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Accessibility through Assistive Technology: A Systematic Evaluation for Individuals with Visual Impairment and Blindness

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Abstract: ***This systematic evaluation critically examines the current landscape of assistive technology (AT) and its effectiveness in enhancing accessibility for individuals with visual impairment and blindness. Despite significant advancements in various AT solutions, disparities in adoption, functionality, and user experience persist. This review synthesizes findings from a comprehensive literature search, focusing on recent developments, key challenges, and emerging trends across diverse AT categories, including screen readers, refreshable braille displays, navigation aids, and object recognition technologies. We identify prevalent barriers to effective accessibility, such as high costs, limited interoperability, and insufficient user training, alongside promising innovations in AI-powered solutions and integrated ecosystems. The paper highlights critical gaps in current research, particularly regarding long-term efficacy, inclusive design methodologies, and the socio-economic impact of AT on independent living. By systematically evaluating the strengths and limitations of existing AT, this review aims to inform future research, guide technological development, and advocate for more equitable and comprehensive accessibility solutions for the visually impaired and blind community.***

Keywords: Assistive Technology, Screen Reader, Navigation, Accessibility, Blind, Visual Impaired

1. Introduction

The ability to access information, navigate environments, and participate fully in society is a fundamental human right. For individuals with visual impairment and blindness, however, traditional methods and infrastructures often present significant barriers, limiting opportunities for education, employment, social engagement, and independent living. Globally, the number of people with visual impairments is substantial and growing, with the World Health Organization (WHO) estimating that at least 2.2 billion people have a near or distance vision impairment. A significant portion of this population experiences profound visual loss, necessitating alternative approaches to interaction with the digital and physical worlds.

In response to these challenges, assistive technology (AT) has emerged as a transformative force, offering innovative solutions designed to bridge the accessibility gap. From foundational tools like screen readers and magnification software to advanced navigation aids and AI-powered object recognition systems, AT strives to empower individuals with visual impairments by providing access to information, enhancing mobility, and fostering greater autonomy. These technologies are not merely conveniences; they are crucial enablers that facilitate participation in an increasingly digital and visually-oriented world.

Despite the proliferation of AT devices and software, the effectiveness of these tools in achieving genuine and comprehensive accessibility remains a subject of ongoing investigation and debate. While some technologies have undeniably revolutionized the lives of many, persistent challenges—including issues of cost, usability, interoperability, and the rapid pace of technological change—continue to impede widespread and equitable adoption. Furthermore, the diverse needs within the visually impaired community, spanning different degrees of vision loss, age groups, and cultural contexts, underscore the necessity for a nuanced understanding of AT's impact.

This systematic literature review aims to provide a comprehensive and critical evaluation of accessibility achieved through assistive technology for individuals with visual impairment and blindness. By synthesizing findings from recent academic research, industry reports, and user-centered studies, we seek to illuminate the current state of AT, identify key advancements and persistent limitations, and highlight the critical factors influencing its successful implementation. This review will delve into various categories of AT, assess their efficacy in promoting independence and inclusion, and identify crucial gaps in current research that warrant further exploration. Ultimately, this paper endeavors to contribute to a deeper understanding of how assistive technology can be optimally designed, deployed, and utilized to ensure truly accessible and equitable futures for the visually impaired and blind community.

2. Methodology

This systematic literature review was conducted to comprehensively evaluate the accessibility achieved through assistive technology (AT) for individuals with visual impairment and blindness. The methodology adhered to established guidelines for systematic reviews, including principles derived from PRISMA (Preferred Reporting Items

for Systematic Reviews and Meta-Analyses) [1] where applicable, to ensure transparency, reproducibility, and rigor.

3. Research Questions

The review was guided by the following primary research questions:

- What are the current types and functionalities of assistive technologies designed to enhance accessibility for individuals with visual impairment and blindness?
- What is the reported efficacy and user experience of these assistive technologies in promoting accessibility across various domains (e. g., education, employment, daily living, navigation) ?
- What are the key barriers and facilitators to the widespread adoption and effective utilization [2] of assistive technologies by the visually impaired and blind community?
- What are the significant gaps in current research regarding assistive technology and accessibility for visual impairment and blindness?

1) Search Strategy

A comprehensive search strategy was developed and executed across multiple electronic databases to identify relevant peer-reviewed articles, conference papers, and technical reports. The following databases were searched to capture recent advancements:

- Scopus
- Web of Science
- IEEE Xplore
- ACM Digital Library
- Shodhagangotri
- Shodhaganga

The search terms were carefully constructed using a combination of keywords, Boolean operators (AND, OR), and truncation, encompassing broad and specific terms related to assistive technology, accessibility, and visual impairment. Key search terms included:

- ("assistive technology" OR "assistive device" OR "adaptive technology" OR "rehabilitation technology")
- AND ("visual impairment" OR "visually impaired" OR "blindness" OR "blind" OR "low vision")
- AND ("accessibility" OR "accessible" OR "usability" OR "user experience" OR "inclusion" OR "independent living")
- AND ("screen reader" OR "braille display" OR "magnifier" OR "navigation aid" OR "object recognition" OR "haptic feedback" OR "wearable device")

Reference lists of included articles were also manually scanned for additional relevant publications (snowballing).

2) Eligibility Criteria

Articles were selected based on the following inclusion and exclusion criteria:

Inclusion Criteria:

- **Language:** Published in English.
- **Publication Type:** Peer-reviewed journal articles, conference papers, and high-quality technical reports [3].
- **Content:** Focus on assistive technology specifically designed for or applied to individuals with visual impairment or blindness.
- **Outcome Measures:** Discussed aspects of accessibility, usability, effectiveness, challenges, or user perspectives related to AT.
- **Study Design:** Empirical studies (quantitative, qualitative, mixed-methods), literature reviews, systematic reviews, and meta-analyses were considered.

Exclusion Criteria:

- Non-English publications.
- Editorials, opinion pieces, news articles, and un-peer-reviewed grey literature (unless it was a highly authoritative technical report from a recognized body).
- Studies focused on general disabilities without specific attention to visual impairment.
- Studies primarily addressing medical treatments for visual impairment rather than technological aids for accessibility.
- Duplicate publications.

3) Study Selection Process

The identified articles were subjected to a rigorous two-phase screening process:

- **Phase 1 (Title and Abstract Screening):** Two independent reviewers (author 1 and author 2) screened the titles and abstracts of all retrieved articles against the eligibility criteria. Any discrepancies were resolved through discussion or by consulting a third reviewer.
- **Phase 2 (Full-Text Review):** The full texts of potentially relevant articles were retrieved and independently assessed by the same two reviewers. Articles that met all inclusion criteria were selected for data extraction. Reasons for exclusion during the full-text review were recorded.

4) Data Extraction

A standardized data extraction [4] form was developed and utilized to collect pertinent information from the included studies. The following data points were extracted:

- Author (s) and publication year
- Study design and methodology
- Specific type (s) of assistive technology evaluated
- Population studied (e. g., age range, degree of visual impairment)
- Key findings related to accessibility, usability, effectiveness, and user experience
- Identified barriers and facilitators to AT adoption
- Recommendations for future research or development

5) Quality Appraisal (Optional, but Recommended for Rigor)

The methodological quality of included empirical studies was appraised using appropriate tools. For quantitative studies, a tool like the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Quantitative Studies might be used. For qualitative studies, the JBI Critical Appraisal Checklist for Qualitative Studies could be employed. This step helps in understanding the strength of the evidence presented in individual studies. Reviews were not excluded based on quality appraisal but the findings were considered in the synthesis.

6) Data Synthesis

A narrative synthesis approach was employed to integrate the findings from the diverse range of included studies. Data extracted from the selected articles were grouped thematically based on the research questions. Commonalities, discrepancies, key trends, and emerging themes were identified across the literature [5]. This synthesis involved:

- Categorizing AT based on functionality (e. g., screen readers, navigation aids).
- Summarizing reported effectiveness and challenges for each AT category.
- Identifying overarching themes related to user experience, barriers (e. g., cost, complexity, interoperability), and facilitators (e. g., training, customization, integration).
- Highlighting gaps in current research and proposing directions for future studies.

This systematic methodology ensures a thorough and unbiased review of the existing literature, providing a robust foundation for understanding the current state and future directions of accessibility through assistive technology for individuals with visual impairment and blindness.

4. Literature Survey

Focus Area of Research	Outcome of the Research	Reference
Mobile Web Accessibility	Developed WebAnywhere, a portable, accessible screen reader for on-the-go web Browse.	Bigham, J. P., Prince, C. M., & Ladner, R. E. (2008)
Open Source Urdu Screen Reader Development	Developed an open-source Urdu screen reader for visually impaired individuals.	Ijaz, M., & Durrani, Q. S. (2011)
Indian Language Screen Readers & TTS	Developed Indian language screen readers and syllable-based text-to-speech.	Kurian, A. S., et al. (2011)
Next-Generation Screen Reader	Framework Proposed a framework for advanced screen readers improving accessibility for visually impaired.	Verma, Prabhat & Singh, Raghuraj & Singh, Avinash. (2012)
Screen Reader Use in India	Analyzed patterns and challenges of screen reader usage among Indian users.	McCarthy, T., Pal, J., Marballi, T., & Cutrell, E. (2012)
Moodle Accessibility for Visually Impaired	Evaluated Moodle's accessibility for visually impaired users.	Calvo, R., Iglesias, A., & Moreno, L. (2012)
Finding Aid Accessibility (Screen Readers)	Evaluated the accessibility of library finding aids for screen reader users.	Southwell, K. L., & Slater, J. (2013)
Screen Reader Adoption in India	Examined factors influencing screen reader adoption and switching behavior in India.	McCarthy, T., Pal, J., & Cutrell, E. (2013)
Arabic Text-to-Speech Synthesis Systems	Conducted a comparative study of various Arabic text-to-speech systems.	Bakhsh, N. K., Alshomrani, S., & Khan, I. (2014)
Moodle Accessibility Barriers (Screen Readers)	Identified accessibility barriers for screen reader users in Moodle LMS.	Calvo, R., Iglesias, A., & Moreno, L. (2014)
Marathi Text-to-Speech for Screen Readers	Developed Marathi TTS system for Linux/Windows screen readers.	Kayte, S., Mundada, M., & Kayte, D. C. (2015)
MOOC Platform Accessibility (Instructor Perspective)	Investigated MOOC platform accessibility from the perspective of instructors.	Sanderson, N. C., Chen, W., Bong, W. K., & Kessel, S. (2016)
Screen Reader Impact on Internet Skills	Assessed how screen readers develop internet skills in blind middle school students.	Mostafa, A. F., & Bin Mta'en, I. B. Y. (2017)
Ubiquitous Accessibility for Visually Impaired	Assessed the current state of ubiquitous accessibility for visually impaired individuals.	Billah, S. M., Ashok, V., Porter, D. E., & Ramakrishnan, I. V. (2017)
MOOC Accessibility for Blind Learners	Explored the accessibility of MOOCs for blind and visually impaired learners.	Królak, A., Chen, W., Sanderson, N. C., & Kessel, S. (2017)
Visual Content Representation for Screen Readers	Created rich representations for visual content, enhancing screen reader user experience.	Morris, M. R., Johnson, J., Bennett, C. L., & Cutrell, E. (2018)
LaTeX for Mathematical Formulae Accessibility	Developed Axessibility, a LaTeX package for accessible mathematical formulae in PDFs.	Ahmetovic, D., et al. (2018)
PDF Accessibility Assessment (WCAG 2.0)	Evaluated accessibility of PDF journal articles for WCAG 2.0 compliance.	Nganji, J. T. (2018)
Technologies in Mathematics Teaching (Visually Impaired)	Outcome: Documented experiences of visually impaired students with math teaching technologies.	Souza, A., & Freitas, D. (2019)
Screen Readers and Voice Assistants for Web Search	Bridged screen readers and voice assistants for enhanced eyes-free web search.	Vtyurina, A., et al. (2019)
Visualizing for Non-Visual Users	Developed methods to enable visually impaired users to interact with visualizations.	Choi, J., et al. (2019)
Accessibility for Visually Impaired (State of Art)	Reviewed the current Screen Reader Applications	Gaggi, O., Quadrio, G., & Bujari, A. (2019)
Information and communication technology (ICT) for visually impaired	ICT plays a vital role in supporting visually impaired individuals to overcome issues.	Waqar et al. (2020)
Sentence Length Impact on Web Readability	Investigated how sentence length affects web readability for screen reader users.	Kadayat, B. B., & Eika, E. (2020)

Efficient Web Access with Screen eaders	Improved web access for screen reader users via automatic summary and tagging.	Sarwar, U., & Eika, E. (2020)
Tactile maps for orientation and mobility training	Tactile maps improve comprehension, memory, and navigation along unfamiliar routes for visually impaired persons.	Papadopoulos et al. (2020)
Understanding Screen Reader Plugins	Gained insight into the functionality and use of screen reader plugins.	Momotaz, F., Islam, M. T., Ehtesham-Ul-Haque, M., & Billah, S. M. (2021)
Understood blind screen-reader	Users' experiences with digital artboard tools.	Schaadhardt, A., Hiniker, A., & Wobbrock, J. O. (2021)
Screen Reader Users & Online Data Visualizations	Understood screen reader users' experiences with online data visualizations.	Sharif, A., Chintalapati, S. S., Wobbrock, J. O., & Reinecke, K. (2021)
Accessible Data Visualization for Screen Readers	Created rich screen reader experiences for accessible data visualization.	Zong, J., et al. (2022)
Usability of platforms for visually impaired	Highlights the need for inclusive design in platforms; emphasizes AT's role in daily needs, communication, mobility, and education.	Al-Khalifa et al. (2025), Mashiata et al. (2022)
Screen reader use and efficiency among employed BLV individuals	Using multiple screen readers can improve efficiency and troubleshooting; persistent challenges include inaccessible digital content and technical issues.	Okolo et al. (2025), Almeida & Ferreira (2024), Joshi & Salmerón (2023)
Haptic feedback in navigation aids	Haptic feedback assists BLV individuals, particularly in understanding graphical information and guiding navigation.	Jiang et al. (2024)
User perceptions and adoption of smart canes	Despite potential, adoption is low due to concerns about durability, lack of awareness, trust, and perceived lack of novel features.	Islam et al. (2025), Kim et al. (2024), Yadav et al. (2020)
AI and computer vision in smart assistive devices	Users prioritize text recognition and obstacle detection; AI-powered solutions offer rich contextual information, but face challenges in real-time processing and accuracy.	Du & Bulusu (2025), Akbari et al. (2020), Lee et al. (2021)
Barriers to AT adoption (financial, institutional, training)	High costs, insufficient institutional support, limited availability, compatibility issues, and inadequate training are major barriers.	Akinsiku et al. (2025), Al-Zboon (2024), Almekhalfi & Tibi (2024), Almeida & Ferreira (2024), Loveys & Butler (2023)
Policy and access to AT for visually impaired	Discusses national data and government initiatives; highlights challenges in acquiring AT due to cost, awareness, and availability.	Sharma & Singh (2023)
Smart assistive navigation systems (voice-over, object detection)	Proposed systems enhance independent mobility via auditory feedback and tactile input; potential for advanced obstacle detection.	Umar et al. (2025)

Accessibility Through Assistive Technology for Individuals with Visual Impairment and Blindness (2020-2025).

This section synthesizes key findings from a targeted selection of 20 recent academic papers (published roughly between 2020 and 2025) focusing on assistive technology (AT) and its impact on accessibility for individuals with visual impairment (VI) and blindness. The reviewed literature highlights advancements in various AT modalities, user perceptions, and persistent challenges in ensuring equitable and effective access.

1) Overview of Assistive Technology Landscape

Recent literature continues to showcase a diverse and evolving landscape of AT for VI and blindness. Many studies provide comprehensive overviews of different AT types. For instance, Al-Khalifa et al. (2025) [6] conducted a systematic literature review on the usability of platforms for individuals with visual impairments, emphasizing the need for inclusive design from the outset. Mashiata et al. (2022) [7] similarly highlighted the crucial role of AT in enabling visually impaired individuals to participate fully in society. The overarching theme [8] is the recognition of AT as essential for daily needs, communication, mobility, and education, though effective implementation remains a challenge.

2) Screen Readers and Digital Accessibility

Screen readers remain a cornerstone of digital accessibility for blind and low-vision users. Recent research delves into their effectiveness and limitations. Okolo et al. (2025) [9] found that employed individuals who are legally blind often benefit from using multiple screen readers, which can improve efficiency and troubleshooting abilities when encountering inaccessible digital content. However, studies like Almeida & Ferreira (2024) [10] and Joshi & Salmerón (2023) [11] continue to identify persistent issues, such as difficulties in accessing printed classroom materials, inherently inaccessible digital content, and time lost due to technical glitches. These papers underscore the need for accessible document formats, universally designed websites, [12] and comprehensive accessibility training for content creators and technical support staff in educational and professional settings.

3) Navigation and Mobility Aids

Advancements in navigation and mobility aids are a significant area of research. Umar et al. (2025) [13] proposed a smart assistive navigation system combining voice-over with object detection, aiming to enhance independent mobility through auditory feedback and tactile input. The concept of "smart canes" is frequently explored, with studies like Kim et al. (2024) [14] and Yadav et al.

(2020) [15] demonstrating their potential in obstacle detection beyond the traditional white cane's capabilities. However, user adoption remains a concern, as highlighted by Islam et al. (2025), [16] who found that despite interest, issues with durability, lack of awareness, trust, and the perceived lack of novel features contributed to low adoption rates. The importance of haptic feedback in navigation is also gaining traction, with Jiang et al. (2024) [17] providing a systematic review of how haptic feedback can assist BLV individuals, particularly in understanding graphical information [18] and guiding navigation.

4) AI and Computer Vision in AT

The integration of Artificial Intelligence (AI), particularly computer vision, is a prominent trend in developing smart assistive technologies. Du & Bulusu (2025) [19] explored what blind and low-vision people truly want from smart assistive devices, emphasizing tasks like text recognition and obstacle detection as high priorities for users. Akbari et al. (2020) [20] and Lee et al. (2021) [21] have developed and evaluated smartphone applications and wearable devices utilizing AI for object identification and environmental understanding. These AI-powered solutions hold immense promise for providing richer contextual information, though challenges related to real-time processing, accuracy in diverse environments, and user privacy remain areas of active development. [22]

5) Barriers to AT Adoption and Utilization

Across the reviewed literature, several recurring barriers to AT adoption and effective utilization are consistently identified. Akinsiku et al. (2025) [23] found that financial constraints are a major obstacle, with a significant percentage of visually impaired individuals and professionals recognizing the high cost of AT as a primary deterrent. This aligns with Al-Zboon (2024) [24], who also noted financial issues, lack of awareness, and limited availability of appropriate devices as significant barriers [25].

Furthermore, Almeida & Ferreira (2024) and Loveys & Butler (2023) [26] pointed to insufficient institutional support, limited availability of appropriate assistive tools, and issues related to compatibility and affordability as hindrances. The lack of adequate training and technical support for both users and professionals is another critical barrier highlighted by Almekhalfi & Tibi (2024) [27], emphasizing the need for sustained professional development and accessible support systems.

6) User Perspectives and Design Considerations

User-centered design is increasingly recognized as paramount for effective AT development. Studies like Islam et al. (2025) emphasize the importance of understanding user needs and incorporating their feedback throughout the design process to improve usability and adoption. The call for more comprehensive user studies, focusing on long-term efficacy and the nuanced experiences of diverse user groups within the visually impaired community, is strong. The literature suggests that successful AT is not just about technological sophistication but also about intuitive design, seamless integration into daily life, and addressing specific user priorities.

Conclusion of Survey

The surveyed literature demonstrates continuous innovation in assistive technology for visual impairment and blindness. While sophisticated solutions are emerging across digital accessibility, navigation, and AI-powered tools, the persistent challenges of cost, usability, interoperability, and adequate support continue to hinder universal access and effective utilization. Future research needs to prioritize user-centered co-design, affordability, long-term impact assessments, and robust training programs to ensure AT truly serves as an equitable enabler for individuals with visual impairment and blindness.

5. Articles on Accessibility Through Assistive Technology

This section provides a comprehensive literature survey based on 20 recent academic papers (published roughly between 2020 and 2025), focusing on the multifaceted aspects of accessibility achieved through assistive technology (AT). The reviewed literature highlights technological advancements, user experiences, and persistent challenges in ensuring equitable and effective access, primarily for individuals with visual impairment and blindness, as this is the core focus of the overarching literature review paper.

1) The Evolving Landscape of Assistive Technology for Accessibility

Recent scholarly works consistently underscore the dynamic evolution of AT in enhancing accessibility. Papers such as Al-Khalifa et al. (2025) and Mashiata et al. (2022) provide systematic insights into the usability of AT platforms, emphasizing that successful accessibility hinges on inclusive design principles from the foundational stages of development [28]. The consensus is that AT is not merely supplementary but fundamental for enabling individuals with disabilities to engage in daily activities, communicate effectively, navigate independently, and pursue educational and professional opportunities.

2) Digital Accessibility and Screen Reader Impact

Digital content accessibility remains a critical domain, with screen readers being indispensable tools for blind and low-vision users. Research by Okolo et al. (2025) reveals that proficient users often leverage multiple screen readers to navigate diverse digital environments efficiently and to mitigate issues arising from inaccessible content. However, the journey towards seamless digital accessibility is ongoing. Almeida & Ferreira (2024) and Joshi & Salmerón (2023) highlight persistent barriers, including the inaccessibility of traditional printed materials, poorly designed digital content, and technical difficulties that consume valuable user time. These findings advocate for universal design principles [29] in digital content creation and robust accessibility training for all stakeholders.

3) Innovations in Navigation and Mobility Aids

Significant strides have been made in developing advanced navigation and mobility aids. Umar et al. (2025) introduced a smart assistive navigation system that integrates voice

guidance with object detection, aiming to bolster independent mobility through multi-modal feedback [30]. The concept of "smart canes" is a recurring theme, with studies like Kim et al. (2024) and Yadav et al. (2020) demonstrating their capacity for extended obstacle detection beyond conventional white canes. Despite these innovations, user adoption rates for smart canes remain relatively low. Islam et al. (2025) attributed this to concerns about durability, a lack of user awareness and trust, and the perceived absence of truly groundbreaking features. The growing importance of haptic feedback in conveying spatial information is also noted by Jiang et al. (2024), who reviewed its efficacy in assisting visually impaired individuals with graphical information understanding and navigation.

4) Artificial Intelligence and Computer Vision for Enhanced Accessibility

The integration of Artificial Intelligence (AI), particularly computer vision, is revolutionizing smart assistive devices. Du & Bulusu (2025) investigated user preferences, identifying text recognition and obstacle detection as high-priority tasks for AI-powered solutions. Studies by Akbari et al. (2020) and Lee et al. (2021) showcase the development and evaluation of smartphone applications and wearable devices that leverage AI for environmental understanding and object identification. While these technologies promise richer contextual information and greater autonomy [31], challenges related to real-time processing, accuracy in varied environments, and data privacy continue to be active areas of research and development.

5) Persistent Barriers to Assistive Technology Adoption and Utilization

Despite technological progress, the literature consistently identifies several systemic barriers hindering the widespread adoption and effective utilization of AT. Akinsiku et al. (2025) and Al-Zboon (2024) underscore financial constraints as a major impediment, with the high cost of AT devices often rendering them inaccessible [32]. Furthermore, Almeida & Ferreira (2024) and Loveys & Butler (2023) highlight inadequate institutional support, limited availability of suitable tools, and issues concerning compatibility and affordability. The lack of comprehensive training and ongoing technical support for both AT users and the professionals who assist them is another critical barrier, as emphasized by Almekhalfi & Tibi (2024), pointing to a need for sustained professional development and accessible support infrastructures.

6) The Role of Information and Communication Technology (ICT) and Policy

The broader impact of Information and Communication Technology (ICT) on accessibility is also a significant area of focus. Waqar et al. (2020) [33] conducted a systematic review on how ICT supports visually impaired individuals in overcoming various daily challenges. Beyond individual technologies, policy and systemic access play a crucial role. Sharma & Singh (2023) [34] discussed national data and government initiatives related to AT access, drawing attention to the persistent challenges in acquiring AT due to factors beyond just cost, including awareness and overall availability within a given region.

7) User-Centered Design and Future Directions

A recurring theme across the literature is the imperative for user-centered design in AT development. Studies like Islam et al. (2025) stress the importance of deeply understanding user needs and integrating their feedback throughout the design lifecycle to enhance usability and drive adoption. The surveyed papers collectively call for more extensive user studies, particularly those focusing on long-term efficacy, the nuanced experiences of diverse user groups (considering varying degrees of vision loss, age, and cultural backgrounds), and the socio-economic impact of AT on independent living. The literature suggests that truly effective accessibility solutions [35] are not solely about technological sophistication but also about intuitive design, seamless integration into daily life, and a direct response to specific user priorities and challenges.

6. Current Status and New Related Issues

The landscape of assistive technology (AT) for individuals with visual impairment and blindness is in a state of continuous evolution, characterized by both remarkable advancements and persistent, emerging challenges. This section delves into the current status of AT, highlighting key innovations and their impact, while also addressing new and evolving issues that demand critical attention for truly comprehensive accessibility.

Current Status of Assistive Technology for Visual Impairment and Blindness

Currently, AT has firmly established itself as an indispensable enabler for the visually impaired and blind community, facilitating greater independence and participation across various life domains.

1) **Sophistication of Core Technologies:** Traditional ATs like screen readers (e. g., JAWS, NVDA, VoiceOver) have become highly sophisticated, offering extensive customization and compatibility with a wide range of digital platforms. As highlighted by Okolo et al. (2025), proficient users often leverage multiple screen readers, demonstrating their critical role in digital access. Similarly, refreshable braille displays continue to evolve, offering more lines and improved tactile feedback [36].
2) **Advancements in Mobility and Navigation:** Smart canes, wearable devices, and smartphone applications leveraging GPS, computer vision, and haptic feedback are transforming outdoor and indoor navigation. Systems incorporating voice-over and object detection, as described by Umar et al. (2025), provide enhanced environmental awareness. The exploration of haptic feedback, reviewed by Jiang et al. (2024), is particularly promising for intuitive, non-visual information delivery [37].
3) **Integration of Artificial Intelligence (AI) and Machine Learning:** AI is a major driver of innovation. Computer vision applications for object recognition, text reading, and environmental description are becoming more accurate and integrated into daily tools. Du & Bulusu (2025) underscore that users prioritize AI

for tasks like text recognition and obstacle detection, signaling a shift towards more intelligent and context-aware assistance. Wearable AI devices and smartphone apps (e. g., Akbari et al., 2020; Lee et al., 2021) are making significant strides in providing real-time information about surroundings [38].

4) **Increased Focus on User Experience (UX):** There is a growing recognition within the development community of the importance of user-centered design. Studies like Islam et al. (2025) emphasize that user perceptions, trust, and the perceived utility of features are crucial for adoption, moving beyond mere technical capability to focus on practical usability and seamless integration into daily routines [39].

New and Related Issues

Despite these positive developments, several significant and often interconnected issues are emerging or gaining prominence, posing new challenges to achieving universal accessibility through AT.

1) **The Persistent Digital Divide and Affordability:** While technology advances, the fundamental barrier of cost remains significant. Akinsiku et al. (2025) and Al-Zboon (2024) consistently point to financial constraints as a primary impediment to AT adoption. This creates a "digital divide" where advanced ATs are inaccessible to many, particularly in developing regions or for individuals with limited socioeconomic resources. This issue extends beyond the device itself to the cost of training, maintenance, and compatible infrastructure [40].
2) **Interoperability and Ecosystem Fragmentation:** The proliferation of diverse AT solutions often leads to a lack of seamless interoperability between devices and platforms. Users frequently encounter situations where different ATs do not communicate effectively, or where software is not fully compatible across operating systems or applications. This fragmentation can lead to a disjointed user experience and limit the overall utility of individual devices [41]
3) **Algorithmic Bias and Data Privacy in AI-Powered AT:** As AI becomes more central to AT, new ethical concerns arise. Algorithmic bias, where AI models might perform less accurately for certain user demographics or in specific environmental contexts, could inadvertently create new forms of discrimination. Furthermore, the collection and processing of sensitive user data by AI-powered devices raise significant privacy concerns, necessitating robust data protection protocols and transparent usage policies [42].
4) **Rapid Obsolescence and Maintenance Challenges:** The fast pace of technological innovation means that AT devices can quickly become outdated. This rapid obsolescence can be costly for users who need to frequently upgrade their equipment. Additionally, ongoing maintenance, software updates, and technical support are crucial but often under-resourced, leading to frustration and reduced utility for users when devices malfunction or become incompatible [43].
5) **Lack of Comprehensive Training and Support Infrastructure:** Even the most advanced AT is ineffective without proper training and ongoing support. Almekhalfi & Tibi (2024) highlight the critical need for sustained professional development for educators and therapists, and accessible technical support for users. Gaps in training can lead to underutilization of AT features, user frustration, and ultimately, abandonment of the technology [44].
6) **Accessibility in Emerging Digital Environments:** New digital frontiers, such as virtual reality (VR), augmented reality (AR), and the metaverse, present both opportunities and significant accessibility challenges. Ensuring these highly visual and interactive environments are accessible from their inception is a new frontier, requiring proactive design principles to avoid replicating existing barriers [45].
7) **Longitudinal Efficacy and Real-World Impact Studies:** While many studies demonstrate the immediate effectiveness of AT, there is a continued need for more longitudinal research to assess the long-term impact of AT on user independence, quality of life, and socio-economic integration. Understanding sustained benefits and evolving challenges over time is crucial for informing future development and policy [46].

In conclusion, while assistive technology continues to empower individuals with visual impairment and blindness, the current landscape is complex. Addressing the persistent issues of affordability, interoperability, and support, alongside navigating the ethical and practical implications of new technologies like AI, will be paramount in ensuring that AT truly fosters an inclusive and accessible world for all.

7. Research Gaps

Despite the significant advancements and extensive research in assistive technology (AT) for individuals with visual impairment and blindness, a systematic evaluation of the current literature reveals several critical research gaps that warrant further investigation. Addressing these areas is crucial for developing more effective, equitable, and user-centered AT solutions and policies.

1) Lack of Longitudinal Studies on Long-Term Efficacy and Adoption:

While many studies evaluate the immediate usability and effectiveness of AT prototypes or newly introduced devices (e. g., Umar et al., 2025; Kim et al., 2024), there is a notable scarcity of longitudinal research. This gap prevents a comprehensive understanding of:

- The sustained impact of AT on users' independence, quality of life, and socio-economic integration over extended periods.
- How user needs and AT effectiveness evolve as individuals age or their visual conditions change [47].
- The long-term factors influencing continued adoption versus abandonment of AT, beyond initial impressions (as suggested by Islam et al., 2025 regarding smart canes).

2) Limited Research on Diverse and Intersectional User Groups:

Much of the existing literature tends to generalize the "visually impaired" or "blind" population. There is a need

for more nuanced research that specifically addresses the unique AT needs and experiences of:

- Children and adolescents: Their developmental stages, learning styles, and social integration challenges with AT.
- Elderly individuals with age-related vision loss: Their specific physical, cognitive, and technological literacy considerations [48].
- Individuals with co-occurring disabilities: How AT can be effectively integrated for those with visual impairment alongside other sensory, motor, or cognitive challenges.
- Users from diverse cultural and socioeconomic backgrounds: Understanding how cultural contexts, access to resources, and digital literacy influence AT adoption and utility, particularly in low-resource settings (as touched upon by Sharma & Singh, 2023).

3) Insufficient Focus on Interoperability and Ecosystem Integration:

While the "Current Status" section identified ecosystem fragmentation as a new issue, there is a research gap in developing and evaluating concrete solutions for seamless interoperability between different AT devices, software, and mainstream technologies. Research is needed on:

- Standardized frameworks or protocols for AT interoperability [49].
- User experiences with integrated AT ecosystems versus fragmented solutions.
- The impact of proprietary systems versus open-source solutions on overall accessibility.

4) In-depth Exploration of Policy, Funding, and Sustainable Access Models:

The literature consistently identifies financial constraints and lack of institutional support as major barriers to AT access (Akinsiku et al., 2025; Al-Zboon, 2024; Loveys & Butler, 2023). However, there is a gap in comprehensive research on:

- The effectiveness of different national and international policies in ensuring equitable access to AT.
- Innovative funding models (e. g., insurance coverage, government subsidies, public-private partnerships) that can overcome affordability barriers [50].
- Sustainable models for AT provision, maintenance, and upgrade in various socioeconomic contexts.

5) Ethical Implications and Algorithmic Bias in AI-Powered AT:

As AI integration accelerates (Du & Bulusu, 2025; Akbari et al., 2020), research on the ethical dimensions of these technologies is still nascent. Specific gaps include:

- Systematic studies on algorithmic bias in AI-powered AT, particularly how it might disproportionately affect certain user groups or environmental conditions.
- User perceptions and concerns regarding data privacy and security with AI-driven AT devices.
- Frameworks for ensuring transparency, accountability, and user control in AI-powered accessibility solutions.

6) Accessibility Design and Evaluation for Emerging Technologies (VR/AR/Metaverse):

The rapid emergence of highly immersive and visual technologies like VR, AR, and the nascent metaverse presents both opportunities and significant accessibility challenges. A proactive research gap exists in:

- Developing and evaluating accessibility standards and design guidelines for these new platforms from their inception.
- Exploring novel AT approaches to enable meaningful participation for visually impaired and blind individuals in these immersive environments, rather than retrofitting solutions.
- Understanding user needs and preferences for interacting with virtual spaces non-visually.

7) Empirical Evaluation of Comprehensive Training and Support Programs:

While the lack of training is identified as a barrier (Almekhalfi & Tibi, 2024), there is a need for more empirical studies evaluating the effectiveness of different AT training methodologies and support models. This includes:

- Comparative studies of various training approaches (e. g., in-person, online, peer-to-peer).
- Research on the optimal duration, content, and frequency of AT training.
- Evaluation of the impact of ongoing technical support on user proficiency and AT retention.

Addressing these research gaps through rigorous and interdisciplinary studies will be instrumental in advancing the field of assistive technology, ensuring that it truly fulfills its potential to create a more accessible and inclusive world for individuals with visual impairment and blindness.

8. Research Agenda

Building upon the identified research gaps, this systematic review proposes several critical research agendas to guide future investigations into assistive technology (AT) and accessibility for individuals with visual impairment and blindness. These agendas aim to foster a more comprehensive, equitable, and impactful development and deployment of AT solutions.

1) Longitudinal Studies on AT Efficacy and Adoption Trajectories

A significant research agenda involves conducting rigorous longitudinal studies that track the long-term efficacy, sustained adoption, and evolving impact of AT on users' lives.

- **Proposed Research:** Investigate how the use of specific ATs (e. g., screen readers, smart canes) influences users' independence, employment outcomes, educational attainment, and overall quality of life over periods of several years.
- **Methodological Focus:** Employ mixed-methods approaches, combining quantitative measures of AT usage and functional outcomes with qualitative insights into user experiences, challenges, and adaptations over time.
- **Key Questions:** What factors contribute to the long-term retention or abandonment of AT? How do user needs and AT effectiveness change across different life stages or as visual conditions progress?

2) Inclusive Design and User-Centric Research for Diverse Populations

Future research must prioritize inclusive design methodologies and conduct studies specifically tailored to the diverse needs of various user groups within the visually impaired and blind community.

- **Proposed Research:** Conduct targeted studies focusing on the AT requirements and preferences of children, adolescents, and older adults with visual impairments, considering their unique developmental, cognitive, and physical attributes.
- **Methodological Focus:** Emphasize co-design approaches, actively involving users with varying degrees of vision loss, cultural backgrounds, and co-occurring disabilities throughout the AT development and evaluation process.
- **Key Questions:** How can AT be designed to be more intuitive and adaptable for users with limited technological literacy or multiple disabilities? What are the specific accessibility challenges and opportunities for visually impaired individuals in low-resource settings?

3) Interoperability and Seamless Ecosystem Development

A crucial agenda is to research and develop solutions that promote seamless interoperability and integration across diverse AT devices and mainstream digital platforms.

- **Proposed Research:** Investigate the feasibility and impact of developing open standards and protocols for AT communication. Explore the design of integrated AT ecosystems that allow different devices and software to work cohesively.
- **Methodological Focus:** Include technical research on API development, software architecture, and hardware compatibility, alongside user studies evaluating the benefits and challenges of integrated systems.
- **Key Questions:** Can a standardized framework significantly reduce ecosystem fragmentation? What are the most effective strategies for ensuring AT compatibility with rapidly evolving mainstream technologies?

4) Policy, Funding, and Sustainable Access Models

Research is urgently needed to inform and evaluate policies and funding mechanisms that ensure equitable and sustainable access to AT globally.

- **Proposed Research:** Conduct comparative analyses of national and international policies related to AT provision, funding, and accessibility mandates. Evaluate the effectiveness of different funding models (e. g., public subsidies, insurance coverage, community-based programs) in overcoming affordability barriers.
- **Methodological Focus:** Employ policy analysis, economic modeling, and large-scale surveys to assess the impact of different policy interventions on AT access and utilization rates.
- **Key Questions:** What policy levers are most effective in promoting AT affordability and availability? How can sustainable models for AT distribution, maintenance, and technical support be established in diverse economic contexts?

5) Ethical AI and Trustworthy Assistive Technology

As AI integration in AT grows, a dedicated research agenda must address the ethical implications, focusing on bias, privacy, and fostering user trust.

- **Proposed Research:** Conduct empirical studies to identify and mitigate algorithmic bias in AI-powered AT, ensuring fair and accurate performance across all user demographics. Investigate user perceptions of data privacy and security in AI-driven AT.
- **Methodological Focus:** Combine technical audits of AI algorithms with qualitative research on user trust, ethical considerations, and preferences for data handling.
- **Key Questions:** How can AI-powered AT be designed to be transparent and explainable to users? What ethical guidelines are necessary to ensure responsible development and deployment of intelligent AT?

6) Proactive Accessibility Design for Emerging Technologies

Future research must proactively address accessibility for visually impaired and blind individuals in nascent and emerging technological environments, such as virtual reality (VR), augmented reality (AR), and the metaverse.

- **Proposed Research:** Develop and test novel AT concepts and accessibility guidelines for immersive virtual environments from their foundational design stages. Investigate non-visual interaction paradigms for VR/AR.
- **Methodological Focus:** Involve interdisciplinary teams (computer scientists, accessibility experts, user researchers) in iterative design and evaluation cycles within these new technological spaces.
- **Key Questions:** How can immersive experiences be made genuinely inclusive for non-visual users? What new forms of AT are required to enable meaningful participation in the metaverse?

7) Empirical Evaluation of Training and Support Programs

Given the identified gap in comprehensive training, a research agenda should focus on empirically evaluating the effectiveness of various AT training and support models.

- **Proposed Research:** Conduct randomized controlled trials or quasi-experimental studies comparing different AT training methodologies (e. g., individualized vs. group, in-person vs. remote, peer-led vs. professional-led).
- **Methodological Focus**: Measure not only initial proficiency but also long-term skill retention, user confidence, and the impact on daily functioning.
- **Key Questions:** What are the most effective components of AT training programs? How can ongoing technical support be best delivered to ensure sustained AT use and problem-solving capabilities?

By systematically pursuing these research agendas, the field can move beyond identifying challenges to actively developing and implementing solutions that truly enhance accessibility and empower individuals with visual impairment and blindness in an increasingly complex technological world.

9. Conclusion

This systematic literature review, "Accessibility Through Assistive Technology: A Systematic Evaluation for Individuals with Visual Impairment and Blindness, " has provided a comprehensive overview of the current state, advancements, challenges, and future directions in the field of assistive technology (AT) for the visually impaired and blind community. Our evaluation, guided by a rigorous methodology, underscores the transformative potential of AT in fostering independence and inclusion, while simultaneously highlighting the persistent barriers that prevent equitable and universal accessibility.

The review demonstrates that AT has evolved significantly, moving beyond basic tools to incorporate sophisticated functionalities, particularly with the integration of Artificial Intelligence and advanced sensory feedback systems. Core technologies like screen readers continue to be indispensable, while innovations in smart mobility aids and AI-powered environmental understanding are paving the way for unprecedented levels of autonomy. The growing emphasis on user experience and user-centered design in recent research is a positive indicator of the field's maturity.

However, despite these remarkable strides, the journey towards truly seamless accessibility remains ongoing. The literature consistently points to critical challenges, including the high cost of AT, which perpetuates a significant digital divide; issues of interoperability and fragmentation within the AT ecosystem; and the rapid obsolescence of devices. Furthermore, the lack of comprehensive training and sustained support infrastructure continues to impede effective AT utilization, even for the most advanced solutions. Emerging concerns related to algorithmic bias and data privacy in AI-powered AT, along with the need to proactively design for accessibility in new immersive digital environments, present new frontiers for research and development.

The identified research gaps underscore the necessity for a concerted and interdisciplinary effort. Future research agendas must prioritize longitudinal studies to understand the long-term impact and adoption trajectories of AT. There is a critical need for more inclusive research that addresses the diverse and intersectional needs of various user groups, including children, older adults, and individuals with co-occurring disabilities, as well as those from varying socioeconomic backgrounds. Developing standardized frameworks for interoperability, exploring innovative funding models, and rigorously evaluating comprehensive training programs are also paramount. Finally, ensuring ethical considerations and proactive accessibility design are embedded in the development of emerging technologies like VR/AR will be crucial for preventing the creation of new barriers.

In conclusion, assistive technology holds immense promise for empowering individuals with visual impairment and blindness, enabling them to navigate, learn, work, and engage with the world more independently. Realizing this full potential, however, requires a sustained commitment from researchers, developers, policymakers, and support organizations to address the identified challenges and pursue the proposed research agendas. By fostering affordability, promoting seamless integration, ensuring robust support, and embedding ethical considerations, we can collectively work towards a future where accessibility is not an afterthought, but an inherent characteristic of our increasingly technological world.

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