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UPDATE ARTICLE

Assistive technologies in visual rehabilitation: wearable devices, navigation systems, and digital accessibility

Tecnologias assistivas na reabilitação visual: dispositivos vestíveis, sistemas de navegação e acessibilidade digital

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KEYWORDS:

Assistive technology; Low vision; Blindness; Visually impaired individuals.

SUMMARY

Assistive technologies have been pivotal in enhancing independence and quality of life for individuals with visual impairments. Recent innovations include head-mounted displays, wearable systems leveraging virtual and augmented reality, electronic mobility aids, and accessibility features integrated into computers and smartphones. This article provides a critical review of these technologies, examining their operating principles, clinical applications, and practical limitations in visual rehabilitation.

PALAVRAS-CHAVE:

Tecnologia assistiva; Baixa visão; Cegueira; Indivíduos com deficiência visual.

RESUMO

As tecnologias assistivas têm desempenhado papel fundamental na promoção da autonomia e qualidade de vida de pessoas com deficiência visual. Entre os avanços recentes destacam-se os dispositivos de visualização montados na cabeça, sistemas vestíveis baseados em realidade virtual e aumentada, auxílios eletrônicos de mobilidade e recursos de acessibilidade integrados a computadores e smartphones. Este artigo revisa criticamente essas tecnologias, discutindo seus princípios de funcionamento, aplicações clínicas e limitações práticas na reabilitação visual.

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INTRODUCTION

According to the World Health Organization, the prevalence of visual impairment and blindness is increasing. It is projected that over the next three decades, the number of individuals with moderate to severe visual impairment will exceed 550 million, compared with approximately 200 million in 2020[1].

Assistive technologies have been developed to enhance the quality of life for individuals with visual impairments. These technologies include wearable devices that enable safe interaction with indoor and outdoor environments while facilitating greater access to information[2].

Recent advances in assistive technologies can be categorized as follows:

1. Head-mounted display devices (HMDs) are portable electronic magnifiers—also available as tabletop versions—that not only enlarge text for reading but can also capture and present visual information from the surrounding environment or read text aloud;
2. Wearable assistive technologies utilizing virtual and augmented reality are rapidly evolving devices that provide additional options for individuals with low vision to navigate safely in both indoor and outdoor environments;
3. Computers and smartphones with accessibility features have applications and built-in functions.

This article focuses specifically on the accessibility features available through digital devices.

Assistive technologies for low vision

Individuals with visual impairments face numerous challenges in enhancing their visual experience and navigating safely and independently in both indoor and outdoor environments.

1. HMDs are wearable electronic devices designed to improve visual function in patients with low vision who do not benefit from refractive correction. HMDs employ various visual enhancement techniques, including magnification, optimized lighting, expanded field of view, and increased contrast. More advanced devices integrate features such as virtual reality, text-to-speech, and blind-spot remapping. Despite these advances, practical challenges remain, including limited commercial availability, high cost, need for customization to individual patient characteristics, and potential social stigma[3].

Examples of wearable technology for low vision include the Jordy (Enhanced Vision Systems, Huntington Beach, CA), an electronic magnifier featuring a side hinge for pantoscopic tilting, manual contrast-mode switching, and an autofocus camera with multiple zoom settings for near, intermediate, or far distances, providing magnification up to 66×. Both Jordy and its counterpart, Flipperport, have demonstrated improved intermediate visual acuity compared with conventional optical aids or glasses[4].

The eSight Eyewear (eSight Corp., Toronto, ON, Canada), commercially launched in 2013, was designed to improve upon earlier devices by providing variable magnification, enhanced focus, improved contrast, and hands-free operation. This semi-immersive device employs a virtual reality system to assist patients with functional vision across all distances within a 30° field of view. A major update incorporated organic light-emitting diodes in the display, producing brighter images. Users can adjust device settings via a handheld remote control connected to the headset[5].

AceSight (developed collaboratively by Zoomax Technology, UCLA, and MIT, Boston, MA) is an augmented reality device that allows image adjustment on a semi-transparent screen using a remote control. A central front camera captures images and magnifies them up to 9×, with a field of view of 90° or 45° per eye. The device uses algorithms to optimize magnification and contrast according to the user's specific visual impairment. For patients with peripheral vision loss, the real-time image can be reduced to 0.5× or 0.25×, compressing a wide field of view into a smaller one that aligns with the patient's remaining visual field. Studies indicate that younger users (under 60 years) tend to derive greater benefit from the device than older users[6].

Unlike conventional augmented reality devices, Eyedaptic (Eyedaptic, Laguna Hills, CA) does not overlay images onto the user's visual field. Instead, adaptive algorithms reconstruct environmental images by enhancing pixels and remapping areas lost due to central scotomas. The compact design of these augmented reality glasses allows patients with retinal diseases to retain full use of their intact peripheral vision. The Eye4 and Eye4XC, launched in 2022, introduced improvements in contrast sensitivity. Eye4 glasses feature a lightweight design (85 g), achieved by relocating most processing power from the headset to a connected smartphone (EyeSwitch). Each headset incorporates 1080p displays with over 2 million

pixels and a 50° field of view, offering automatic zoom, image stabilization, and contrast enhancement. The upcoming Eye6, not yet commercially released, is expected to include Wi-Fi and 5G connectivity and integrate artificial intelligence (AI) systems, including large language models, to further enhance visual experiences for patients with low vision. This AI functionality is designed to read text aloud, describe visual scenes in detail, and provide support in nearly 100 languages[7].

IrisVision (IrisVision Global Inc., Pleasanton, CA) is a smartphone-based virtual reality device designed to restore visual information in patients with macular degeneration, diabetic retinopathy, Stargardt disease, glaucoma, and optic atrophy. Developed collaboratively by the inventors, the National Eye Institute, and Samsung, and launched in 2017, the device captures environmental images via a built-in smartphone. Adaptive algorithms then remap these images to compensate for areas of vision loss caused by central scotomas or peripheral visual field defects. The latest versions of IrisVision feature voice control, streaming capabilities, and a lightweight design compatible with mobile use.

In a 2024 comparison with two other augmented reality devices—the Ziru (Dodrotu, Oxford, UK) and the NuEyes Pro 3 (NuEyes, Newport Beach, CA)—IrisVision demonstrated significant improvements in both distance and near vision across a range of lighting conditions, including varying luminance and contrast[8].

2. Recent advances in mobility support for individuals with visual impairments include wearable devices and electronic travel aids that leverage technologies such as ultrasonic sensors, Light Detection and Ranging (LiDAR)-based obstacle detection, and computer vision[9,10].

To compensate for the absence of visual cues, effective strategies combine hardware and software solutions. These solutions encompass smartphone applications, object-recognition techniques using sensors (e.g., infrared, ultrasound, radio-frequency identification, and GPS), adaptive algorithms, feedback mechanisms, and smart cane systems enabled by the Internet of Things (IoT)[11,12].

Emerging technologies, including IoT and AI, further enhance accessibility by enabling real-time object detection, integration with smartphone applications, and intelligent cane systems[12].

Leading mobility-assistive devices now incorporate Global System for Mobile Communications (GSM) and GPS technologies to automatically identify the user's location and transmit it to caregivers, improving safety and independence[13].

Mobility-assistive systems provide sensory input through smartphones, radio-frequency identification, depth cameras, infrared sensors, or ultrasonic sensors. Users receive feedback in the form of directional signals delivered via vibrations, sounds, or tactile cues. Some systems combine multiple feedback modalities, offering a multimodal approach to navigation. The primary goal of these technologies is to facilitate independent mobility, requiring users to integrate directional information effectively.

In addition to technological solutions, Braille signage is increasingly installed in public spaces, train stations, educational institutions, doors, elevators, and other infrastructure to assist navigation for individuals with visual impairments. Nevertheless, challenges remain, as some users are unfamiliar with these technologies, which can limit their mobility and independence.

Smart canes enable individuals with visual impairments to navigate their environment more effectively and recognize obstacles of varying sizes, a task often challenging with traditional white canes. When an obstacle is detected, the cane's embedded microphone emits an auditory signal. Additionally, the cane can assess ambient lighting conditions, indicating whether an area is bright or dark[14].

Depth sensors generate spatial representations of the environment, which can be converted into auditory information to guide users. Several systems translate this spatial data into sound: for example, an audio guidance system for individuals with visual impairments integrates an ultrasonic sensor to measure distances, an infrared receiver to detect objects, and an automatic voice recognition system to provide real-time auditory instructions. This system is implemented via an embedded microprocessed platform dedicated to device control. Ultrasonic sensors detect optical signals, which are then converted into audio data. Users, who typically exhibit heightened auditory sensitivity, receive navigation cues through combined voice and vibration feedback, both indoors and outdoors[15].

AI-based assistive technologies can detect and identify objects, pedestrians, signs, and environ-

mental scenes. Deep convolutional neural networks (CNNs) are commonly employed for object recognition. The DEEP-SEE framework integrates computer vision algorithms with CNNs to detect, track, and recognize both moving and static objects in real time, utilizing the You Only Look Once algorithm for outdoor tracking[16].

Innovative solutions have also combined AI with traditional mobility aids. For example, a smart white cane equipped with a light source and auditory alerts signals the presence of obstacles. The device employs accelerometers, cameras, and microcontrollers to interact dynamically with the surrounding environment[17].

3. In addition to wearable devices, computer- and smartphone-based resources provide critical support for individuals with visual impairments. These technologies operate through interfaces that convey information via visual, auditory, and haptic (touch or proprioception) modalities, often combining multiple senses to present information in formats that differ from its original form.

The primary goal is to transform information from digital screens or the physical environment, such as printed materials, objects, urban infrastructure, or people, into accessible formats. This can involve enhancing and modifying visual content (visual solutions), vocalizing information using synthesized speech (voice solutions), or creating tactile representations through Braille or other haptic feedback.

For individuals with low vision, accessibility tools include screen readers, screen magnifiers, keyboard navigation, image descriptions, text-based headings, and responsive websites.

For individuals who are blind, solutions primarily include screen readers, keyboard navigation, internal accessibility functions, image descriptions, and semantically structured websites incorporating headings, links, and images.

Windows operating systems offer a variety of accessibility features for individuals with visual impairments, including mouse pointer customization (color, contrast, trail, and speed), cursor settings (movement and thickness), screen contrast adjustment, and screen magnification tools such as Windows Magnifier. Screen readers such as NVAccess (free, with optional paid voice) and IVONA (paid voice, compatible with NVAccess) further enhance accessibility.

Smartphones also provide built-in accessibility features that enable visually impaired users to interact with device content.

Smartphones also provide built-in accessibility features that enable visually impaired users to interact with device content. On Android devices, the most widely used feature is the TalkBack screen reader, which audibly identifies content and app icons when a user hovers their finger over the screen. For Apple iOS and Mac devices, accessibility tools include VoiceOver (a screen reader providing spoken feedback), Siri (intelligent voice assistant), Magnifier and Zoom (screen magnification), and Dictation (converts spoken words into typed text)[18].

Individuals with low vision can utilize features such as Zoom to enlarge the entire smartphone screen to a desired level. The Invert Colors function assists users who have difficulty reading standard interfaces by reversing the color scheme. A study evaluating iPhone accessibility features reported that Zoom and Large Text were the most frequently used toolsamong individuals with low vision[19].

The study also indicated that many participants were interested in using accessibility features if provided with appropriate training. Training individuals with visual impairments to use assistive technologies typically requires structured instructional sessions and a significant time commitment. Factors influencing the effectiveness of training include age, educational level, type of visual impairment (low vision or total blindness), and severity of the condition.

There is a critical need to develop clinical training protocols for caregivers, family members, and eye care professionals to guide the recommendation of smartphones as accessible technologies and to facilitate effective training of visually impaired individuals in their use.

Other applications

- Kibo (Android): Audio-based – Reads images, PDFs, e-books, and DOC files; supports Hindi and English; includes voice recorder functionality
- Be My Eyes (Android, iOS): Audio-based – Connects users with sighted volunteers via video call for assistance
- Supersense (Android, iOS): Audio-based – Provides information about the environment using AI

- Display (Android, iOS): Video-based – Acts as a magnifying glass for nearby objects
- Binoculars (Android, iOS): Video-based – Enables distance vision using a super-zoom camera
- Mani (Android, iOS): Audio-based – Mobile note identifier
- BlindSquare (iOS): Audio-based – Facilitates navigation, location finding, etc.
- Khabri (Android): Audio-based – Provides news, current affairs, job listings, horoscopes, stories, and promotional podcasts (in Hindi)
- PhonePe/Google Pay (Android, iOS): Audio-based – Offers accessible online payment and electronic transaction solutions
- AccessNote (iOS): Audio-based – Supports annotations
- KNFB Reader (Android, iOS): Audio-based – Converts text to speech, supports Braille output, and highlights text
- Seeing Eye GPS (iOS): Audio-based – Fully accessible iPhone GPS application providing step-by-step navigation and comprehensive orientation features
- Audible (Android, iOS): Audio-based – Provides access to audiobooks
- TapTapSee (Android, iOS): Audio-based – Users can photograph any two- or three-dimensional object from any angle, and the app announces the object's name (requires VoiceOver or TalkBack for voice output)
- Optelec (iOS): Video-based – Enables reading of text and viewing of photos using simple magnification and high-contrast functions
- Color Picker (Android, iOS): Audio-based – Identifies colors from the camera or images and includes additional features for color recognition
- Color Grab (Android, iOS): Audio-based – Provides exact color identification, including hexadecimal values, with an extensive database of color names
- Dolphin EasyReader (Android, iOS): Audio/video-based – Allows browsing and downloading of the world's largest collection of audiobooks and newspapers

Examples of smartphone applications

- Clear Sight (iOS) / Big Launcher (Android): Provides options for zooming and adjusting screen colors
- TalkBack (Android): Screen reader for spoken feedback on content
- KNFB Reader (Android): Enlarges photos
- MdevReader (iOS): E-book reader designed for individuals with macular degeneration; moves text to maintain the fixation point in the peripheral field
- Moovit: Navigation app for public transportation and walking routes
- Citta Mobi: Monitors bus routes in real time
- BusAlert: Provides alerts for bus boarding and warnings (available in select cities)
- Be My Eyes: Interactive website
- Seeing AI: OCR for printed or handwritten text, barcode scanning, color and lighting identification, facial recognition, and description of objects and environmental features
- Alia, MovieReading, Whatscine: Applications providing audio description

Sites of interest

- Optical Aids – Faculty of Medical Sciences, UNICAMP, Universidade Estadual de Campinas: https://www.fcm.unicamp.br/auxilios-opticos/index.html
- American Academy of Ophthalmology (AAO) – Low Vision: https://www.aao.org/low-vision-and-vision-rehab
- American Academy of Ophthalmology (AAO) – Recommendations on Assistive Technology for Patients with Low Vision: https://www.aao.org/education/clinical-statement/recommendations-on-assistive-technology-patients-w

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