Virtual Reality and accessibility : what users need?

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Abstract. The variety of functions involved in the use of virtual reality (VR) raises questions about its accessibility to a population with diverse profiles. We chose to explore these questions, particularly in the context of the use of VR headsets. Therefore, we designed an online survey in French with the aim of better understanding usage habits and user needs. This survey targets a broad population. Our research is based on the multidimensional approach to disability according to the International Classification of Functioning, Disability and Health (ICF) provided by the World Health Organization (WHO). This means that VR accessibility needs can concern all users, whether or not they have a disability. These results showed that VR users rarely use accessibility settings, but they still encounter difficulties in using it, especially regular users. This study allowed us to identify respondent profiles, based on their life habits, that might have accessibility needs in VR.

Keywords: Virtual Reality · VR · Accessibility · Interactions · Abilities.

1 Introduction

Virtual reality (VR) is a broad field accessible through various devices, including real spaces like the Cave Automatic Virtual Environment (CAVE), simple screens, and VR headsets [1].
The decrease in VR headset prices has made them more affordable [2], increasing their adoption since 2015 [3]. Due to the growing interest among users and the diversity of possible uses, our research focuses on this system. VR operates on the premise of engaging in sensory-motor and cognitive activities within a 3D artificial environment [5], involving motor functions for actions, sensory functions for perception, and cognitive functions for decision-making [6].
The range of functions involved in using VR devices raises questions about their accessibility for individuals with non-typical abilities. Most VR applications and games are designed for people with typical needs and abilities, and deviations from these norms can affect usability. However, few studies have investigated the accessibility of VR headsets for people with disabilities. One notable exception is the "Seeing VR" project, which developed 14 tools for visually impaired

users, allowing them to adjust contrasts and activate text-to-speech functionality within the immersive environment [7]. The study by Teofilo et al. (2018) [8]suggests accessibility options for VR users with visual or motor impairments. Agullo et al. [9]introduced a method for implementing subtitles in 360° videos to improve VR accessibility for hearing-impaired users. Dhruv Jain et al. [10] examined VR accessibility for the deaf and hard of hearing, proposing a design space for mapping sound to visual and haptic representations. Other studies, such as those by Heilemann [11], Ciccone [12], Mott [13], and Hamilton[14], have proposed accessibility guidelines for game design and virtual reality environments. Despite these valuable resources, they are insufficient for comprehensive system design due to the wide range of interaction modalities and diverse user needs. Notably, few studies address the challenges faced by individuals with cognitive, psychological, neurodevelopmental, or intellectual disabilities.
Furthermore, most studies have focused on using virtual reality for individuals with specific disabilities, such as visual impairment, except for the Creed et al. study published in 2023 [15]. This recent publication outlines a methodology involving interdisciplinary working groups to identify challenges related to the accessibility of VR and augmented reality. While it highlights many barriers faced by users with disabilities, it lacks direct feedback from users. To our knowledge, no study has directly queried individuals with disabilities, including those with multiple disorders, about their usage patterns and needs in virtual reality. Thus, we aimed to identify the current uses of VR among a diverse population with varying profiles and needs to enhance the system's usability. Inspired by Beeston et al. (2018) [16], who created a questionnaire to gain insights into disabled gamers and expand accessible gaming research, our objective is to better understand the behaviors and requirements of VR users. These findings aim to directly inform research and application development for VR headsets.

2 Approach

We chose the survey method for its ability to reach a broad audience and objectively analyze the results [17]. Our goal was to query users with various profiles to gain insight into overall VR accessibility requirements. Digital accessibility aims to minimize barriers faced by individuals with disabilities when accessing digital resources [18]. Disability is not solely determined by one's health condition but by the interplay of multiple elements. The Human Development Model and Disability Creation Process (HDM-DCP 2) [20] aims to identify and explain the causes and consequences of diseases, traumas, and developmental disruptions. This model measures a person's life habits to determine the outcome of their interaction with their environment and their quality of social participation. Life habits result from a combination of factors, including identity, choices, organ impairments, abilities, disabilities, and environmental characteristics. Our study focuses on social participation in virtual reality, specifically interactions within virtual environments using headsets. Measuring life habits in digital and virtual environments, as proposed in the HDM-DCP 2 model, should highlight factors that facilitate or hinder social participation. However, this model lacks sufficient elements to evaluate habits with digital tools. Therefore, our study aims to develop indicators to determine individuals' needs for accessing virtual environments.

3 Method

3.1 Survey structure

The survey was divided into four sections: respondent's life habits, VR usage habits, VR usability needs, and demographic questions.

Respondent's life habits: As mentioned earlier, the first part of the questionnaire focused on respondents' life habits, addressed through a series of questions. One specific question explored whether accessibility needs when using a computer are comparable to those when using VR. To address this, respondents were asked about adaptations, use of technical aids, or the need for human assistance when using a computer. Their responses were then correlated with their specific needs and settings in the context of VR. Beyond this initial inquiry, it became evident that VR poses unique accessibility challenges not encountered with traditional computer usage. VR experiences often involve physical movement in real space. Therefore, we considered it essential to inquire about users' mobility habits and their use of assistive devices in this context. This data allowed us to analyze users' mobility patterns in relation to their VR requirements and challenges.
Following inquiries into computer use and mobility habits, we included a question about the settings used for watching films or videos on a screen. This aimed to compare needs between screen-based activities and VR-based activities. The final part of the "life habits" section focused on the respondent's communication habits. We sought to explore whether there was a correlation between the respondent's usual mode of communication and specific needs or challenges encountered in VR usage. Our hypothesis was that accessing textual or auditory content could be challenging for users who communicate through alternative modes, such as French sign language (FSL), when using VR.

VR usage habits: Following the initial section on life habits, the second part focused on VR usage habits. It inquired about the frequency of VR usage, the contexts in which respondents used it, and the equipment utilized.

The usability needs of VR users: The third section aimed to delineate the usability needs of VR users. It queried respondents about any challenges faced when using the system, the requirement for adaptations or specific settings to overcome encountered difficulties, and the settings or options lacking in this context.

Demographic questions: Lastly, the final section aimed to collect socio-demographic information from participants, such as age, gender, and level of education.
To streamline questionnaire completion and data processing, most questions were presented in multiple-choice or single-choice formats. However, we also included some open-ended questions to allow respondents to provide additional details on specific situations or address any aspects that might have been overlooked.

3.2 Accessibility

To maximize accessibility and participation, we carefully designed the survey form. After evaluating different platforms, we chose the LimeSurvey platform for its compliance with the General Data Protection Regulation (GDPR) and its flexibility in form design. This allowed us to manage the visual appearance of the form, ensuring contrasts met Web Content Accessibility Guidelines (WCAG) standards [21]. We promoted the use of list or text field choices to aid users of screen readers. Considering various modes of communication, we included videos in French Sign Language (FSL) and provided the option for respondents to reply via an FSL video repository. Questions were crafted to be straightforward and clear, aiming to ensure understanding by a broad audience

3.3 Validation and distribution

The questionnaire underwent an iterative design process starting with an initial version pre-tested with 10 respondents, some of whom encountered digital accessibility issues. These tests aimed to evaluate the form's accessibility, question sequencing logic, clarity of wording, and comprehensibility of terms.

Based on feedback from the pre-tests, we rephrased certain questions and adjusted access conditions for specific items. Once finalized, the questionnaire was distributed through various channels. It was shared on social media platforms, particularly in groups focused on disability or video games, and distributed via email to associations and organizations dedicated to people with disabilities and research laboratories using virtual reality. Additionally, posters featuring a QR code linked to the survey were distributed to increase accessibility and reach.

4 Results

After six months of distribution, we collected the questionnaire data from the LimeSurvey platform.

4.1 What are the uses and needs?

Who are the respondents? Out of 215 visitors to the questionnaire homepage, data from 160 complete responses were analyzed after excluding 55 incomplete submissions. Among these respondents, approximately 46% identified as men (n=74), 51% as women (n=81), 1% as non-binary (n=2), and 2% chose not to respond (n=3). Participants' ages ranged from 21 to 64, with a mean age of 34.5 (SD=11.1).

What are the respondents' life habits? As mentioned in section 3.1, the initial questions of the questionnaire inquired about respondents' habits regarding communication, mobility, computer usage, and video viewing (Table 1).

- **About communication:** Among respondents, the majority preferred oral communication (n=94). Nearly 38% favored written communication (n=60), while less than 3% used alternative methods like French Sign Language (FSL) (n=2) or simplified French (n=3). One respondent reported using a combination of written and oral communication modes.
- **About moving habits:** Nearly 94% of respondents indicated they move around without mobility aids (n=151). The remaining 6% reported using either an electric wheelchair (n=6) or a white cane (n=3).
- **About computer usage habits:** Regarding computer usage habits, nearly 67% stated they did not use any adaptations (n=107). Among the 33% who reported using adaptations (n=53), the majority mentioned modifying the screen display, such as adjusting contrast or zoom (n=26). Some respondents used multiple adaptations simultaneously.
- **About watching videos:** When asked about viewing videos and the use of adaptations, 38% of respondents reported typically using adaptations such as subtitles (n=58), audio description (n=2), or connecting their hearing aids to the system (n=1). These insights helped outline the diverse life habits of the respondents based on the earlier questions. Further statistical analyses of these data will be elaborated upon in subsequent sections of this article.

What are the usage habits of VR? Nearly 74% of respondents have used virtual reality before (n=119). Among these respondents, over 85% use it less than once a month (n=101), about 10% use it approximately once a month (n=12), less than 3% use it approximately once a week (n=4), and almost 2% use it daily (n=2) (Fig. 1). When queried about their use of virtual reality, most respondents cited video games (n=62), followed by work (n=46), education (n=28), and entertainment activities such as watching videos (n=24). Other uses included cultural activities like visiting museums and exhibitions (n=5) and therapy (n=2). Additionally, a minority of respondents mentioned uses not provided in the multiple-choice options, such as visiting amusement parks or testing the technology without engaging in specific activities (n=7). Regarding gamers' VR habits, the top two games mentioned were "Beat Saber" and "Superhot" (n=21 and n=6 respectively). In total, respondents cited 28 different game titles, the majority of which were : "Beat saber" (n=21), "Superhot" (n=6), "Half-life: Alyx" (n=4), "A Fisherman's Tale" (n=2)," Resident Evil 4" (n=2) and "The climb 2" (n=2). Twenty five respondents cited other games ansd twenty-five respondent's didn't know the name of the game they had played.

More than half of those surveyed could not specify the model of headset used (n=69), while the majority of those who could specify mentioned using the "Meta Quest 2" headset (n=27).

Why do respondents rarely use VR? To identify potential obstacles to virtual reality usage, we asked users who reported using VR less than once a month about their reasons for infrequent usage (Fig. 2). The primary reason cited was lack of opportunity (n=72). Other reasons included lack of interest in the technology (n=28), difficulties in using the system (n=15), content not meeting their needs (n=11), and equipment being too expensive (n=3). When asked why the content offered did not meet their needs, the primary concern raised by users was the lack of originality and quality in VR content (n=8). Additionally, two respondents mentioned discomfort from the equipment.
Regarding difficulties encountered, the majority of respondents mentioned experiencing motion sickness (n=10), a common side effect of VR causing nausea, dizziness, vomiting, and cold sweats [22]. A minority mentioned struggles with fatigue when maintaining activity over a prolonged period (n=5), and some mentioned difficulties interacting with the virtual environment (n=2). Among users who reported using virtual reality more than once a month, over 66% mentioned experiencing difficulties (n=10).

The primary difficulty encountered was motion sickness during VR usage (n=7). Other difficulties mentioned included experiencing visual or cognitive fatigue during use (n=6), challenges with interactions within the virtual environment (n=3), perception of visual information (n=2), perception of 3D (n=2), spatial orientation (n=2), and perception of sounds (n=1).

What adaptations for VR? More than half of frequent virtual reality users (those who use VR more than once a month) indicated they did not make any adaptations or activate accessibility options when using VR headsets (n=10). The remaining frequent users mentioned making adjustments such as adjusting contrast or brightness (n=4), reconfiguring buttons (n=2), using alternative controllers (n=2), changing the viewpoint for seated use (n=1), adding subtitles (n=1), and activating text vocalization (n=1).

Why don't respondents use VR? When respondents who reported never having used VR were asked about their reasons for non-use, the most frequently cited reason was a lack of opportunity (n=29). Other reasons included lack of interest (n=8) or inability to use it (n=4). Among those who stated they were unable to use VR, three explained it was due to lack of head mobility, often caused by the headrest of their wheelchair. Another respondent mentioned the system's incompatibility with their typical adaptations, such as a screen reader and Braille display.
Following inquiries about their challenges with using VR, respondents were asked to propose adaptations that could facilitate their VR usage. One respondent, facing limitations in head movement, suggested using gaze-based interaction control

and contactors. Another respondent, experiencing compatibility issues between VR and their usual assistive tools, proposed integrating haptic feedback and technical interfaces to support the use of dedicated compensatory tools for computers.

4.2 What's the relationship between respondents profile and VR use?

Profiling by usage frequency The statistical analysis using the Chi-square test of independence showed a significant relationship between the frequency of VR usage and the difficulties encountered (Chi2: $p < 0.05$) (Table 2). Comparing difficulties in VR between non-regular users (using VR less than once a month) and regular users (using VR between once a month and daily), it was found that regular users reported proportionally more difficulties with VR usage.

Profiling by life habits As mentioned in section 3.1, we explored the relationship between accessibility needs when using a computer and when using VR. While no statistically significant relationship was found between the use of adaptations for the computer and VR, the chi-square test of independence revealed a significant correlation between using adaptations on a computer and experiencing difficulties with VR (Chi-square: $p < 0.05$). Thus, although direct adaptation use in VR and on a computer showed no direct link, users of computer adaptations often encountered more difficulties with VR. Furthermore, considering VR involves physical movement, we examined whether using mobility assistive technology (AT) influenced difficulties in VR usage. Statistical analysis indicated a significant correlation between using mobility AT and experiencing challenges with VR (Chi-square: $p < 0.05$).

The independence tests conducted between alternative communication usage and encountering difficulties in VR, as well as between screen subtitles usage and VR subtitles usage, did not yield statistically significant results.

5 discussion

The findings presented in section 4 indicate that a majority of respondents have experience with VR, primarily for gaming, mentioning popular titles like "Beat Saber" and "Superhot." Despite this, most respondents use VR sporadically, with only a small proportion using it frequently.

The correlation between VR usage frequency and reported difficulties raises questions about the reasons behind this disparity. It appears that difficulties mentioned by frequent VR users do not necessarily hinder their ability to interact with the system directly, but rather affect comfort and sustained engagement (e.g., visual fatigue, motion sickness, spatial orientation).

It is reasonable to infer that addressing these challenges requires more regular and sustained use of VR than occasional users typically engage in. The link between usage frequency, duration, and the need for adaptations merits further investigation.

The lack of significant relationship between VR and PC adaptation use prompts several considerations. We hypothesize that VR adaptations may not be as readily available, which could explain their limited use. The correlation between needing adaptations for computer use and potentially needing them for VR supports this hypothesis. This suggests that while users requiring adaptations for computers may also need VR adaptations, accessibility features for VR may not be easily accessible or set up.

Further research into the availability and setup challenges of VR accessibility features would provide valuable insights into barriers to VR accessibility.
The response from an open question supports the hypothesis of potential unawareness about available solutions. One respondent noted, "the different proposals I saw in the previous question are, for me, adaptations that I will think about next time." This suggests that users may not be fully aware of the options to adapt their VR headset.

Furthermore, the statistically significant relationship between the use of mobility aids and the inability to use VR, particularly among electric wheelchair users hindered by their headrest, underscores the importance of profiling respondents based on their usage habits to identify VR-related needs. This approach allows us to draw parallels between accessibility needs in VR and the respondents' daily life habits.

6 Conclusion and future work

The analysis of our online questionnaire data revealed that a majority of the general public has experimented with virtual reality headsets, primarily for video games. Despite this familiarity, VR usage remains sporadic, with few users activating accessibility options. Respondents did report various difficulties with VR, focusing on comfort issues like visual or cognitive fatigue and orientation challenges, particularly among frequent users. Some participants noted being unable to use VR due to compatibility issues with their mobility aids. This study allowed us to profile respondents based on their life habits, providing insights into potential VR accessibility needs. By emphasizing life habits rather than just impairments, we aimed to broaden accessibility considerations in VR research and practice. This approach offers valuable insights into diverse user needs and guides strategies for improving accessibility in virtual environments. Currently, the questionnaire is being distributed in English and Swedish versions. After collecting data from these languages, we will conduct a comparative analysis on usage patterns and accessibility needs across English, Swedish, and French respondents.

APPENDIX

Table 1. Adaptations used in everyday life

Communication	Number of respondents
Oral communication	94
Written communication	60
Any form of simplified French	3
French Sign Language	2
Written/oral language	1
Moving habits	
Without a mobility aid	151
Electric wheelchair	6
White cane	3
Computer use habits	
Whithout adaptation	107
Display modifications	35
Mouse/keyboard adapted	21
Screen reader	4
Voice recognition	3
Human assistance to start the computer	2
Human assistance to get on the computer	1
Eye tracking	1
software for moving the pointer	1
Watching videos	
Without adaptation	99
Subtitles	58
Audio description	1
Connecting hearing aids	1

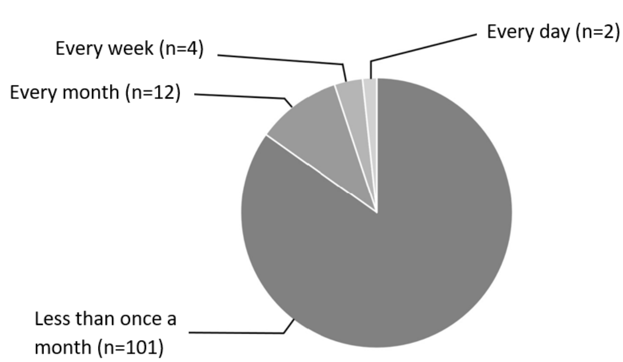

Fig. 1. Frequencies of virtual reality use.

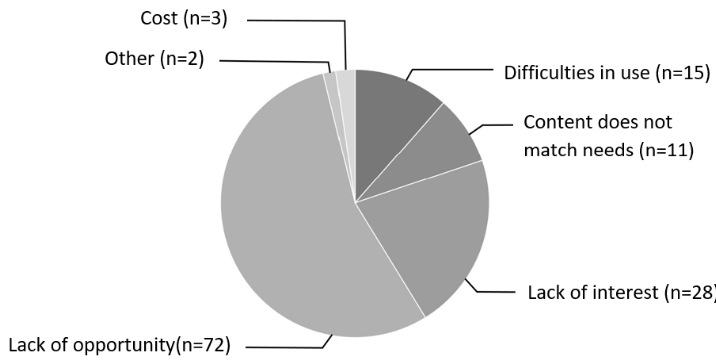

Fig. 2. Barriers to using virtual reality.

Table 2. Results of chi-squared independence tests

	x-squared	df	p.value
Frequency of use - difficulties in VR	**12.899**	**1**	**$p<0.001$**
Adaptations on PC - adaptations in VR	2.025	1	$p>0.05$
Adaptations on PC - difficulties in VR	**8.4591**	**1**	**$p<0.05$**
Inability to use VR - adaptations on PC	**3.8704**	**1**	**$p<0.05$**
VR use - mobility aids	**23.698**	**1**	**$p<0.001$**
Inability to use VR - mobility aids	**11.116**	**1**	**$p<0.001$**
VR subtitles - PC subtitles	5.6738e-32	1	$p>0.05$
Communication mode - difficulties in VR	7.4219e-30	1	$p>0.05$

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