Wearable Travel Aids for Blind/Partially Sighted People

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The ability to travel (independently) is very important for participation in education, work, leisure activities, and all other aspects of modern life. Blind and partially sighted people experience a number of barriers to travel, including inaccessible information and environments, and consequently require support from technology or other people to overcome them.

Keywords: travel aid ; blind ; design ; wearability ; features and functions

1. Introduction

There are about 253 million visually impaired people in the world, 2015 data, with about 39 million blind [1]. 80% of them are 50 or over, and 78% live in low or middle-income countries. Subsequently, the term blind will be used to indicate a person with a significant visual impairment that affects their mobility. However, the term used in the literature will be used to indicate the group(s) of people a particular device is designed for or tested with. Services, facilities and infrastructure are designed for sighted rather than blind people. Consequently, they experience a number of barriers. These barriers affect travel, for instance, through inaccessible information and environments. This impacts the ability of blind people to participate in education, work, leisure activities, and all other aspects of modern life. Therefore, they require support from (assistive) technology or other people to overcome these barriers.

Despite the potential of advanced technologies and the development of electronic travel aids, the long cane and guide dog remain the most commonly used solutions. The long cane is simple, robust, low cost, reliable and requires minimal maintenance. However, it is unable to provide information on distant or high-level obstacles or to support wayfinding and navigation. A survey of 300 blind people found that about 40% experienced head height collisions at least once a year and 15% once a month [2]. The long cane's visibility and distinctiveness mean that it acts as an indicator that the user is blind, making it easier for them to obtain assistance and other people to take particular care not to bump into them. However, this visibility leads many potential users to avoid its use due to fears of being stigmatised [3]. Guide dogs provide similar guidance to a human guide, but only on known routes. They also have social benefits with regard to companionship and can facilitate interaction with other people. However, they are only suitable for people who like dogs and are able to care for them.

2. Overview of Travel Aids

There are a number of different ways of classifying travel aids, including their applications, the main technologies used, their form and how they are carried or worn. Classification by their applications and the associated technologies gives three overlapping phases of travel aid development [4]. The first phase focused on obstacle detection devices with additional functionality compared to the long cane. Many of these devices are in the form of a cane e.g. the laser cane [5], the smart cane [6], the ultracane [7] and the Tom Pouce and Télétact [8]. They use infrared, ultrasonic and/or laser sensors to obtain environmental information and communicate it to users via vibration or non-speech sounds, which are sometimes musical. Some of the more recent devices extract environmental information using camera vision with signal processing of the camera images to identify and sometimes also recognise objects e.g. [9][10]. This facilitates the addition of object recognition and scene representation functions. Other devices in this category include BBeep [11], which detects people and emits an alert to encourage the detected person to avoid the user. A few aids, e.g., Smart Environment Explorer Stick [12], combine obstacle avoidance and wayfinding/navigation functionalities.

The second phase involved the development of navigation and wayfinding devices using two distinct approaches with overlapping functionality to detect either the user's location or a point in space [13]. Global navigation satellite systems, most commonly global positioning systems (GPS), locate the user and have point of interest and other functions. GPS systems designed for or which can be used by blind people include Trekker Breeze, Trekker GPS, Navigator and Captain, and software such as Wayfinder on a mobile device [4]. Environmental information beacons locate a point in space using active or passive radio-frequency identification (RFID) tags or infrared transmitters [14], e.g., the Talking Signs system and the Haptic Pointer Interface [4]. They may have additional functions, such as providing information about located facilities or requesting that vehicle doors are opened. More recently, Bluetooth low-energy (BLE) beacons have been used in navigation systems, particularly for large complex indoor environments e.g. [15][16], but there are other systems that be used both indoors and out e.g. [17].

BLE systems generally involve apps on smartphones, giving the third or current phase of apps on smart mobile devices and vision sensors linked to smart mobile devices. Thus, there has been a progression from the first two phases, with phase one involving mainly hardware, phase two a combination of hardware and software and phase three purely software, with the hardware provided by an existing mobile device. Many of the apps provide specific contextual information that is relevant to both blind and sighted people, e.g., Find my bus and Find my bus stop. However, the appropriate design for compatibility with audio and tactile output is required to ensure they can be used by blind people. Three-dimensional vision sensors are increasingly being used in navigation, including on mobile devices [14]. Cameras and signal processing are also being used with mobile devices to detect particular types of objects, such as tactile tiles or surfaces [18].

3. Wearable Devices

The devices discussed so far are portable but generally not also wearable. Wearable devices are becoming increasingly popular and have the advantage of keeping the hands free [19]. This is particularly useful to blind people who may want to use a cane or guide dog or other (travel) device at the same time. There is a growing body of research on wearable devices for blind people, but few devices have gone beyond the prototype stage.

Wearable devices (prototypes) have been developed for a wide range of different applications for blind people in addition to travel. This includes devices to support social interaction, recognise social signals and gestures [20][21], provide information about facial expressions [22], the number of people in their surroundings and their position relative to the user [23] and simulate eye contact [24]. Other applications include reading devices [25][26], reading music notation for people with low vision [27], dancing [28][29], running [30], education [31], colour perception [32], identifying medicines in a cabinet [33] and improving gait [34][35]. The development of devices for deafblind people has focused on tactile communication, using Braille or a deafblind manual alphabet [36][37][38], but also includes other applications such as support for deafblind cat owners [39].

The three previous surveys of wearable assistive devices and wearable travel aids for blind people will now be discussed briefly. Velázquez [40] organises wearable assistive devices by the part of the body or type of garment they are worn on, namely wrist and forearm, tongue, head, vests and belts, and feet. There is some discussion of wearable travel aids, but the focus is on tactile displays to be used on different parts of the body.

Dakopoulos and Bourbakkis [41] consider wearable obstacle avoidance devices rather than travel aids more generally, including navigation and wayfinding devices. They present a number of prototypes and projects and provide what they call ‘maturity’ analysis based on 14 criteria divided into ‘user’ needs and ‘engineer’s perspective’. This includes real-time/fast response, reliability, low cost, ease of learning and use, simplicity, performance, availability and portability (lightweight and small size). However, some of particularly the engineering criteria are not relevant to all devices. For instance, wireless connectivity is not relevant to all devices and, unless appropriately managed, can lead to privacy and security risks. Possibly unsurprisingly, none of the systems evaluated has all the features. Users were not confident about the reliability, robustness and performance of any of the systems. This is an area that could benefit from further research. The consideration of only obstacle avoidance systems and the possibility that users did not consider them to have overall benefits compared to the long cane could have been a factor. The authors note the importance of devices that are useful long term rather than having all possible functionalities.

Tapu et al. [42] consider assistive devices, with some portable rather than wearable and many, though by no means all, supporting travel. They divide electronic travel aids into active/sensorial network systems and passive/video camera systems and then further divide these two categories by the type of sensor and type of video camera, respectively. However, this classification does not take account of different types of device functionality and, in particular, the important distinction between obstacle avoidance and navigation/wayfinding devices. There is some overlap between their seven evaluation criteria and those of [41] with regard to real-time use, ease of learning, robustness (to scene dynamics and lighting conditions) and portability. However, their other conditions are specific to object detection and not relevant to other types of travel aid. They also focus on camera vision systems and pay less attention to ultrasonic (and infrared) ones. Consequently, the main focus is head (and body)-worn devices, and no foot-worn ones are included.

Thus, existing surveys of travel devices for blind people are useful but have a number of limitations. This includes a focus on obstacle avoidance systems and camera vision technologies, and limited attention to other applications and technologies. A particular limitation is the lack of discussion of wearability and whether and, if so, how this makes a difference to the design.

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