Published in final edited form as:
Assist Technol. 2024 January 02; 36(1): 60–63. doi:10.1080/10400435.2023.2205490.

Wearables for persons with blindness and low vision: form factor matters

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Abstract

Based on statistics from the WHO and the International Agency for the Prevention of Blindness, an estimated 43.3 million people have blindness and 295 million have moderate and severe vision impairment globally as of 2020, statistics expected to increase to 61 million and 474 million respectively by 2050, staggering numbers. Blindness and low vision (BLV) stultify many activities of daily living, as sight is beneficial to most functional tasks. Assistive technologies for persons with blindness and low vision (pBLV) consist of a wide range of aids that work in some way to enhance one's functioning and support independence. Although handheld and head-mounted approaches have been primary foci when building new platforms or devices to support function and mobility, this perspective reviews potential shortcomings of these form factors or embodiments and posits that a body-centered approach may overcome many of these limitations.

Keywords

assistive technologies; body-mounted; handheld; head-mounted; visually impaired

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Disclosure statement
No potential conflict of interest was reported by the author(s).

Introduction

Blindness and low vision (BLV) impede the efficient performance of activities of daily living (Rizzo et al., 2020). As such, the scientific community continues to develop novel therapies to combat potential causes of BLV (Boldini et al., 2021). However, until such advances are fully realized for all causes of vision loss, there is a clear and pressing need for assistive technologies that help mitigate complications faced during activities of daily living, provisioning access to new information that is typically hard to perceive through nonvisual sensing (Boldini et al., 2020, 2021).

Recent technological advancements have opened the door to innovative solutions that either work in conjunction with or in isolation from mobility aids such as white canes and dog guides, to augment mobility. One such field focuses on smart wearables as assistive technologies; these tools are typically based on electronic systems that obtain environmental information via sensors, process acquired data, and then generate inferences for feedback, often displayed through an alternate sense – sensory substitution (Tapu et al., 2020). Wearables are traditionally crafted into handheld and head-mounted embodiments. Recently, however, research suggests that body-centered embodiments may be more compelling (Kandalan & Namuduri, 2020).

Approaches for wearable embodiments

The field of smart wearable technology has grown significantly over recent years as the size and cost of sensors have continued to decrease (Vijayan et al., 2021). Wearable devices with myriad assist modes have the potential to significantly assist pBLV in many tasks, especially navigation. BLV-focused wearable assistive technologies often incorporate complex sensor systems in the form of lidar, sonar, radar, cameras, and GPS, among others, to extract information from the surrounding environment (Shoureshi et al., 2017). Data is then filtered and processed either onboard or remotely via cloud computing through wireless connectivity. Feedback is sent back to the user via multiple modalities, such as audio and haptics (Kuriakose et al., 2022). Devices are designed and configured given placement on the user's body: handheld, head-mounted, and body-mounted (Figure 1).

Handheld approaches

Handheld devices often rely upon the use of smartphones, as most recent offerings contain the requisite fundamental components and are mainstream devices with myriad uses (Martiniello et al., 2022). Despite their convenience, there are limitations pertaining to sensor selection on a phone-based platform. Integrated phone-based cameras are often constrained due to their small footprint and may suffer from limited optics. Data obtained from phone-based cameras are also unlikely to provide depth information that is accurate or long-range. Even with multiple cameras, there are still limitations to depthscaping (Ranftl et al., 2020; Rizzo et al., 2017). Smartphones also employ GPS, gyroscopic, and accelerometer sensors, which can be used to assist in navigation. Each sensor has its own strengths and weaknesses. For example, GPS has revolutionized wayfinding. Consumer-level devices are typically accurate to within 5 meters but are largely dependent on unobstructed lines of site to satellites (Yang et al., 2022). As a result, in urban environments, home to larger populations of pBLV, non-line of sight becomes a significant impediment and accuracy plummets (Merry et al., 2019).

Smartphone-based assistive technologies may require offloading of collected data, as local device-based processors may not be powerful enough to run advanced neural networks efficiently and with end-to-end latencies that meet minimum requirements for functional tasks (Aleotti et al., 2020). Current cellular networks are continuing to roll out and expand 5 G networks that promise higher bandwidth and lower latency; however, signal reliability continues to impede the seamless transfer of data (Eze et al., 2018; Yuan et al., 2022). Battery size is another concern, as applications often over-tax the device and quickly drain power, requiring increased charging frequency. Additionally, handheld solutions require the user to hold or manipulate the phone for proper use, leading to musculoskeletal strain of the arm, wrist, and neck well as cognitive reserve depletion (Soliman Elserty et al., 2020). After all, the user may be holding and/or manipulating the vantage point of the device's sensors, simultaneously interpreting the feedback from the device, and walking plus performing other motoric tasks, such as cane sweeping in the opposite hand (Kuriakose et al., 2022). Additionally, handheld device manipulation with use of a cane or guide dog disallows one from holding a beverage, carrying a bag of groceries or even opening a door.

Head-mounted approaches

Head-mounted devices have been another focus in the scientific community in the pursuit of assistive-technology progress. Sensors that are incorporated in such devices usually include forward-facing cameras affixed to eyeglasses, goggles, or headsets, along with IMUs (inertial measurement units), and, occasionally, integrated GPS sensors. Information from the sensors is interpreted by processing hardware and then translated to the user through visual, auditory, and/or haptic feedback. The majority of head-mounted devices are self-contained. Such devices often require that the user's head and therefore camera are relatively aligned with the information to be accessed, for example, the object to be identified; a user must therefore move their head, and neck, to locate objects outside of the cameras' field of view. While a camera that is affixed to the head may be of initial benefit, given alignment between the direction of attention and the device itself, over time discomfort and strain may result. There is also the possibility of camera artifact as the head is very mobile and often in compound motion while walking/moving (body movement plus additional head movement) (Figure 2).

Battery life is certainly a concern as such devices are designed to be light and compact, and so contain smaller batteries. Lastly, these compact form factors on the face create comfort and durability issues. Having a battery and/or hardware pressed near or against the face exacerbates thermal control and results in noted complaints and discomfort (Matsuhashi et al., 2020). Sweat and moisture buildup pose not only further irritation but also potential durable-life concerns, as moisture is deposited on and possibly in the head-worn devices. The goal of this commentary is to explain how a number of limitations delineated for handheld and head-mounted devices might be overcome by a body-mounted approach that provides 1) increased stability, 2) greater comfort, 3) larger carrying capacity, 4) lower cost, 6) augmented mutability and modularity, and 6) more discreet and unobtrusive use.

Body-mounted approaches

Body-mounted embodiments may come in several form factors and offer distinct advantages. One such form factor is a backpack (BP). BP-mounted sensors afford greater versatility in the quality, number, and configuration of sensors because they jostle less, may be employed over greater surface area, and minimize discomfort. Due to closer proximity to the user's center of mass, cameras mounted on BP straps will experience less shaking (Figure 2). As a result, a wider array of sensor technologies may be utilized. Additionally, mounting sensors on a user's torso ensures that the field of view is aligned with the intended travel path and direction of motion, making detection and feedback more straightforward (Lu et al., 2019). In other words, the chest/abdomen will always point in the direction of travel ergo body-based schemes add balance to continuous sensing. By contrast, a handheld and certainly a head-mounted device is easy to align orthogonal relative to the intended travel path, creating detection problems relevant to functional tasks. Take for example a head-mounted device in the form of smart glasses. The user donning the glasses is using a hazard negotiation program. She attends to a honking horn to her immediate left and turns her head 95 degrees (her 8 o'clock) while walking forward (her 12 o'clock). The field of view is now rotated relative to the travel path; the peripheral detection area in the far-right field of view of the sensor(s) is/are now critical to safe forward travel.

Moreover, since backpacks are not restricted to a smaller footprint, the user is able to carry additional and/or larger hardware, inclusive of batteries, enabling longer and more computationally demanding usage. Higher-quality sensors with increased fields of view and greater range can also be integrated, resolving the need to actively maintain objects within a narrow field of view – as in the case of handheld and head-mounted devices – while also minimizing physical fatigue. Furthermore, the more even distribution of the BP's weight across the user's shoulders and torso affords increased comfort. Different styles, materials, and amounts of cushioning can further augment ergonomics. As studies have noted, users have a vast assortment of BPs to select from, which raises the probability of finding a tailored fit for individual user groups (Lee et al., 2021). BPs are also readily available as they can be purchased virtually everywhere and are cost-effective. Lastly, since an important characteristic of assistive technology for pBLV is discreetness, BPs do not draw attention (Martiniello et al., 2022).

The BP, an omnipresent object of modern society, serves as an inconspicuous scaffold that metamorphoses into assistive technology, discreetly housing device components. Nevertheless, there are pitfalls that must be addressed. One of the main advantages of using a BP is the ability to carry larger/more equipment. However, more advanced equipment may increase the weight that must be shouldered, potentially leading to discomfort and pain. Additionally, using BPs may result in increased perspiration due to retention of heat between the user and the pack. Lastly, the BP may be considered casual for those who prefer a more professional style to their garments and accessories. Consequently, it will be essential to offer a range of personalized BPs to afford the best fit for each user.

Conclusion

Although the field of assistive technology for persons with blindness and low vision has expanded and matured dramatically in past decades, there are barriers that must be overcome related to stability, comfort, footprint, expense, and acceptance. Technological advances in processing power as well as high-speed wireless communication will continue to support the development of compact, lightweight assistive technologies that can be fashioned into form factors that are hard to imagine at present. All told, the argument for leveraging a body-centered approach, such as a BP form factor, is underrecognized and underutilized. If adopted, superior results may follow as gains are made in camera shake/artifact, field of view, detection range, cost, modularity, discreetness, and ergonomics.

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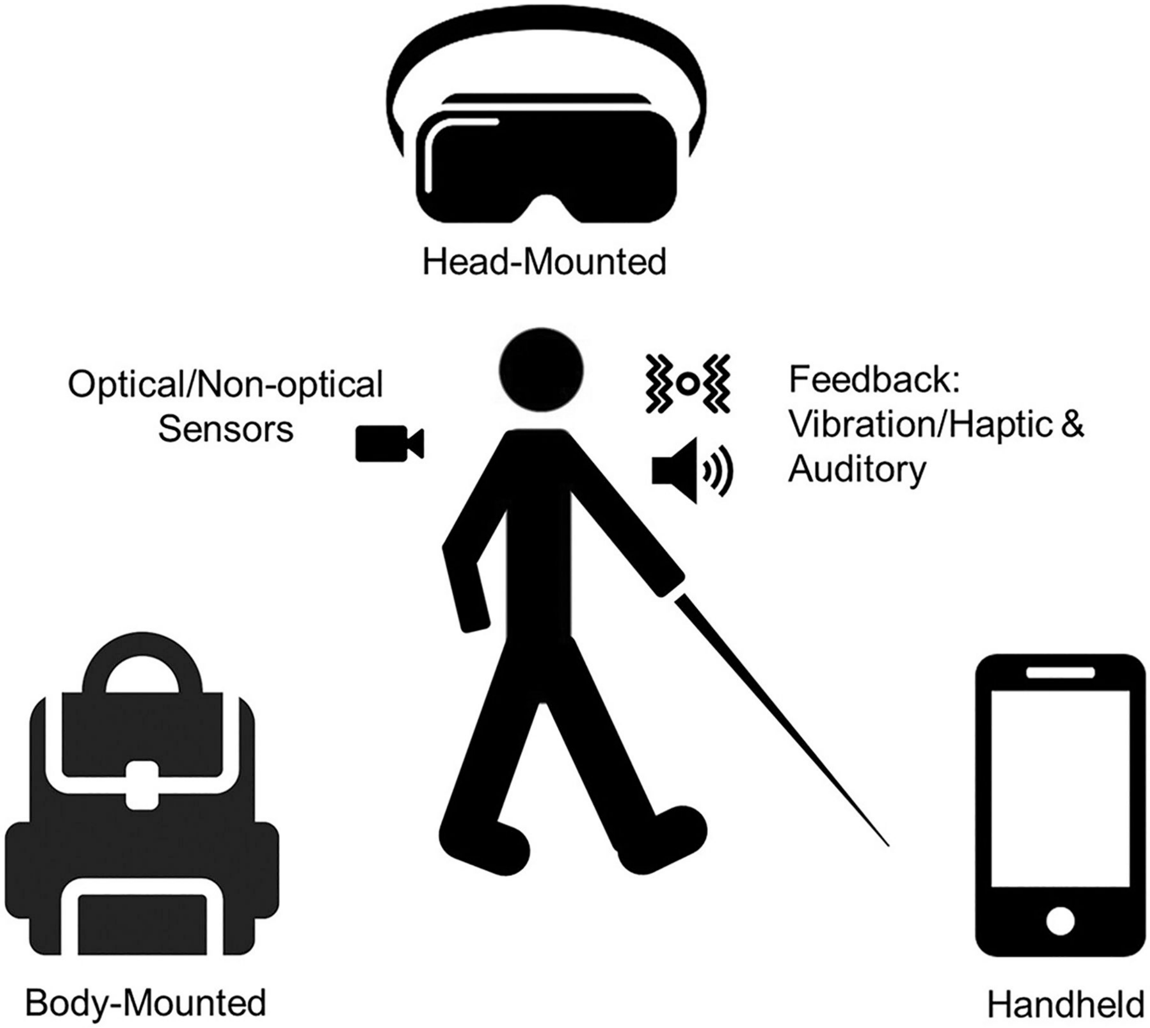

Figure 1.
Approaches to assistive technologies used for navigation.

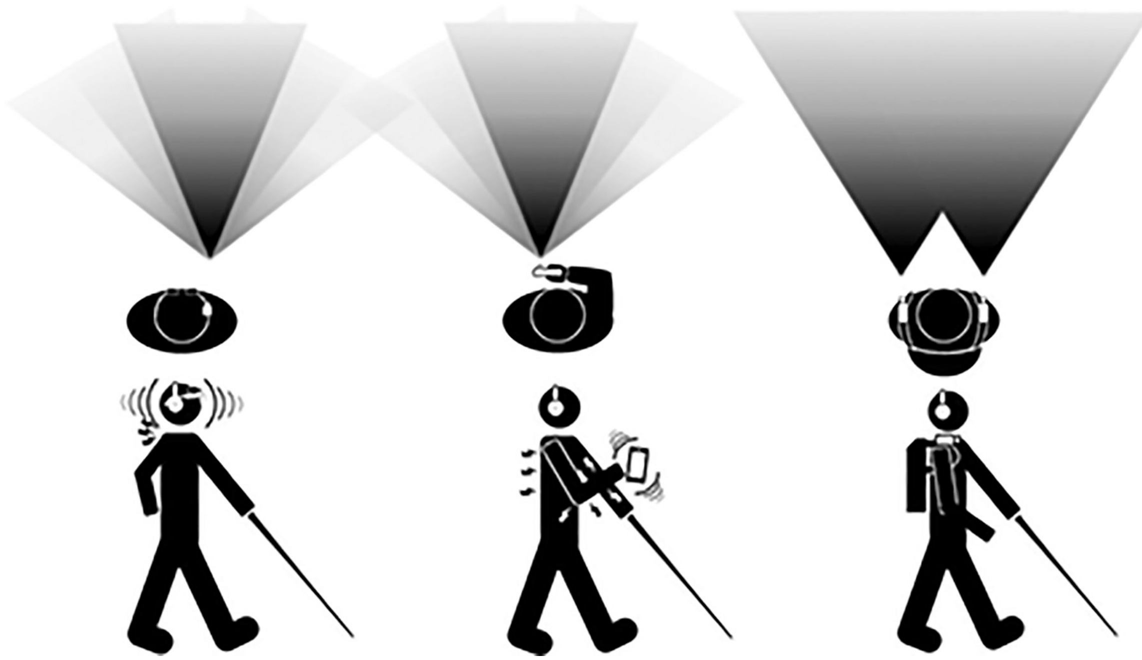

Figure 2.

Different approaches: head-mounted, handheld, and body-mounted. The top row illustrates the field of view from sensors with potential for increased jitter. The lower row illustrates simultaneous use of the devices while using a white cane, highlighting potential issues with the device shaking as user travels as well as potentially causing increased fatigue and stress on the body.