Readful-U: Improving Reading Experience and Social Interaction for Low Vision Elders

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Abstract
Low vision seriously impede people from performing daily tasks especially reading. Readful-U is a mobile application with an attachable stand that helps people with low vision to read easily. It mainly targets the elderly patients since they are the primary group affected. Furthermore, users will be engaged in wider social interactions through inviting people to read for them. Built on current reading assistant technologies, Readful-U steps into the blank space to make audio assistance a vivid interaction between people rather than with a machine generated voice. The user-centered design process is featured with parallel design, primary user research, contextual inquiry, prototyping, user testing and iteration. Going beyond the common functions of current reading assistant devices, Readful-U specially caters for the emotional and social needs of low vision patients in an innovative and cost-effective way.

Author Keywords
Low vision; mobile application; assistive technology; emotional well-being; social interaction, user-centered

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Figure 1 – Building an affinity wall to analyze user interview results

Figure 2 – Current assistive technologies for people with low vision

Introduction

Low vision is a condition characterized by a level of vision that is 20/70 or worse (while perfect vision is 20/20, and legally blind is 20/200), and that cannot be fully corrected with medical treatment, surgery, or conventional glasses [11]. Low vision can occur at any stage of life, but it primarily affects the elderly [1]. Nearly 14 million Americans suffer from low vision [5], but they gain much less social awareness than the blind. As vision deteriorates, those affected often find it difficult to accomplish the tasks of everyday life, such as reading, recognizing faces, cooking, driving, and differentiating colors [6]. Among those challenges, reading is the most common complaint and primary goal [2] [4]. Adults with low vision that cannot read, lose a primary connection to the world [10].

Our goal is to help people with low vision to read more easily through a cost-effective solution. Moreover, we want to make "reading" a bridge to connect users with friends, family, and the society. To achieve our goal, our team conducted user interviews, created personas, built low-fidelity and high-fidelity prototypes, and set up usability testing. In addition to reading assistant functions, the application allows users to invite friends, family and even strangers to read for them, creating unique versions of audio contents together. Readful-U reduces cost by utilizing smartphones owned by most users, and boosts social interactions through widely engaging people to care and support the low vision group.

Preliminary Research

To learn more about our target users, we attended support groups at Kellogg Eye Center, University of Michigan. We listened to discussions of 20 low vision patients aged 50 to 85. We mingled with 8 patients to ask questions concerning the problems they face and the assistive devices they use. To understand patients thoroughly, we also talked to the coordinator of the low vision support group, five interns at Kellogg Eye Center, and one social worker assisting in the support group.

It is uncovered that, although suffering from various levels of vision loss, patients are facing common difficulties such as reading, mobility, and color differentiation. High-end assistive technologies are often unaffordable, but surprisingly, most of patients are proficient in using smartphones. Mental status has prominent impact on adaption to life with low vision. Family and friends can motivate them to stay strong.

Contextual Inquiry

We conducted one-hour video-recorded interviews with four patients. Based on our interviews, we built an affinity wall (See Figure 1) to identify the needs and expectations of users. We discovered the followings:

1. The most mentioned problem is reading. When their vision starts to deteriorate, the first primary activity affected is reading.
2. Various current reading assistant devices used provides three major functions:
    - **Magnifying:** Text in larger font size is easier to read.
    - **Switching to higher color contrast:** For example, people with low vision often find that yellow or white texts on black background is easier to see than black texts on white paper.
    - **Transferring text into audio:** For people with severe vision loss, they may need the device to read texts aloud for them.

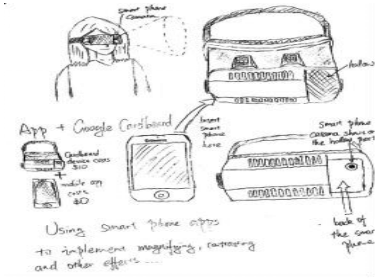

Figure 3 – Smartphone is inserted in a semi-open Google Cardboard headset (the back camera of the smartphone is not covered). The main camera serves as people's eyes. The screen displays the image into two, one for each eye, simulating a full-view magnified view of the image.

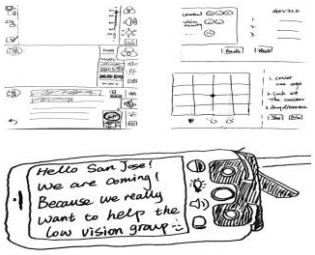

Figure 4 – A mobile application that combines both magnifying by utilizing the back camera and changing color contrast functions. Moreover, once the stand is plugged in, the mobile app will launch automatically.

3. Users prefer portable devices. As elders, all four patients use smartphones routinely. They use smartphones to magnify words on papers or to listen to audio books. They do not consider smartphones extra devices for low vision issue.
4. People with low vision often feel frustrated when they fail to perform simple tasks. Severe frustration could lead to suicide. Most of these elder patients live independently and far away from their children. They have strong emotional and social needs.

Parallel Design of Three Solutions

After identifying the problems related to reading, we visited Doctor Sherry H. Day at Kellogg Eye Center and learned about current technologies and devices that helps low vision patients read (See Figure 2). Those devices are either too limited in functions or too expensive. None of them are utilizing smartphones, devices already owned by most patients. Therefore, we decided to utilize smartphone to develop our solution.

We implemented parallel design, as it is more divergent and effective than serial design [3], and came up with three possible solutions to assist reading. We evaluated each of them with selected users and finalized to one that best achieves our goals.

1. **Design 1:** A virtual reality application that works with Google Cardboard (See Figure 3)
   - **Evaluation:** Although a Google Cardboard generally costs less than $5, the headset requires a wireless remote to control the mobile application. In addition, from feedbacks for "eSight", an eye-wearing product we met in support groups, people may feel uncomfortable wearing such products. Therefore, this solution was voted out.

2. **Design 2:** A mobile application with an attachable stand (See Figure 4)
   - **Evaluation:** A mobile application provides huge flexibility. There are several existing hardware on a smartphone, such as flash light and audio jack, so further functions can be developed without much additional costs. This one was kept as the base of our final design.

3. **Design 3:** A hand-held smartphone case that turns the smartphone into an electronic magnifier (See Figure 5)
   - **Evaluation:** The handhold case fails to free people's hands and its shape makes it inconvenient to carry. Therefore, this solution was also out.

Concept Design and Wireframes

After narrowing down solutions, we sketched out the desired functions based on previous findings. Here are two main functions of our application:

1. **Magnification, color-contrast switch and machine generated audio:** The smartphone serves as an electronic magnifier. Users use multi-touch gestures to control the level of magnification; they can also change color combinations. In dim environment, the flashlight is employed to illuminate the paper. With the supporting stand attached, the application automatically adjusts the image perspective to align with the screen. If audio is demanded, users only need to take a picture of the page. Then our

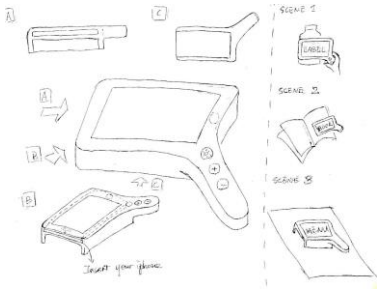

Figure 5 – Smartphone can be fit into a hand-held case, then use the back camera to receive a magnified image on the screen.

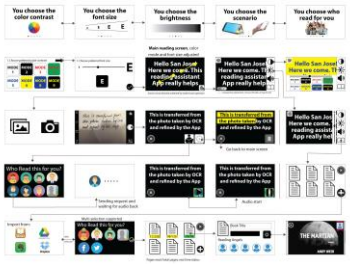

Figure 6 – Wireframe to map our main functions

application will generate audio output of the contents through Optical Character Recognition (OCR) technology [9].

2. **"Read for me" social interaction:** It enables users to send reading requests to friends and family asking them to read contents. The request receiver could respond by sending back voice messages without downloading the App. This function could address urgent needs or objects that are hard to be processed by OCR.

The "read for me" function exhibits the core value of our design: caring for the emotional and social needs of users. Emotional side of design may be more critical to a product's success than its practical elements [8]. Research shows that people with low vision have a higher probability of feeling sad and tearful, having less hope, and wishing for death [7]. By designing "read for me" function, we aim to bring users closer to their family and friends, and boost wide social interactions.

We then created wireframe to depict the screen layout and flow of the application (See Figure 6). Based on our interviews with patients, we created personas and storyboards to illustrate how our application assists our target users in reading and improves their emotional well-being.

Low-Fidelity Prototype with User Testing

We built a low-fidelity prototype to test the following aspects of the application (See Figure 7):

1. Ease of understanding and use of the design
2. Whether elements are clear to see. For example, whether the buttons are big enough or whether the color use is appropriate
3. The effectiveness of the functions we provide to help low vision patients.
4. Any gaps may exist between user expectations and the application functions, and whether concepts behind "read for me" is clearly conveyed.

We invited 4 patients with low vision and 2 family members to participate. We assigned them tasks including presetting, magnifying and changing color settings, voice reading, and social interactions, and asked them to give feedbacks anytime during the process. We observed their interactions with the prototype and documented important findings:

1. Users were happy that the application adjusts the image perspective, which makes them feel more like reading an actual book.
2. The effectiveness of changing color settings was astonishing. Changing normal materials to white words / black background made words much clearer to see.
3. Some functions were confusing, such as why the audio button leads to taking photos.
4. Users thought the "read for me" function as a shining point. They felt their emotional needs were taken into consideration in the design. They hoped to get more direct access to that function since it was hidden in a submenu under audio and library.

Abiding by user-centered design, these feedbacks helped us reassess and improve our design. Originally, if a user clicks the audio reading button, the application will direct the user to take or choose a picture of the paragraph first, and then read the texts. However, users may not understand the internal OCR

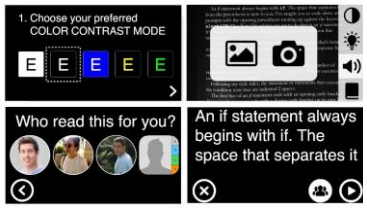

Figure 7 – Design of our low-fidelity prototype

Figure 8 – High-fidelity prototype with the supporting stand

process, so they wonder why a picture needs to be taken to play audio. To eliminate the confusion, we decided to run the picture taking in the background - once a user clicks the audio reading button, the application will take an instant picture automatically, and then read the texts. We also expanded the "read for me" function. We enabled users to make reading requests as public posts on social media such as Facebook and Twitter for higher social awareness, while previously we merely let them resort to people they know.

High-Fidelity Prototype with User Testing

After making these changes, we proceeded to digital prototyping. To meet the expectation of accessing the "read for me" unit more quickly, we upgraded the attachable stand. We designed two physical buttons on the stand - one could instantly trigger the reading requesting to friends and family, and the other gives direct access to Readful-U library collection (See Figure 8). We conducted another user testing session with 3 low vision patients and 2 family members. During the session, we focused more on the following aspects:

1. Design of the user interface and interactions, whether animation is distracting
2. Ease of use of the supporting stand
3. Feedback on the expanded "read for me" function

Users agreed that, in such a design for low vision patients, we should prioritize visibility of elements much higher than aesthetics. Through using enlarged buttons and simple high-contrast colors, the elements on the user interface are presented in the best way to help users locate them. They also found that, by using the stand, their hands were freed and neck was relaxed. They felt less tired and could read for a longer time. They told us that the physical buttons on the stand seemed to be easier to locate than virtual buttons on the touchscreen. When the supporting stand was attached, functions were easier to access.

Final Design

Users are provided a mobile application with an attachable stand (See Figure 9). When the stand is attached through USB port of the smartphone, the application automatically launches, saving users from finding the small app icon on the home screen. For the first-time use, users will go through presettings. Our application will remember their preferences on color contrast and font size. The application also allows users to change those settings during use. If users are reading with a faint light, flashlight will be activated to illuminate the contents. Users always have the audio option. They are free to select the App generated audio, or request other people to read. All received voice messages will be stored in the Readful-U library that can be easily accessed both through the App and the physical buttons on the attachable stand.

Integrated with the handy and widely embraced smartphone, Readful-U helps people with low vision read more easily. While current devices that provides similar functions usually cost thousands of dollars, our application and the supporting stand is absolutely affordable. More importantly, Readful U is featured with "read for me" function, encouraging low vision group to stay close to family, friends, and the society. Most vision loss is irreversible [5]. We cannot cure their vision, but we help them maximize the convenience and joy on what they can do. On the other side, the application reminds family and friends

Figure 9 – This image shows that, once a user's reading request is fulfilled by other people, he or she can access the audio file in the Readful-U library. Our final design focuses on improving reading experience for people with low vision as well as their emotional needs.

of the user's emotional needs, and offer them an effective way to express care by reading for the user. We believe our application will give low vision patients strength to face the vision deterioration and willingness to cope with new situations.

Conclusion

People with low vision are presented many assistive devices for reading, while their related psychological needs are seldom catered for. Our team designed a mobile application that not only helps users read better, but also encourages them to interact more with family, friends and the society. Readful-U makes reading a bridge to connect the low vision group with other people, rather than tie users to assistive devices. Through providing unique reading experiences, Readful-U addresses related emotional and social needs of users and will benefit their low vision rehabilitation as well as improve their life quality.

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