A comprehensive review of non-magnifying assistive technology for low vision individuals

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Abstract:

Currently, the most common form of assistive technology to alleviate low vision is magnifying aid. Examples of magnifying aid would be spectacles with convex lenses, or wearable devices that help individuals view objects in detail. There are currently reviews on magnifying aid for low vision individuals, but these reviews exclude other forms of assistance [2]. The purpose of this paper is to review other forms of assistive technology apart from magnifying aid for individuals with low vision and compare such devices using metrics such as availability, the cost for patients, power consumption, portability, size of the user base, and accessibility. A goal would be to include 11 research papers describing devices apart from magnifying aid. Examples of such research papers include research papers exploring the field of Augmented Reality and how it could be used to help individuals with low vision navigate different spaces, or smart glasses providing audio feedback that could assist low vision individuals in wayfinding. Exploring and comparing such research papers can improve our current understanding of what assistive technology is available to individuals with low vision, and also help us understand to what extent these technologies will be able to help low vision individuals. After reading and analyzing 11 research papers regarding assistive devices for low vision individuals, there were three main findings. The first finding is that all devices attempted to help low vision individuals by either assisting them in specific tasks, such as sign reading, or it could aid users in any daily task that requires vision to complete successfully. The second finding is that factors like high cost hinder the ability of low vision users to access assistive devices, while other factors like short battery life and weight may affect the device's ability to fully assist a low vision user. The last finding relates to social implication: social acceptance of devices and how comfortable users feel when using the device affect user experience and usage rate either positively or negatively.

1. Introduction:

By 2015, more than 246 million individuals in the world suffer from low vision [1]. Low vision is untreatable and affects many aspects of an individual's life. Individuals with low vision find completing certain daily tasks difficult or even impossible, tasks such as walking down the stairs, reading, driving a car, or navigating an unfamiliar environment. Individuals with low vision also often cannot access public spaces easily without assistance. Conventional aids such as guide dogs and canes help low vision individuals navigate different environments, but these aids often cannot aid individuals in more nuanced tasks such as shopping or recognizing different signs. Such limitations give rise to Assistive Technology (AT) aimed at helping low vision individuals.

AT can come in many forms, but when used to help low vision individuals it can be generally categorized into two areas. One area would concern ATs used to enhance a low vision user's existing but limited vision. Examples of such ATs would be the commercialized eSight device, an HMD (Head Mounted Device) that allows low vision users to see objects clearer through magnification, and an expanded Field of Vision (FOV) [7]. Another example would be the ForeSee device, similar to eSight since it is also an HMD, but it provides other functions to further enhance the vision of a low vision individual [12]. Functions such as contrast enhancement and Black-White Reversal help users especially when reading.

The other category of AT would be ATs that supplement one's vision through engaging with a user's other senses, such as hearing and touch. An example of this kind of device would be a belt that detects objects and warns users through vibrations and voice feedback if an obstacle/object is nearby [8]. This device does not enhance the existing visual capabilities of the user, rather it provides users with an understanding of the nearby environment through audio and haptic cues.

This paper will discuss ATs mostly in the two categories mentioned above: vision enhancing and vision supplementing. Another two categories, devices for general use and for specialized use will also be mentioned within the paper. A device can be designed to help a user with one specific task; for example, a device can be designed to help users read signs. Another kind of device would be useful in all kinds of daily tasks, such as the eSight device that is able to provide better vision throughout the day [13].

Finally, the social implications of ATs will also be discussed. Although not mentioned in most papers that will be presented in this paper, social implications provide insight into the usability of the device and whether users will be comfortable using ATs.

1.1. Definitions:

This paper will analyze different assistive devices/ATs for low vision individuals through 5 metrics: availability, the cost for patients, power consumption, portability, and user base. Some metrics may not apply to certain devices, such as the fact that availability and cost for patients might not apply to a prototype device that is still in its testing phase. These 5 metrics are defined as follows:

- 1. Availability. Availability refers to the ability of low vision individuals to obtain the device. Availability is an important metric to consider since it directly indicates how much impact a device is able to make on the low vision community, or how many people the device is able to reach.
- 2. Cost for patients. Cost refers to the price of devices or the amount of money that needs to be paid in order to acquire the device. If the device costs a lot to purchase, it can block out many low-income low vision users with less purchasing power from accessing it. Or it requires low vision users to sacrifice other items in order to purchase the device (ex. Sell a car).
- 3. Power consumption. Power consumption refers to how long it will take for the device to run out of power. Considering how low vision individuals might need the assistive device for long periods of continuous time throughout the day, it is important devices are designed to last long enough to satisfy user needs.
- 4. Portability. Portability can be measured by looking at the weight and size of the device. Portability can be important since most devices are either HMDs or devices that users wear on other parts of their bodies. Thus, portability of the device directly affects the

physical comfort of the low vision individual using it, and also how low vision users of the device are perceived socially by people around them.

- 5. User base. User base refers to the number of users who have used the device and it shows how accessible the device is. Apart from the size of the user base, the makeup of the user base presented in each paper will also be analyzed. Many papers included demographic information of users, information such as type of visual disability (not all users had low vision, some had other visual disabilities such as complete blindness), the region in which users reside, how the users accessed the device, etc. Some papers did not include low vision users, which meant that the results presented within these papers might not be representative of the low vision population.

	Is it purchasable?	Does it use custom components?	Purpose
Vtrain [3]	No	Yes	Used to train low vision individuals: stimulate walking in an unfamiliar environment.
Stairvision [4]	No	No	Projects visuals onto stairs to help low vision individuals identify and move up/down staircases better.
Wayfinder [5]	No	No	Shows low vision users direction they need to walk in to reach designated destination in unfamiliar environment.
SignSee [6]	No	No	Identifies and enlarges signs for low vision users.
Aira [7]	Yes	No	Aid low vision users in daily difficulties.
Radar [8]	No	Yes	Alert low vision individuals of nearby obstacles.
NavCane [9]	No	Yes	Helps low vision users avoid obstacles and navigate environments.
CueSee [10]	No	No	Aid low vision users in identifying certain products during shopping.
iSight [11]	No	Yes	Helps low vision users identify objects through computer vision.
ForeSee [12]	No	No	Aid low vision users in daily tasks through enhancing their vision.
eSight [13]	Yes	No	Aid low vision users in daily tasks through enhancing their vision.

Figure 1: Overview of the low vision assistive technology devices reviewed throughout this paper.

2. Devices enhancing vision

Devices enhancing vision will be analyzed in this section through two categories: devices for specific use and devices for general use. It should be noted here that although devices in these two categories have different functions, one major similarity is that most of these devices come in the form of an HMD. HMDs allow the direct enhancement of a user's vision, whether it is through the projection of visuals onto the user's screen, or if it is the development of different functions on the HMD itself such as color contrast.

2.1. Devices for specific uses

All 3 papers belonging to this category attempted to create a device that enhances vision to solve a specific problem low vision individuals face during their daily lives. The four problems/scenarios are walking down the stairs, navigating an unknown environment, reading signs, and shopping. The devices that are created for each scenario help low vision users complete the designated task better to a certain degree, but the device is not optimized for other scenarios. For example, a device created to help low vision users read signs would not necessarily be convenient in helping users navigate the environment better.

The first device is smart glasses that use projection-based AR to help low vision individuals navigate stairs better [4]. The device wasn't named by the researchers who authored the paper, but it will be referred to as Stairvision for conciseness purposes. Stairvision comes in two forms: a user can either use their phone to project chosen visuals onto stairs that indicate the location of each step, or the user can wear Microsoft HoloLens, a pair of smart glasses, and be able to see the visuals through the glasses. Both forms include audio assistance, indicating the direction of the stairs and also the number of stairs. Researchers tested Stairvision on 12 low vision individuals, and the test results showed that users took less time to walk down the stairs when using smartphone projected visuals. However, when the users used the second form of projection-based AR using HoloLens, the time taken to walk down the stairs increased. Individuals also indicated that they felt less psychological safety when wearing HoloLens, an HMD. Psychological safety, according to the paper, refers to the user's confidence when using Stairvision; low psychological security when using HMDs explains why it took more time for users to navigate stairs when using HoloLens. A similar trend can be observed in a device named Wayfinder, an HMD used to help individuals navigate unfamiliar environments, where the paper reported that there were no significant differences in the speed at which low vision users navigated the environment with Wayfinder compared to the control, despite differences in other metrics such as errors made during navigation task [5].

In terms of accessibility and cost, smartphones are more accessible and also lower in cost than HoloLens-based solutions. Since HoloLens is a newly developed device, the price given on the official website is $3,500, which is significantly more compared to regular smartphones. Considering how many individuals own a smartphone already, it is costless for them to access the AR system, while users pursuing HoloLens would have to pay an extra price. High prices are a common characteristic of HMDs such as HoloLens, and many assistive technology devices for low vision people rely on HMDs. Specifically, in the context of low vision individuals who often struggle financially due to a lack of job opportunities, HMDs are unaffordable for many.

SignSee (name made up for conciseness purposes) also relies on Microsoft HoloLens, but the function is primarily used for sign identification [6]. A low vision user using the device can point their HoloLens at the sign they want to identify, and the device would generate an enlarged version of the text onto the FOV of the user. In a situation where there are multiple signs, SignSee would identify all signs and allow the user to choose which sign to enlarge. The control presented within the paper is sighted users identifying signs with a low vision simulator but without the SignSee device. Users ranked SignSee higher than the control in three different aspects: ease, comfort, and confidence. However, similar to the Stairvision, the time taken for users to complete a sign identification task was not faster compared to the control. The group of users who used SignSee on average “walked at a slower speed and needed substantially more time to complete the task” [6]. It is worthwhile to note here that the users that took part in this experiment were not low vision individuals, they were individuals who wore a low vision simulator. In terms of accessibility, similar to the first device it can be hard for many low-income low vision users to purchase it due to its cost. Additionally, the device can exclude users in regions with unstable internet connections. The device relies on a cloud-based service, and it requires an internet connection for its sign identification function to work. For users living in regions without stable internet connection, the device might not work best, meaning that the time taken for users to identify signs would be even longer due to lag. This is a problem that can extend to all devices that need a stable internet connection to function. Furthermore, it can be inconvenient for users to set up Wi-Fi for every building they enter.

The third device is also a device developed using HoloLens, and it will be referred to as Wayfinder [5]. Wayfinder helps low vision individuals navigate unfamiliar environments by providing different visuals. There are different visuals individuals can choose from, all of which show the path the user needs to follow to arrive at the destination. For this device, the researchers also developed an audio system that users can choose to include. A survey of the 16 low vision users that participated in testing found that although users preferred visuals over the audio system for presenting information related to the environment, most users preferred a combination of both audio and visual systems. The researchers noted that the learning time for visual cues fluctuated according to the user's visual capabilities, however, the learning time for audio cues was stable and shorter compared to the learning time for visual cues. The ability to switch between modes, or combine modes (visual and audio) is important for low vision individuals, as they can have varying visual capabilities, which can lead to different preferences. In the context of Wayfinder, low vision users with limited FOV would prefer the audio system over the visual system due to difficulties seeing visual cues. Although Wayfinder did not have a significant effect on wayfinding, users made fewer mistakes when using Wayfinder. Avoiding mistakes in navigation can be useful for low vision users, as individuals can save previously wasted time. It might be difficult for low vision users to use Wayfinder for long periods of time throughout the day, though, when considering metrics such as power consumption and portability. Wayfinder relies on Microsoft HoloLens, which lasts 2-5 hours when full. HoloLens also weighs roughly 500 grams, a weight that can be uncomfortable especially when it is a weight that is felt on a user’s head, where HMDs are strapped onto. Finally, it is unclear if Wayfinder’s pathfinding system can be applied to all unfamiliar environments since the device was only tested out in one building.

The final device in this category is CueSee, an AR application on the Oculus Rift that helps low vision users search for products in a shop or supermarket [10]. The application works by identifying the desired product and then highlighting the product through different visual filters. Some visual filters include color contrast, spotlight (a box that surrounds the device), and sunrays (red lines that extend from the product). Users can choose to combine different visual cues to enhance their search experience. According to the paper, different individuals found some visual cues more effective than others, highlighting the importance of flexibility to the user experience. StairVision, SignSee, Wayfinder, and CueSee all offer users a wide variety of choices for visual enhancements. CueSee yielded positive results in regard to accuracy: all 12 low vision users had an accuracy of 100%, meaning that users were able to find the correct product in all trials. It is unclear though if CueSee can still achieve the same results in a larger, open environment different from the experimental environment with only one shelf that the researchers tested on. For the device itself, the cost is a lot cheaper compared to Microsoft HoloLens, with the Oculus Rift DK2 costing around $300. The comparatively lower cost means many more low vision individuals are able to access CueSee. In terms of portability, researchers who authored the paper claim that the device is “big”, “heavy” and impractical for real due to discomfort. For HMDs especially, if the device is too heavy and large, users will not be able to carry the device around. Considering how the devices are used in specific scenarios, however, portability as a factor might not be as important as it is in devices for daily use. Discomfort during use can still negatively affect user experience and even lead to many choosing not to use the device completely.

2.2 Devices for daily use

Devices for daily use refer to devices that can help low vision users complete a variety of daily tasks requiring vision, unlike devices for specific uses which are designed to be applied in specific situations. There are two devices that fit into this category.

The first device is ForeSee, an HMD aimed at enhancing vision [12]. The physical device is an Oculus Rift DK2 combined with a video camera. It has 5 enhancement methods that are similar to CueSee: magnification, contrast enhancement, edge enhancement, black and white reversal, and text extraction. The difference between ForeSee and CueSee is that the enhancements of ForeSee are designed to improve a user’s shopping experience, while the enhancements provided in ForeSee can be applied to any situation. For example, a visual provided in the ForeSee paper shows a low vision user reading the time on a watch while using the device’s magnification functions. Individuals are able to choose what visual enhancement they would like to use for each task, and according to the paper, each user’s preferences varied. No individual had the same preference, which shows that the ability to customize is important to the specialized needs of each individual. Although all users were low vision individuals, their remaining vision can vary according to the cause of their low vision. The researchers emphasized that they do not expect users to use the device in real life considering its weight and bulkiness. The lack of portability negatively impacts the benefits the device can bring to low vision individuals, since users may not be able to use the device for long uninterrupted periods of time during the day to satisfy their daily needs.

The second device is eSight, a commercialized HMD that has similar functions to ForeSee [13]. The ForeSee researchers made a direct comparison with eSight, claiming that ForeSee has more visual enhancements compared with eSight. However, eSight has an advantage in terms of portability. The eSight device does not use Oculus Rifts or HoloLens, instead, it uses its own smart glasses that weigh less than both the Oculus Rift and the HoloLens as seen in figure 2. A lighter HMD can ensure that users will feel comfortable wearing it for the majority of the day. Since eSight is a device that is purchasable, extra steps were taken to transform the device from a research-quality device into a market-quality device, and an example of these extra steps can be seen in the lighter weight of the eSight device. The eSight device weighs 200 grams, less than the 500-gram weight of HoloLens and Oculus Rift. Although the researchers did not discuss the functions of the device extensively, the researchers did present information about how eSight users felt about the device, and also the social implications of the device. For example, users of eSight were asked about their experience with the device. A user described eSight as life-changing, and though the price for purchasing the eSight device is higher compared to other HMDs (when the paper was written, the cost of eSigth was 15,000 dollars), none of the participants expressed regret about purchasing the device. Though eSight users did initially have concerns about the cost, and the cost might be one of the reasons the device might not be accessible for many low vision individuals. Some users talked about how they had to sell their possessions in order to purchase eSight or start campaigns on donation websites. Apart from cost, researchers also collected users' opinions on social acceptance. Some users described eSight as a device that contributed positively to their sense of self-worth and social value since they can use eSight to complete daily tasks, interact with family members, and even pursue job opportunities. While other users talked about the device's bulkiness inhibiting natural, face-to-face interactions with others. One user specifically talked about how HMDs prevent eye-to-eye contact, thus people felt less trust when talking to them.

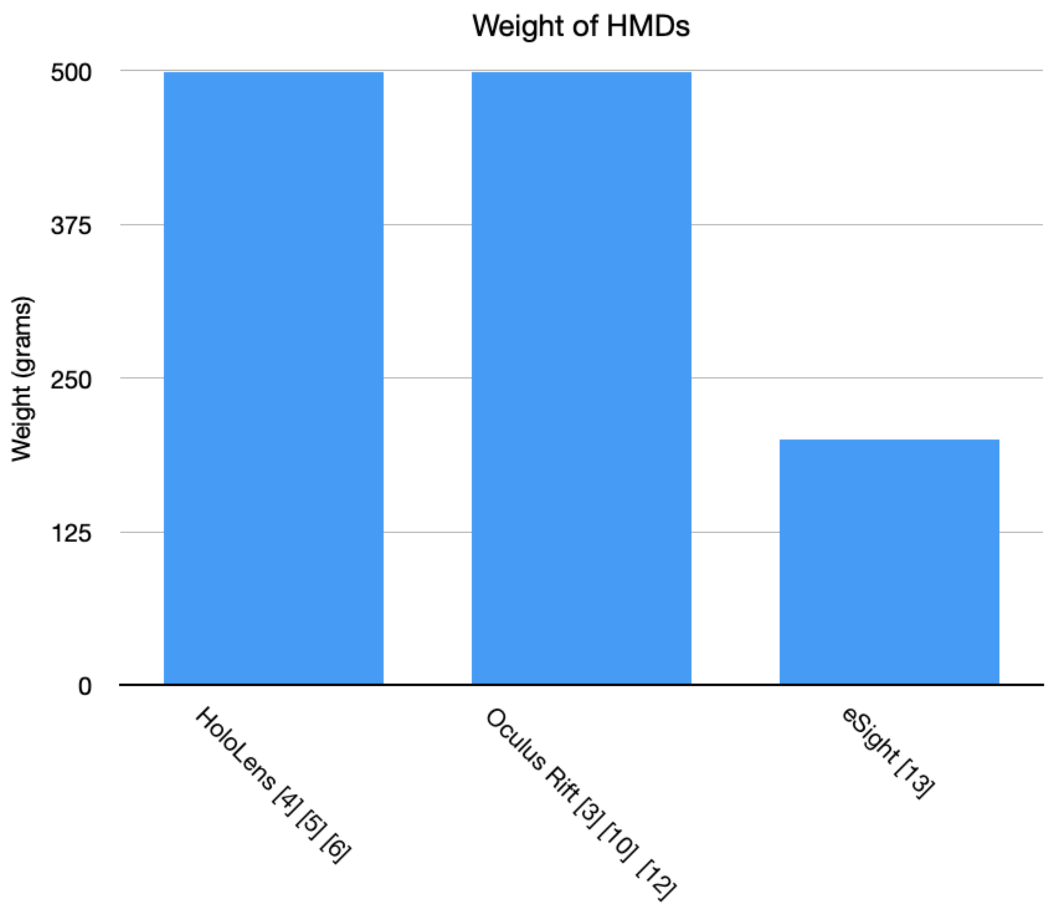

Figure 2: Weight of HMDs

Finally, ISight is a device that utilizes computer vision to help low vision individuals recognize objects better [11]. The device works by pointing either a tablet computer or a mobile phone at an object. The application running on the camera device would then identify the object, and present an enhanced image of the object. There are three different modes low vision users can choose from when attempting to identify an object: icon, enhance, and cartoon. Both the icon and cartoon mode attempt to simplify the object into an easy to recognize image. For example, when the camera is pointed at a car positioned far away from the user, iSight would show the user a large, generic image of a red car. The other mode, enhance, directly magnifies the object. The accuracy of the iSight device, or how accurate it is at identifying objects is at around 70 percent. The iSight paper doesn't include much information about the device related to the metrics mentioned in this paper, but the technology of computer vision can definitely be applied to other HMDs to identify objects better.

3. Devices supplementing vision

Devices supplementing vision refer to devices that not only enhance one's vision but also interact with the user's other senses, such as hearing and touch. Another key difference between the two categories would be the makeup of devices. Whereas devices that enhance vision mainly consist of HMDs, devices that supplement vision are more diverse in their appearance and also in the technological aspects utilized within the device.

3.1 Devices for a specified use

The first and only device in this category, Vtrain (named for conciseness purposes) helps low-vision individuals train to navigate in unfamiliar environments. Virtual Reality (VR) is used to design virtual environments with different obstacles that are similar to those in real life. Users train within the virtual environment by wearing an Oculus Rift headset, which is connected to a computer that the user carries around throughout the training session. The system also consists of a tracking system to track the user's movement, a pair of headphones to provide audio feedback, and two vibration motors to provide haptic feedback. The vibration motors and the headphones are part of an alert system that warns users of obstacles within the virtual environment since users are not shown the virtual environment. The alert system is designed to alert users more frequently when they get closer to an obstacle. When Vtrain was tested in different environments with varying amounts of obstacles, the researchers found that although test subjects were able to navigate the virtual environments, the 13 users experienced 147 collisions in total. The users were not low vision individuals, rather they were sighted, potentially explaining why they might not be as accustomed to using audio or haptic feedback to avoid obstacles. Since Vtrain was not tested on low-vision individuals, one cannot conclude that low-vision users would collide with obstacles less compared to sighted users simply due to their familiarity with methods of feedback. In terms of cost and portability, Vtrain is slightly more expensive and a lot heavier than the radar device above, considering how users have to carry a computer around during training. Training sessions are less time-consuming and frequent compared to daily activities; thus, the negative impacts of the Vtrain's weight are less compared to other HMDs.

3.2 Devices for daily use

The Aira assistive technology is a pair of smart glasses that connects an Aira human operator with a user [7]. The human operator would guide the low vision users and assist them in any task with which they need help. The main uses of the device, according to the paper, include reading, home management, navigation, shopping, etc. A human operator can help low vision users by connecting with the front-facing video camera installed on the glasses, after which the operator can see what the low vision user wants help with and assist them by giving instructions, or in some cases helping them complete the task itself (e.g., reading a book out loud for a low vision user). The paper collected data from more than 800 individuals with visual disabilities and analyzed more than 10,000 calls. From the data collection, researchers who authored the paper found that although the device had above 70 percent success rate for all popular uses (reading, home management, family, social, instructions, navigation, shopping, the arts, employment assistance), about 40 percent of low vision individuals used the Aira device only once throughout the entire experiment. Other groups of individuals, such as individuals from the light perception or blind group had slightly higher frequencies of use. Researchers also pointed out that their study's included user base might not be representative of the entire low vision population, as these are individuals who have the financial resources to purchase the subscription as well as the technological literacy to operate the device. The cost of the device itself was not specified within the paper, but the call time costs $99 for 120 minutes of call time, and $199 for 300 minutes. On average 27.5 percent of low vision users call for more than 9 minutes per day, and the cost goes up along with more frequent use of the device. The Aira device also only is accessible currently to individuals living in the US, Canada, and Australia. Even if Aira manages to expand its reach to more locations, it is unclear if users in other regions can have stable connections with human operators who are in faraway locations. Connection problems also severely disadvantage users living in less developed areas.

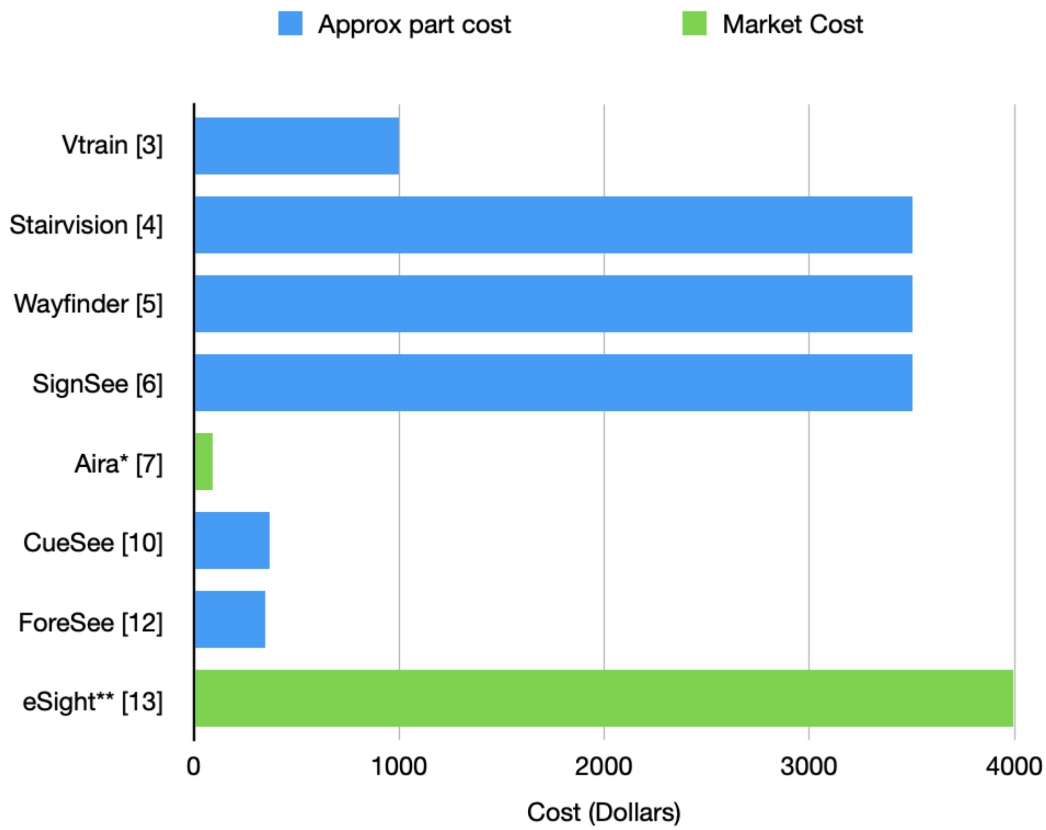

Figure 3: Cost of devices in dollars

*The Aira device can be acquired through purchasing call time. The device costs 99 dollars for 120 minutes of call time, and 199 dollars for 300 minutes

**The price of the eSight device is cut off in the figure. The actual price should be 15,000 dollars.

The second device is called NavCane [9]. The device is a white cane used mostly by blind and low vision individuals to avoid obstacles, but with extra components that allow it to help low vision individuals beyond the navigation help a regular cane can provide. Although the ultimate goal of NavCane is still to help low-vision individuals identify obstacles and paths, it has more nuanced methods of helping individuals achieve that result. NavCane contains several components: a radio frequency identification reader, ultrasonic sensors, a GPS module, vibration motors, a gyroscope, and a wet floor sensor. Five ultrasonic sensors are placed on different parts of the cane to detect objects at different heights, combined with vibration motors and a sound device to form an alert system. The wet floor sensor prevents users from stepping into wet floors, and if a user does fall the GPS module sends the user's location to family members so they can assist the potentially injured user. The gyroscope/accelerometer helps detect the tilt of the cane to ensure that distance calculations made by the ultrasonic sensors are correct. The researchers who created the device were able to achieve good results with low-cost components: 80 low vision, blind, or old age users using the device were able to navigate an unfamiliar environment faster and experience fewer collisions with objects that had varying heights. Using the cane can be difficult for users, however. The cane has lots of components on it to ensure that it can achieve a variety of functions, and it also needs to be held in an upright position to ensure the accuracy of distance measurements. Nevertheless, NavCane is still able to build onto a traditional assistive device that many are familiar with, and even with the multiple electrical components on it NavCane's battery can last for 6 hours 40 minutes to 10 hours on average, which is long compared to other devices seen in figure 3. Long battery lives ensure that users will be able to use the device throughout the day, and especially for an assistive device like a cane that will be used in all settings NavCane's battery suits the requirement well.

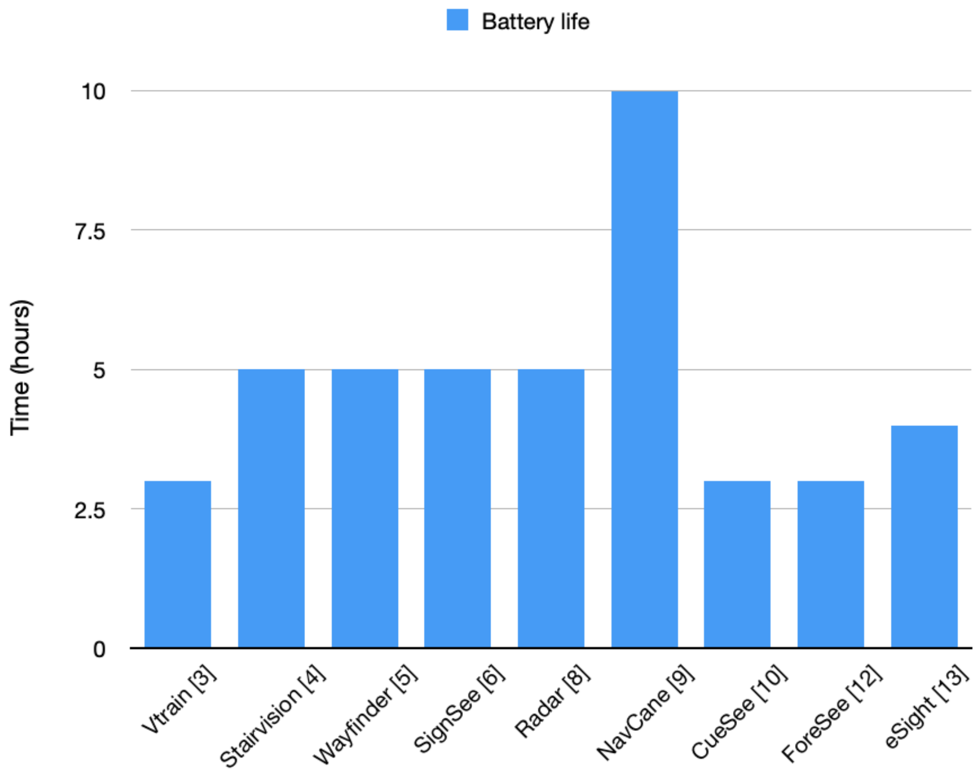

Figure 3: Battery life of all devices.

The last device that belongs in this category is a radar device, Quest 2.0, that helps individuals identify objects within an environment [8]. The device is wearable, and it is strapped onto the user's abdomen. The miniaturized radar within the device sends signals in the user's walking direction, and if the signals reach an object the signals would reflect off the object and be detected by the radar. The radar sensor detects a 0.9-meter-wide area up to 2 meters in front of the user, and it can provide haptic and voice feedback if the radar detects an object within that area. Out of the 25 individuals who participated in the experiment, 92 percent of the users answered that the device improved their environmental perception, and 80 percent of test users reported that the device improved their confidence in independent mobility at least to some extent. Although not all users were low vision users, with 7 low vision users out of 25 total users, the paper did state that the results indicated people with low vision were one of the groups that benefited the most from this device. The paper also stated that many of the test users "would be willing to obtain this device if it was commercialized". Perhaps the main advantage of this device, Quest 2.0, as compared to other devices is its portability. The device can be strapped onto a user, and the average user satisfaction with the weight of the device is 4.1/5, which belongs in the "quite satisfied" category. HMDs are also hands-free devices that can be strapped onto a user's head, but the weight of the device poses a problem for users who would like to use HMDs for long periods of time. Finally, although the device has not been commercialized, the cost of the device is likely to be lower compared to HMDs. The device only consists of a 3D printed case, a miniature radar, a vibration motor, and a speaker for sound feedback, which all can be cheaply acquired.

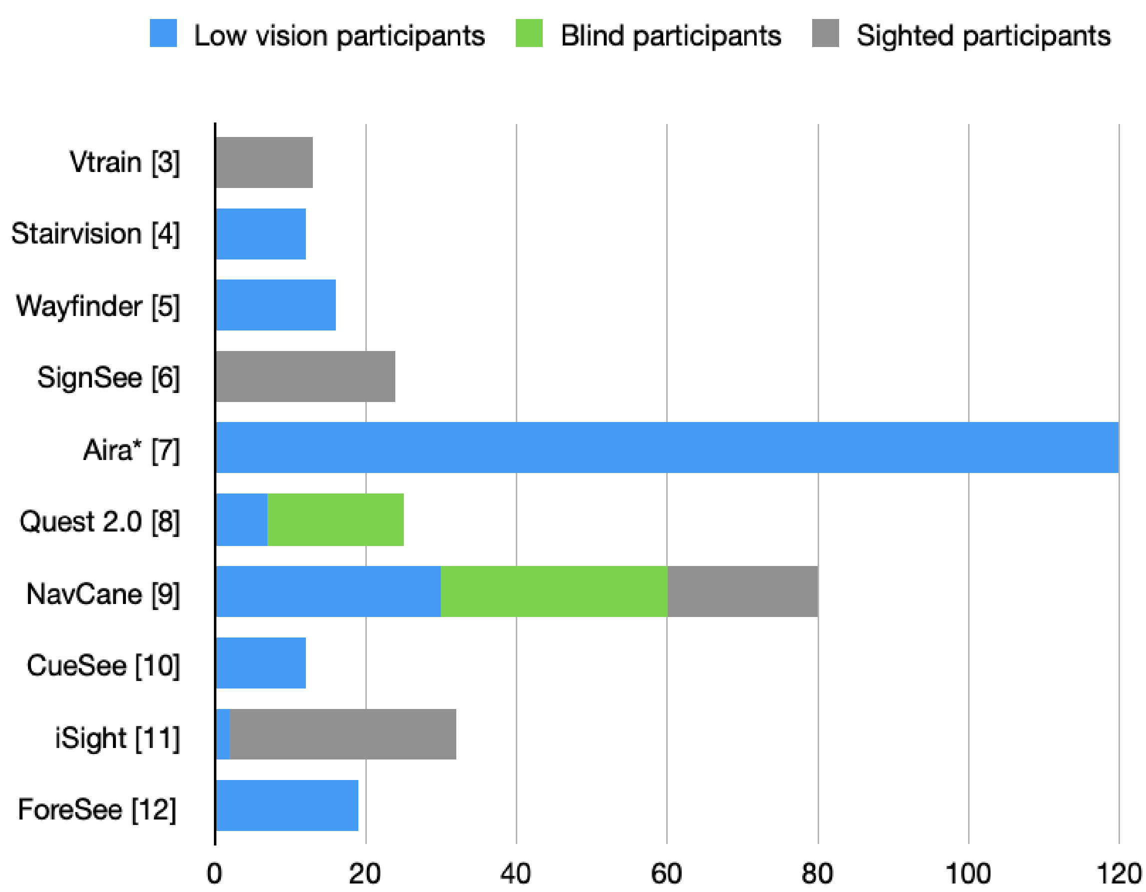

Figure 3: Makeup of participants who tested out devices. Participants are categorized according to their vision: low vision, blind, and sighted.

*The number of users who used Aira was cut off on the graph, the actual value is 878 users.

Conclusion:

There are a few areas devices mentioned above can improve on to potentially better help low-vision individuals. Since many devices are prototypes, researchers mentioned some of the following areas within their papers as areas they will be focusing on for future prototypes.

1. **Weight and Size.** Future devices can be lighter to improve user experience. Since HMDs and their weight apply pressure to the user's head, HMDs especially need to consider decreasing weight in future products/prototypes. As seen in figure 2, eSight, the only assistive device for low vision individuals on the market out of the 11 mentioned in this paper weighs the lightest compared to other devices. It would be best if devices can retain their functions, but decrease the weight of parts or potentially eliminate unnecessary parts that contribute to the weight of the device. Devices like Quest 2.0 that strap around one's torso might be more comfortable than HMDs with the same weight, but researchers who developed Quest 2.0 did point out that they will try to create lighter prototypes in the future [8]. Devices could also be smaller in size, as researchers have claimed that the bulkiness of HMDs has prevented real-life use of devices for low-vision individuals [10].
2. **Price.** Future devices can be less costly for users to purchase to reach more low-vision individuals. A positive trend of decreasing prices can already be observed in the status quo: new HoloLens and Oculus devices are less costly compared to earlier models. HMDs such as the HoloLens were relatively new when some of the devices mentioned above were developed, which explains why the prices might be higher compared to recent models. Apart from increased accessibility, lower costs also ensure that low vision users aren't sacrificing much financially to purchase a device.
3. **Battery life.** It would be beneficial if future devices could have longer battery lives. Longer battery life for devices means that users can use the device throughout the day without having to fear that the device would run out of battery in the middle of use.
4. **Customization.** Many devices already contain multiple choices for features and allow users to combine different features for the best experience. Multiple features and the freedom of choice caters especially to the low vision population, as users have varying

visual capabilities. One feature might be better suited for a specific condition, such as audio cues for low-vision individuals with limited FOV [5].

5. **User base.** When testing devices, the majority of the users should be low vision participants to ensure that experimental results are representative of the low vision population. It is also important to understand the actual needs of low-vision individuals to improve assistive devices aimed at bettering their lives.
6. **Social implications.** According to users mentioned in the eSight paper, eSight improved their sense of self-worth and social value. However, a user claimed that eSight impacted them negatively since they felt like they couldn’t naturally socialize with others wearing an HMD [13].

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