Accessibility in the Metaverse: A Rapid Review of the Literature

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Abstract

The Metaverse gained popularity with the rebranding of Meta, and since then, headsets, multimodal devices, and applications with immersive experiences have evolved and been applied in various domains such as marketing, education, and industry, among others. However, we question whether individuals with disabilities are also able to have immersive experiences. Therefore, this study aims to conduct a Rapid Review to identify the state of the art in accessibility within the Metaverse. From 145 studies identified in the Scopus search engine, 141 studies were excluded, resulting in 4 articles for data extraction. We found that there is significant ambiguity in the use of the term "accessibility," which led to a high exclusion rate of studies. Furthermore, we did not identify any work that implements assistive technologies to enable immersive experiences for individuals with disabilities. For future research, we aim to conduct a more comprehensive systematic review to obtain more consistent results on the state of the art in accessibility within the Metaverse.

Keywords

Accessibility, Metaverse, Rapid Review

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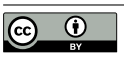
1 Introduction

Technology has enabled individuals from different parts of the world to communicate, interact, and co-exist in a digital environment. The Internet has removed physical, linguistic, and temporal barriers. Immersive technologies enable the recreation and invention of new worlds and spaces [10]. However, despite technological advances, some people still face difficulties or barriers in accessing these resources. Therefore, it is crucial to ensure that new technologies meet the needs of as many people as possible [11].

In recent years, major technology companies such as Meta, Microsoft, and Apple have invested in the Metaverse. The main difference between desktop/mobile applications and the Metaverse lies in human-computer interaction. Through Metaverse, users can have immersive experiences, interact, and receive feedback through other human senses, in addition to vision, hearing, and touch [9].



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However, the integration of accessibility and Metaverse is crucial to enabling individuals with disabilities to participate more fully in the virtual world, promoting diversity and equal opportunities for all users. It became necessary to investigate whether research primarily focused on the Metaverse is prepared to support accessibility. As a continuation of the work by [11], a rapid review study was conducted to gather evidence on the state of the art in accessibility research for the Metaverse.

2 Theoretical Background

2.1 Accessibility

The definition of accessibility emphasizes the need for information technology systems to be equally available, perceivable, and understandable for all individuals. The 2006 Convention on the Rights of Persons with Disabilities [1] defined persons with disabilities as individuals with long-term physical, mental, intellectual, or sensory impairments that, while interacting with various barriers, may hinder their full and effective participation in society on an equal basis with others.

Addressing (or defining) disability is not a simple task, as it encompasses various aspects related to bodily functions, body structure, functionality, and individual impairments [7]. Additionally, cultural and social aspects reinforce stigmas or prejudices associated with disability [15]. Recently, we observe an appreciation for the integrative biopsychosocial approach, which considers participation in society, the activities individuals engage in, and environmental and personal factors.

2.2 Metaverse

The term “Metaverse” was coined by Neil Stephenson in his 1992 science fiction novel, Snow Crash. In this narrative, humans from the physical world enter and exist in the Metaverse—a parallel virtual realm—through digital avatars that represent their physical selves, using Virtual Reality (VR) technology. The Metaverse, literally derived from the prefix “meta” (meaning transcendence) and the suffix “verse” (a shorthand for universe), is a computer-generated world with a consistent value system and an independent economic system connected to the physical world [22].

Advancements in edge computing, Artificial Intelligence (AI), and Machine Learning (ML) technologies, coupled with concerns about data privacy, ushered in a decentralized web, giving rise to Web 3.0 [19]. The Metaverse leverages the advancements and technological innovations of Web 3.0. Significant progress is being made in key areas such as holographic rendering, user experience in both two-dimensional and three-dimensional spaces, low-latency transport, spatial mapping, and the physics of objects [19]. As a

result, the Metaverse extends beyond merely being a game or a virtual social space.

3 Related Work

Damasceno et al. also conducted a Rapid Review (RR); however, their focus was specifically on distance education [6]. The focus of [23] was on assistive technologies for the Metaverse, specifically for individuals with learning difficulties such as dyslexia, dyspraxia, dyscalculia, dysgraphia, auditory processing disorder, visual processing disorder, nonverbal learning disorder, and apraxia of speech. Dudley et al. excluded the keyword "metaverse" from their search string, which poses a critical threat to the validity of their results [8].

Considering the aforementioned related works, this study distinguishes itself by focusing on the investigation of general solutions that ensure People with Disabilities (PWD) to have the opportunity to experience immersive sensations.

4 Research Method

The main research question behind this study was: "*what is the state-of-the-art of accessibility in the Metaverse*"? A Rapid Review (RR) design was used, following the guidelines of [2]. RRs are practice-oriented secondary studies [21]. The primary objective of an RR is to provide evidence that aids decision-making to resolve or mitigate issues encountered by practitioners. To achieve this objective and adhere to the time constraints of practice, RRs must produce evidence more quickly than Systematic Reviews (SRs), which often takes months to years to complete [21]. To meet these requirements, certain steps of SRs are intentionally omitted or simplified in RRs.

The study presented here covers existing work on Accessibility in the Metaverse: articles and conference papers published and indexed until February 2024. Our RR was performed in three stages: Planning, Conducting, and Reporting. The activities concerning the planning and conducting stages of our RR are described in the following subsections, and the reporting stage is presented in Section 5.

4.1 Planning stage

At this stage, we conducted several activities to establish a review protocol: (1) formulation of the research questions; (2) development of the search strategy; (3) selection of primary studies; and (4) selection of synthesis methods. Each of these activities is detailed as follows.

4.1.1 Research questions. The formulation of research questions represents the initial and essential phase of planning a Systematic Mapping Study (SMS), as these questions guide the entire review process. The research questions were developed to direct the investigation into accessibility in the Metaverse, an emerging and multifaceted field that requires a thorough analysis of existing scientific contributions. For the present study, three main research questions were outlined:

- **RQ1**: How do studies contribute to accessibility in the Metaverse?
- **RQ2**: What are the types of accessibilities covered in the Metaverse?
- **RQ3**: What are the most frequently applied research methods, and in what study context?

The first question (RQ1) includes analyzing the innovations, methodologies, and results presented in the literature, and evaluating the impact and relevance of these contributions in both practical and theoretical contexts. The second (RQ2) considering that accessibility can encompass physical, sensory, cognitive, and other aspects, it is essential to categorize and understand which dimensions of accessibility are most frequently explored by researchers. Finally, the third research question (RQ3) analyzing the employed methods and study contexts allows for a critical assessment of the methodological robustness of the research and the conditions under which the studies were conducted.

4.1.2 Search strategy. Unlike Systematic Literature Reviews (SLRs) that use multiple search engines, RRs may focus on a single search engine [2]. Therefore, the Scopus database was selected as the primary source due to its extensive coverage of peer-reviewed literature across various disciplines, including computer science, engineering, and social sciences. To identify relevant studies on accessibility in the Metaverse, a comprehensive search string was developed based on the PICO approach [13]. PICO is a widely recognized approach for developing search strategies in systematic reviews. This approach stands for Population, Intervention, Comparison, and Outcome, though not all elements are always used. In the context of this research, Population and Intervention were adopted. Given this approach, the search string aimed to comprehensively capture studies that focus on accessibility within the context of the metaverse.

The keyword "*metaverse*" focuses on the digital and virtual environments encompassed by this term. The intervention is represented by the keywords and phrases related to "*accessibility*". These terms were carefully selected to ensure the inclusion of a broad spectrum of literature addressing various aspects of accessibility. Boolean *OR* has been used to join alternate terms and synonyms in each main part, and boolean *AND* has been used to join the three main parts. The asterisk symbol "*" signifies any character whose purpose is to include any word variation of each search term (e.g., the search term "accessib*" includes the following words: accessibility OR accessibilities OR accessible etc.).

4.1.3 Selection of primary studies. The search was performed by applying the search string to the metadata (i.e., title, abstract, and keywords) of each article across the source. Each study retrieved from the automated search was evaluated by the three authors to determine its inclusion, based on its title, abstract, and keywords. Discrepancies in the selection process were resolved by consensus among the authors after reviewing the entire paper.

Studies meeting at least one of the following inclusion criteria were included: paper being accessible for download; full text paper written in the English language; paper answers at least one research question from the review.

The studies that met at least one of the following exclusion criteria were excluded: duplicate paper; paper not being a primary study; paper being a work in progress or short paper; paper not published in journal, conference, or book chapter; authors having

a most recent article; paper not reporting as main contribution accessibility in the Metaverse.

4.1.4 Synthesis methods. We applied both quantitative and qualitative synthesis methods. The quantitative synthesis was based on: counting the primary studies that are classified in each answer from our research sub-questions; defining bubble plots to report the frequencies of combining the results from different research sub-questions. A bubble plot is two x–y scatter plots with bubbles in category intersections. This synthesis method is useful to provide a map and give a quick overview of a research field [16]; counting the number of papers found in each bibliographic source per year.

The qualitative synthesis is based on: summarizing the benefits and limitations of the accessibility in the Metaverse in each proposed research question.

4.2 Conducting stage

The application of the review protocol yielded the following results: from the 145 articles, the screening process began; following the inclusion and exclusion criteria, 141 studies were excluded, resulting in 4 articles for data extraction. At first, the number of selected studies can be understood as a possible threat to validity. During the screening process, many discussions were generated between the reviewers regarding the type of contribution of the studies. Many of the works addressed accessibility in a superficial way and without significant and concrete contributions, from the point of view of breaking down barriers regarding the use of the Metaverse by PWD. Other works had different concepts about accessibility. Some approach accessibility as a broad aspect of facilitating access to certain resources, such as ensuring Internet access, and quality of infrastructure, among others. More details will be discussed in Section 6.

5 Results

5.1 How do studies contribute to accessibility in the Metaverse (RQ1)?

The objective of this question is to identify how the works contribute to accessibility for people with disabilities in the Metaverse. As a result, we obtained contributions that involve software architecture definition, Metaverse as an intervention, and a manifesto.

5.1.1 Software architecture. Chomjan et al. address the development of a software architecture for intelligent virtual museums, focusing on accessibility and the enhancement of immersive learning experiences [4]. The main contribution of this work is the proposal of a software architecture based on the principles of universal design, aimed at creating an accessible and inclusive environment that can be used by people of different ages and abilities. The proposed architecture is the result of a literature review on immersive technologies and universal design principles. The literature analysis enabled the identification of the needs and requirements for developing a platform that integrates immersive technologies with universal design principles.

5.1.2 Metaverse as an intervention. Cheung et al. investigated the effectiveness of a VR based life skills training program for individuals with intellectual disabilities [3]. The primary objective of the study was to assess whether VR technology can significantly improve the autonomy and quality of life of these individuals by facilitating the learning and practice of essential skills in a controlled and safe environment. Participants used high-quality VR headsets equipped with motion tracking to provide a fully immersive experience. The virtual environment was set up to simulate a realistic house and a virtual supermarket. These environments were designed to replicate everyday scenarios where life skills are required. Lee et al. describes the development and implementation of a Metaverse-based social skills training program for children with Autism Spectrum Disorder (ASD) [14]. The study developed and applied a Metaverse-based social skills training program to improve the social interaction skills of children with ASD, aged 7 to 12 years.

5.1.3 Manifesto. Zallio and Clarkson developed a comprehensive set of guidelines and best practices for designing immersive digital environments that promote inclusion, diversity, equity, accessibility, and safety [24]. These guidelines provide a foundation for designers and developers to create virtual experiences that are accessible to everyone and foster a sense of safety and belonging among users. The manifesto consists of 10 principles for designing an accessible Metaverse: open and accessible; honest and understandable; safe and secure; driven by social equity and inclusion; sustainable; values privacy, ethics and integrity; guarantees data protection and ownership; empowers diversity through self-expression; innovates responsibility; and complements the physical world.

5.2 What are the types of accessibilities covered in the Metaverse (RQ2)?

The analyzed studies highlight the Metaverse's ability to address different types of accessibility, ranging from specific needs of children with ASD and individuals with intellectual disabilities to broader principles of universal design.

5.2.1 Universal accessibility. Both studies [24] and [4] addressed a wide range of accessibility issues, focusing on principles of inclusion and universal design. Specifically, Zallio and Clarkson recommend the use of assistive technologies such as screen readers and alternative input devices, the creation of avatars representative of diverse identities and cultures, and the implementation of robust security and privacy policies to protect users [24]. On the other hand, Chomjan et al. designed their architecture based on universal design principles [4]. Universal design aims to make environments usable by all people, regardless of age, ability, or socioeconomic status.

5.2.2 Intellectual disability. Cheung et al. addressed intellectual disability, which is defined by significant limitations in intellectual functioning and adaptive behavior [3]. This includes difficulties in social, academic, and practical skills that are evident in daily tasks and require ongoing support for independence. The use of immersive technologies allowed the practice of daily life skills, such as cooking, cleaning, and shopping, in a safe and simulated environment.

5.2.3 Autism spectrum disorder. The focus in [14] was on children with ASD. ASD is a neurodevelopmental condition characterized

by significant difficulties in social communication, repetitive and restrictive behaviors, and a variety of cognitive and functional skills [20]. The interventions in the study were designed to improve social interaction skills by providing a safe and controlled environment where children could practice these skills through playful and collaborative activities.

5.3 What are the most frequently applied research methods, and in what study context (RQ3)?

The most frequently applied research methods in the analyzed studies include controlled experiments and literature reviews.

5.3.1 Controlled experiments. Lee et al. used a randomized controlled trial to evaluate the effectiveness of a Metaverse-based social skills training program for children with ASD [14]. From an experimental design perspective, the children were randomly divided into intervention and control groups. The intervention group participated in social skills training sessions in the Metaverse, while the control group received usual care or no intervention. The effectiveness of the program was measured through pre- and post-intervention assessments of the children's social skills, using standardized instruments and behavioral observations.

Cheung et al. adopted a multicenter randomized controlled trial design to investigate the effectiveness of VR-based life skills training for individuals with intellectual disabilities [3]. Participants were randomly allocated into intervention and control groups across multiple research centers. The intervention group participated in practical skills training sessions (such as cooking, cleaning, and shopping) in a virtual environment, while the control group continued with conventional training. The outcomes were measured through pre- and post-intervention assessments of the participants' life skills, using standardized scales and practical observations.

5.3.2 Literature reviews. The studies [4] and [24] conducted a comprehensive literature review to develop their proposals. However, only in [4] an evaluation was conducted with 10 experts to validate the proposed architecture for intelligent museums in the Metaverse.

6 Discussion

This study revealed several gaps and challenges in the field of accessibility within the Metaverse. Three main issues emerged from the findings of this review and will be discussed in the following sections:

6.1 Ambiguity

During the process of this review, a significant ambiguity was found in the use and definition of the term "accessibility" among the articles. Several studies were excluded due to the lack of a clear and consistent definition of accessibility. The ambiguity manifested in various ways, such as broad and generic definitions where the term accessibility was used without clearly specifying which types of disabilities or usability aspects were being addressed. Additionally, there was confusion between digital accessibility (hardware/software) and being available or providing access to technology, leading to an ambiguous interpretation of the term.

For example, [5, 12, 17, 18] did not differentiate between device accessibility and user-end accessibility. In these studies, accessibility is treated as a condition that enables access to the target application, such as ensuring that a university has adequate infrastructure for people to access the internet via Wi-Fi [18], or that the application can be accessed by any device and browser [12], among others. Moreover, the lack of specification of specific target populations or types of disabilities addressed led to the exclusion of studies that did not meet specific accessibility criteria, which were defined inconsistently.

6.2 Disability coverage

As a result of the ambiguity problem discussed above, the number of studies found in this review was very low. Consequently, the coverage of solutions addressing disabilities and disorders will also be low. Nevertheless, considering the contributions of the studies, significant coverage was only found in [3] and [14], which specifically utilized a VR application to support the development of social skills in children with Autism [14] and individuals with intellectual disabilities [3]. Zallio and Clarkson and Chomjan et al. only addressed general aspects of accessibility [4, 24].

The lack of broad coverage of disorders and disabilities in the analyzed studies not only limits the generalization of the findings but also overlooks the opportunity to develop truly inclusive solutions.

6.3 Assistive technologies for the Metaverse

Through this study, a gap was identified: the absence of studies focused exclusively on the development and application of assistive technologies. Although the reviewed articles explore the use of VR and Augmented Reality (AR) to improve accessibility, none are specifically dedicated to the creation or evaluation of assistive technologies designed to facilitate the inclusion of people with disabilities, as well as adapting programs, content and information in different formats (simple language, audio description, sign language) must be explored to allow a greater number of users.

This absence is notable and concerning, as assistive technologies play a crucial role in promoting accessibility and inclusion. Technologies such as screen readers, alternative input devices, BCI, and haptic feedback are fundamental for enabling people with various disabilities to fully participate in virtual environments. However, the lack of focus on such technologies in the reviewed studies suggests a significant gap in research and development in this area.

7 Conclusion

This study aims to gather evidence on the current state of accessibility in the Metaverse. Specifically, we seek to investigate how academic articles contribute to overcoming barriers that facilitate access to Metaverse resources for PWD.

Utilizing the RR methodology, we conducted the planning, execution, and data extraction stages to collect evidence aligned with our objectives. During the screening process, we initially identified 145 studies, of which 141 were excluded, leaving a final set of 4 articles for detailed analysis. Despite the small number of selected studies, this result highlights a relevant gap in the literature. Most excluded works addressed accessibility superficially or adopted

broad definitions unrelated to overcoming barriers for people with disabilities in the Metaverse.

Our findings reveal that the definitions of accessibility are often ambiguous, which significantly impacted the number of articles included in the final data extraction. Consequently, we identified a substantial gap in initiatives aimed at breaking down barriers to enable access for people with disabilities. Examples of such initiatives include the development of assistive technologies for the Metaverse, such as screen readers and tools for color blindness.

For future research, we propose conducting a systematic literature review with a broader scope. This will involve different parameters, such as an increased number of search engines and alternative search strings, to enhance the comprehensiveness of the review.

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