Designing Smartglasses Applications for People with Low Vision

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Abstract

While our community has many active projects involving blind people, low vision is rarely addressed. People with low vision have functional vision, but their visual impairment adversely affects their daily life and it cannot be corrected with glasses or contact lenses. Over the last few years, we have been conducting research with this understudied demographic: understanding low vision people's needs and designing applications to address the challenges they face. In this article, we discuss our ongoing research in this area, focusing on designing augmented reality applications for low vision users. We begin this article by describing low vision and motivating our focus on augmented reality applications on smartglasses for low vision people. We then provide overviews of three research projects that exemplify our research agenda: a study where we observed low vision people conducting a navigation and shopping task, a study where we examined low vision people's perception of virtual text and shapes on smartglasses, and the design of a smartglasses application that facilitates a visual search task.

Low Vision

According to the Centers for Disease Control and Prevention (CDC), 3.3 million Americans who are 40 years old and older have low vision, and 19 million Americans have trouble seeing even when wearing glasses or contact lenses [9]. A person has *low vision* if he or she has difficulty seeing when performing daily activities, even with glasses or contact lenses [4,12]. Low vision is especially common among older adults, so the number of people with low vision is expected to rise significantly in the next 20 years with the general aging of the population. There are different kinds of low vision, including limited peripheral or central vision, blurry vision, light sensitivity, or blind spots [1]. While about 90% of people with a visual disability have functional vision, nearly all accessibility research has focused on nonvisual audio or tactile technology [3,16]**.** There is thus a major opportunity to advance low vision accessibility research and impact the lives of millions of people.

Low vision accessibility tools use simple image enhancement techniques and have not changed much in decades[1]. Low-tech low vision aids include handheld optical magnifiers and monoculars. Digital tools are available on desktop and mobile platforms, and most often allow users to magnify the contents of the screen, increase the contrast, or reverse the colors of the display. The simple "signal-to-signal" image processing techniques (image scaling, contrast enhancement, *etc*.) that are pervasive in low vision accessibility tools do not take the user's *context* into account: they are applied regardless of the contents of the screen, the user's task, or the user's visual condition.

[1] OrCam [18], a camera mounted on a user's glasses, is one of the very few recent innovations in low vision technology. If a user points to printed text, OrCam recognizes and speaks the text.

Augmented Reality on Smartglasses

Smartglasses [5] now present an exciting opportunity to revolutionize low vision accessibility: they have embedded sensors that can be leveraged to learn about the user's context and displays for presenting visual feedback that augments the users vision. These devices have the potential to: (1) solve important accessibility challenges and (2) become widely adopted by a wide range of low vision people. Since Google Glass was released in 2013, a variety of companies have already developed smartglasses for augmented and virtual reality. Unlike with smartphones or handheld magnifiers, smartglasses can provide faster hands-free access: the user does not need to pull out a phone and aim the camera to capture her surroundings. They are the next generation of corrective eyewear. As mainstream devices, smartglasses offer additional benefits. Prior research has shown that people with disabilities prefer to use mainstream devices (i.e., not specialized for users with disabilities) because they are more socially acceptable and non-stigmatizing, affordable, and easily available [7,8,10].

Research Questions

Our research on low vision people aims to address three high-level research questions:

1. What challenges do people with low vision face in their daily lives?
2. What are low vision people's perceptual abilities on smartglasses?
3. What designs for smartglasses applications address the challenges faced by people with low vision?

Below we describe examples of recent work that addresses each of our high-level research questions.

Understanding Low Vision People's Daily Challenges

When we first embarked on low vision research, we were surprised that no prior work had studied the challenges that low vision people experience when performing daily activities. Beyond their challenges, no research had explored what tools and accommodations low vision people used in their daily lives. Many low vision tools exist—from hand held magnifying glasses, to monoculars, to the Zoom magnification feature on iOS—but were people using these tools? If so, what were the patterns and challenges of their use?

To answer these questions, we conducted a study [11] where we observed low vision people conducting a navigation and shopping task, activities necessary for an active and independent life. Specifically, we tasked participants with finding a nearby pharmacy and buying a specific Tylenol product. We recruited 11 participants with low vision (5 males, 6 females) with a variety of visual conditions. Their age range was 20-68, with a mean of 41. Seven participants were born with low vision or became low vision as children, 3 participants became low vision as young adults, and one participant became low vision as an (slightly) older adult (age 55).

We used *contextual inquiry* to interview and observe participants in-situ. This method, of examining participants' behavior in a daily activity in real-time, allowed us to discover how people with low vision perform tasks, what kind of struggles they encountered, what aids they tended to use, and how these aids helped them.

During the task, participants used their vision extensively to gain information about their environment, but they experienced many challenges. The main aid participants used was their smartphone, which was mostly used for outdoor navigation (*e.g.*, using a map application).

Navigation using the smartphone was challenging, because the smartphone's accessibility tools did not provide adequate support. For example, participants continually readjusted the magnification level of the built-in magnifier to see text at different font sizes. Meanwhile, the gestures needed for these operations were difficult to perform. Navigating around the pharmacy was the most challenging part of the task. Participants did not use any tools for indoor navigation or searching for the product. When participants found the correct aisle, finding the correct product among rows of similar products was daunting. Most picked up each product individually, examined it closely (sometimes using a magnifying glass), until they found the desired product.

In sum, the study revealed many open problems for the accessibility community to consider. While many recent innovations have focused on blind people, our participants did not use any nonvisual accessibility tools. They used their vision extensively and desired better tools for their mainstream devices.

Understanding Low Vision People's Perceptual Abilities on Augmented Reality Glasses

While augmented reality smartglasses are advancing rapidly, these technologies are still limited in many ways. Consider the Epson Moverio or Microsoft HoloLens. Their displays are small compared to the user's field of view and the range of visual stimuli that can be projected is limited. Virtual elements are somewhat transparent so they have relatively low contrast. Given these limitations, we sought to determine whether and what low vision people can perceive on smartglasses. Is it feasible to design smartglasses applications with today's commercial platforms? What kinds of stimuli (text, shapes, colors) could low vision people see, if at all, on such platforms?

We conducted a study [14] with 20 participants with low vision (9 male, 11 female, mean age=45), evaluating their ability to see virtual elements on the Epson Moverio BT-200 glasses [2]. We used the Epson Moverio glasses because, by our assessments, they have advanced features for a consumer-grade device. Compared with Google Glass, for example, Epson Moverio glasses provide a larger projection area in the center of both the user's eyes, which makes them more versatile for people with different visual abilities.

The study consisted of one lab session where we assessed participants' visual perception of virtual objects on the smartglasses while they sat and walked in an office conference room. We displayed different sets of short phrases and shapes on a transparent background and varied their size, color, thickness, and, for text, font faces. We did this by varying one parameter as we held the rest constant. Participants identified randomly selected stimuli with the given parameters. After presenting the set of stimuli, we reviewed participants' performance and sought their feedback on their preferred parameters for short phrases and shapes.

Figure 1. Actual stimuli presented on smartglasses in our study, shown over dark (top) and light (bottom) backgrounds. The triangle and a short phrase are shown in the different colors used in the study. In addition to color, we also varied the stimulus size, thickness, and font face (for text).

On a high level, we found that people with low vision can benefit from commercial smartglasses. Participants identified the projected shapes and read short phrases while sitting and walking. While all participants could comfortably recognize shapes, only participants with mild to moderate low vision were able to comfortably read the short phrases.

We were pleasantly surprised with these findings, which indicated that there is much potential for designing smartglasses applications that use shapes and even text to augment people's vision. Text and shapes are basic visual output elements that can convey a wide variety of information in different contexts. For example, distant signs or nearby small text can be made accessible by displaying it on the smartglasses. Similarly, simple shapes like arrows can be used to provide guidance in navigation applications. Of course, our study only examined one smartglasses platform in a well-lit office environment with mostly white walls. However, our findings suggest that accessibility smartglasses applications may be feasible with today's technology.

Designing Novel Smartglasses Applications for Low Vision

As we found in our navigation and shopping study, certain daily tasks were not supported by existing low vision tools. Participants had difficulty with *visual search*, finding a known target among a set of distractors. Visual search tasks are common in our daily lives: people search for a friend in the crowd, the bathroom sign in an airport, or a certain word in a document. An example of a visual search task from our study was searching for the specified product on the store shelves. Low vision people could use a magnifier to see the details of each product, but no tool was available to help them quickly scan the shelves and recognize the desired product.

We designed *CueSee* [15], a video see-through smartglasses prototype to address product search for low vision people. CueSee located a specified product with computer vision and presented visual cues to direct the user's attention to the product. A cue that a sighted person can easily see (*e.g.*, a red dot) may be outside a low vision user's field of view or may not have sufficient contrast with the background for a low vision user. We thus designed the cues for different low vision conditions [1,17], based on cognitive psychology theories on attention [6,13]. The visual cues included: *Guideline*, *Spotlight*, *Flash*, *Movement*, and *Sunrays* (Figure 2). In addition to the cues,

Figure 2. **Visual cues in CueSee, a product search smartglasses system with five visual cues that guide the user's attention to the target product. CueSee was implemented on video see-through smartglasses and evaluated in a lab study with the mock grocery store shelf shown here** [15].

the system enhanced the target product with magnification and increased contrast to help users read the product information.

We explored the effectiveness of the cues in the product search context in a laboratory study with a mock grocery store shelf (Figure 2). We recruited 12 low vision participants with different visual conditions. Our results were promising: all participants found products significantly faster with CueSee than with their best-corrected vision. Moreover, participants did not make a single error (picking up an incorrect product) with CueSee. They had a variety of cue preferences: people with mild low vision preferred Guideline and Spotlight, while people with moderate to severe low vision preferred Flash and Sunrays. None of the participants liked Movement. While it attracted their attention, they felt this cue hindered their ability to see the product (which they wanted to be able to do).

The initial CueSee prototype was implemented on a *video see-through* display (an Oculus Rift with a web cam attached), unlike the perception study describe above which used an *optical see-through* display. Optical see-through displays tend to be lighter and more portable, designed for use in mobile scenarios. Moreover, they don't cover the user's eyes or cause disorientation. We plan to implement CueSee on optical see-through glasses, improve the cues with further studies, and add support for a variety of visual search tasks.

Conclusion

Studying low vision has been a fascinating and challenging journey. Unlike blindness, low vision manifests in different forms and degrees of severity. Visual perception is complex, and people's vision can change depending on the time of day, their task, and their environment. People with low vision often don't identify as "disabled" and don't necessarily associate with an advocacy or service organization. Sadly, many lose their sight as they age and view their condition as a medical problem that cannot be treated, rather than a disability they can overcome. Recruiting low vision users and understanding their experiences and visual abilities has thus been an interesting challenge. Similarly, we have also found it difficult at times to describe our work to researchers in the community. While low vision tools exist, there are many exciting open research problems that could significantly impact people's lives; simple tools like optical and digital magnifiers help many people, but they are not a one-stop solution for low vision. We hope you will join us in exploring new solutions for this large and growing population.

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References

1. AOA (American Optometric Association). Common Types of Low Vision.
2. Epson. Epson Moverio™ BT-200 Smart Glasses (Developer Version Only) - Product Information - Epson America, Inc.
3. JA Jacko and A Sears. 1998. Designing interfaces for an overlooked user group: considering the visual profiles of partially sighted users. *Proceedings of the third international ACM …*. Retrieved July 5, 2015 from http://dl.acm.org/citation.cfm?id=274512
4. Lighthouse International. All About Low Vision. Retrieved July 17, 2015 from http://www.lighthouse.org/about-low-vision-blindness/all-about-low-vision
5. S. Mann. 1997. Wearable computing: a first step toward personal imaging. *Computer* 30, 2, 25–32. http://doi.org/10.1109/2.566147

6. Peter McLeod, Jon Driver, and Jennie Crisp. 1988. Visual Search for a Conjunction of Movement and Form is parallel. *Nature* 336, 403–405.
7. TLB Pape, J Kim, and B Weiner. 2002. The shaping of individual meanings assigned to assistive technology: a review of personal factors. *Disability and rehabilitation*. Retrieved July 5, 2015 from http://www.tandfonline.com/doi/abs/10.1080/09638280110066235
8. Betsy Phillips and Hongxin Zhao. 1993. Predictors of Assistive Technology Abandonment. *Assistive Technology* 5, 1, 36–45. http://doi.org/10.1080/10400435.1993.10132205
9. JS Schiller and JW Lucas. 2012. Summary health statistics for US Adults: National health interview survey, 2010. *... National Health Survey*. Retrieved July 17, 2015 from http://europepmc.org/abstract/med/22834228
10. Kristen Shinohara and Jacob O. Wobbrock. 2011. In the shadow of misperception. *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*, ACM Press, 705. http://doi.org/10.1145/1978942.1979044
11. Sarit Szpiro, Yuhang Zhao, and Shiri Azenkot. 2016. Finding a Store, Searching for a Product: A Study of Daily Challenges of Low Vision People. *The 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp'16).*, ACM New York, NY, USA.
12. VisionAware. Low Vision and Legal Blindness Terms and Descriptions. Retrieved September 22, 2014 from http://www.visionaware.org/info/your-eye-condition/eye-health/low-vision/low-vision-terms-and-descriptions/1235
13. Steven Yantis and John Jonides. 1990. Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance* 16, 1, 121–134.
14. Yuhang Zhao, Michele Hu, Shafeka Hashash, and Shiri Azenkot. 2017. Understanding Low Vision People's Visual Perception on Commercial Augmented Reality Glasses. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, ACM Press, 4170–4181. http://doi.org/10.1145/3025453.3025949
15. Yuhang Zhao, Sarit Szpiro, Jonathan Knighten, and Shiri Azenkot. 2016. CueSee: Exploring Visual Cues for People with Low Vision to Facilitate a Visual Search Task. *The 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp'16)*, ACM New York, NY, USA.
16. What You Need to Know About Low Vision - American Foundation for the Blind. Retrieved July 19, 2015 from http://www.afb.org/info/low-vision/living-with-low-vision/23
17. What Causes Low Vision? Retrieved February 11, 2016 from http://www.aoa.org/patients-and-public/caring-for-your-vision/low-vision/what-causes-low-vision?sso=y
18. OrCam - See for Yourself. Retrieved June 18, 2015 from http://www.orcam.com/

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