absorb new content and instructions before adaptation proceeds.

In terms of system-side requirements on adaptation there is a suggestion of supporting variable automatic adaptation for fluctuating conditions and a desire for the adaptation system to be able to ignore unintended movements and actions with high accuracy.

3.2 Augmented Reality

The most popular is Customisation (FG5, FG6, FG7). The second most prioritised solution strategy is Interaction (FG5, FG7). Finally, one focus group (FG8) prioritises Awareness.

Customisation: Similarly to VR, there is a strong desire to be able to fine-tune the visual appearance of graphical elements, such as adjusting the size and colour of all text (FG5, FG6, FG7) and changing colour, transparency, and contrast on all virtual content (FG5, FG7). Again, similarly to VR, there is a desire to vary the speed of animations and any scrolling text (FG6, FG7).

In terms of user interface organisation, there should be options to reduce choices and simplify the interface (FG5, FG6) and change the layout of virtual objects and controls (FG7). There should be an option to prevent pop-ups (FG7) and an option for sticky menus that remain in view until they are explicitly dismissed by the user (FG7). Finally, users should be able to set the field-of-view (FG5, FG7).

Audio design is another prioritised high-level requirement area. It should be possible to turn on and off audio, verbal prompts, subtitles and captions (FG5, FG6). In addition, there is a desire for the ability to configure audio cues to represent different elements of the design (FG5). There should be audio descriptions of text (FG5), and ways of probing the environment and receiving audio descriptions, such as “What is in front of me?” (FG5, FG6).

There should be support for British Sign Language in addition to text and audio (FG6) and the ability to enable or disable vibration cues (FG5).

In terms of ergonomics, it would be beneficial to be able to adjust the perspective for a user sitting upright or in a wheelchair (FG5). Object rotation could be supported by button interaction or manual input of degree of rotation, in addition to standard rotation interaction that requires the user to twist their wrist or fingers (FG5).

Interaction: All focus groups (FG5–FG8) desire support for offline editing of AR content and enabling interaction without the need to hold a device.

Again, similar to VR, a range of modalities are requested for input, including voice activation and voice commands (FG5, FG7), gaze interaction (FG7), and support for wearables to allow for longer reach and to enable alternative means of input and output (FG5, FG7).

In terms of output, there is a need for audio and haptic feedback (FG5), voice output of menus (FG5), and context-informative audio cues when traversing menus (FG5). As with VR, there is also a suggestion of functionality that allows users to point at a particular location and receive an audio description (FG). In addition, there is also a request to provide soundscapes when moving around (FG5). Finally, systems should have audio-only and visual-only modes (FG7).

Regarding user interface design, there should be a simple means of resetting the device, such as shaking the phone (FG5), and a mechanism for partitioning the user interface into separate chunks that can be used in isolation (FG7).

Relating to ergonomics, systems should support multiple ways of holding or mounting a device (FG5) and a variety of methods for users to hold equipment and tools, such as styli, to assist with dexterity and fine movements (FG7).

Finally, one focus group (FG7) expresses a requirement for systems to provide easy means for users to remain aware of their physical surroundings, which we will elaborate on when discussing the requirements for the next solution strategy: supporting awareness of the physical world.

Awareness: One focus group (FG8) considers this strategy. Systems should support a mechanism that allows users an easy way to leave AR and return to an unobstructed view of the physical surroundings. Related, another requirement is an ability to regulate the amount of virtual content to prevent virtual content clutter from obstructing the physical surroundings. Last, systems should maintain a view of virtual objects even when the user is moving, such as when using a wheelchair.

Systems should be transparent on who can view the user's surroundings and what these observers will perceive. In addition, systems should be aware of pavements and other surfaces, and their level of degradation, to ensure they can give users sufficient guidance to prevent accidents.

4 Discussion

This work represents a preliminary exploration of inclusivity requirements for VR and AR immersive content consumption. Our findings complement other efforts seeking to establish user requirements in this space. W3C's XR Accessibility User Requirements (2021) is an excellent attempt to document specific user needs and requirements. Oculus, a major VR headset manufacturer and content developer, also now offers developer guidance on Designing Accessible VR (2022). We contribute to the emerging understanding in this space by capturing and summarising the voice of the user. This includes providing insight into the prioritisation of inclusivity requirements that are otherwise typically presented as if they all have equal importance to the user.

We now briefly reflect on several limitations of this work. First, our assignment of participants to focus groups based on their dominant capability loss was imperfect due to scheduling constraints. This limits our ability to directly relate specific requirements to particular access needs. Nevertheless, a benefit of partly mixed groups was that the discussion could focus on high-level solution strategies that were broadly effective for different capability loss types. We consider this high-level discussion an advantage given the nascent stage of the requirements process.

Another important limitation of this work is that participants had varying levels of exposure to VR and AR content. This limited prior experience may have reduced the specific insights participants were able to bring. In addition, it is difficult to separate usability issues associated with encountering a new and unfamiliar form of technology from those usability issues arising from a given capability loss.

Future work involves using the identified high-level requirements as a basis for further investigation, including follow-up focus groups, to validate findings and elaborate further on user requirements, and iterative research around concrete solutions to access barriers to immersive content consumption.

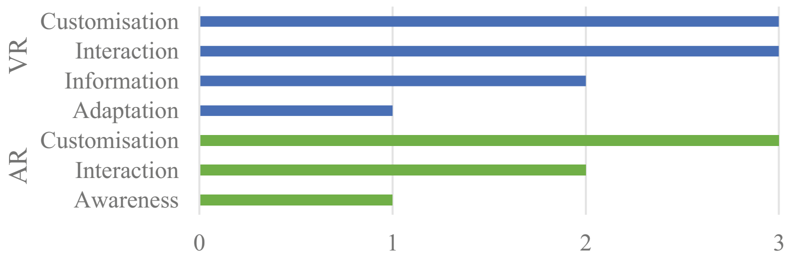

Fig. 1. The prioritised solution strategies for more inclusive VR and AR

5 Conclusion

We have reported the outcomes from eight focus groups involving participants with disabilities. We used card sorting to understand users' prioritised strategies for tackling barriers. Figure 1 summarises the number of focus groups listing each strategy as critical. For VR, we found that they were, in order of priority, customisation, interaction, information, and adaptation. For AR, we found that they were customisation, interaction, and awareness.

We clustered the elicited high-level requirements and found that customisation was consistently of the highest priority to users and providing this is critical for fully inclusive VR and AR content consumption.

We also found that interaction should be multimodal and allow users to mix and match hand tracking, controllers, gaze, and support for accessible technology, such as switch-based systems. In both VR and AR, users further desired means to point at various elements of an interface and be given descriptions.

In VR, information and help was another area identified as being of high importance and a range of high-level requirements emerged, such as providing initial guidance, offering spoken help with a clear voice with careful pacing, and ensuring there are tutorials in place explaining how to achieve specific tasks or goals.

In addition, in VR, one focus group identified adaptation as an important strategy that resulted in several high-level requirements, including the need to provide variable adaptation, means of turning it off, and means for users to provide deliberate training data to the system for adaptation. Finally, in AR, one focus group considered the strategy of allowing users to be aware of their physical environment to be important and suggested a range of requirements in this area.

These focus group results provide the basis for the prioritisation of subsequent efforts seeking to establish more specific requirements and corresponding technological solutions. We anticipate that this enhanced understanding of users' needs and wants within this design space will be of greatest benefit in the immediate term to developers of immersive content who currently lack effective guidance on making VR and AR content accessible.

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