EyeR: Detection Support for Visually Impaired Users

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ABSTRACT

Lack of adequate support in navigation and object detection can limit independence of visually impaired (VI) people in their daily routines. Common solutions include white canes and guide dogs. White canes are useful in object detection, but require physically touching objects with the cane, which may be undesired. Guide dogs allow navigation without touching objects in the vicinity, but cannot help in object detection. By addressing this gap, employing a user-centric research approach, we aim to find a solution to improve the independence of VI people. Here, we began by initially gathering requirements through online questionnaires. Working from this, we build a prototype of a glove that alerts its users when an obstacle is detected at the pointed position; we call this *EyeR*. Lastly, we evaluated *EyeR* with VI users and found out that in use our prototype provides real time feedback and is helpful in navigation. We also provide future recommendations for VI prototypes from our participants, who would additionally like the device to recognise objects.

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Figure 1: Participant A detecting door opening with *EyeR* while walking.

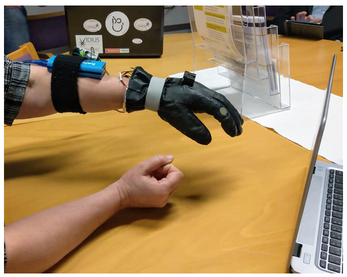

Figure 2: Participant B detecting an object on the table with *EyeR*.

Figure 3: Participant A detecting a floor lamp with *EyeR*.

KEYWORDS
Assistive technology; visually impaired; indoor navigation; object detection

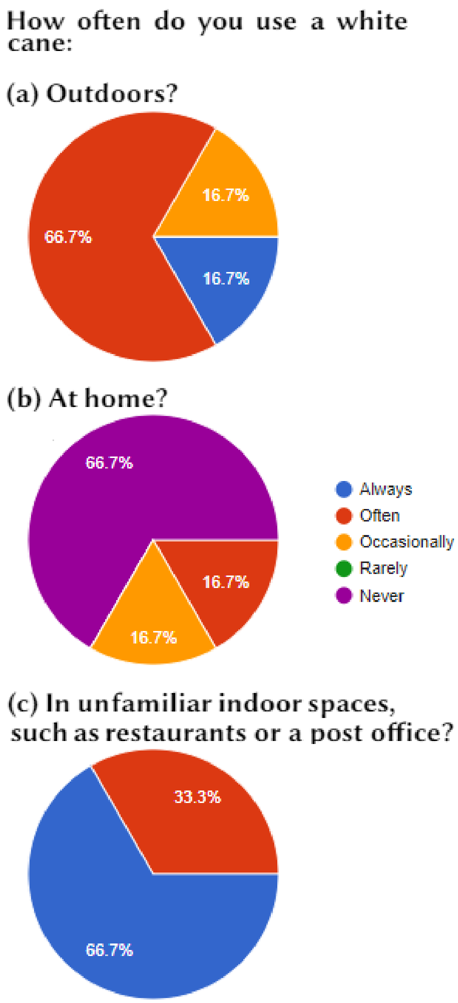

Figure 4: Questionnaire results to the question about how often participants use use a white in different places.

INTRODUCTION

The World Health Organisation predicts that 1.3 billion people live with some form of visual impairment. Whilst for digital content best practises have been put in place for accessibility there are few technical systems to support Visually Impaired (VI) users in everyday life. One of the main areas of interest to support VI users is to develop mobility aids which supplement a remaining sense for vision by transforming visual information into another sense. Currently the most common methods to avoid obstacles in navigation utilised by VI people are white canes and navigation dogs [3], which have some shortcomings, e.g. guide dogs can get distracted and white canes are inconvenient to use in crowded places [4, 8]. To make up for these fallacies, technology systems for detecting objects without touch and indoor navigation have been investigated, such as technologies with auditory [5, 10] and vibration [2, 5, 7, 9] output.

Auditory display were found to be inconvenient in noisy situations and with its continuous feedback may cause distraction and annoyance; while prolonged vibration can result in fatigue or pain and make users lose sensation [2, 5, 9]. Yet, these findings report and VI people indicate, that this group of users rely heavily on their non-visual sense in not only navigation tasks but also in doing everyday functions. This includes the use of auditory senses such as echolocation, which should be taken into consideration in terms of usability of navigation systems. [2] There are also many needs of VI people that lack feasible support such as detecting salient obstacles [7].

In this paper, we delineate from prior work involving the end stakeholder (VI people) to give them more agency over the objects they use by designing with and for the participants in a User-Centred Design (UCD) approach. This study is conducted in three parts. Firstly, through an online questionnaire drawing from current literature to form an initial set of requirements. Secondly, from this we design a low-fidelity prototype called *EyeR*, a glove composed of affordable materials, such as an infrared (IR) sensor to detect objects and translates their position into vibration output. Thirdly, we evaluated the prototype with two VI participants on the affordances and the feedback mechanism of *EyeR*. The key contributions of this paper are the development of a prototype device with VI users and the initial set of requirements. In these steps it is important to note that our aim is not to replace current support methods, such as white canes, echolocation or guide dogs, but instead to develop novel devices to fill in the missing end-user requirements.

PART I: GATHERING REQUIREMENTS

To identify issues in current navigation aids we shared an online questionnaire [1] (also offered as an interview) with nine closed and nine open questions on multiple support groups for the VI via Facebook in March 2018. Our questions drew from the literature and focused on the current use of white canes outdoors and indoors, their advantages and limitations. The six participants age ranged

[1]Requirements Gathering Questionnaire. https://goo.gl/forms/8N7XVR4xHWp6jJLx2

Sidebar 1: Requirements gathered from previous work and online questionnaire.

R1. Object detection should work at distances above 30cm, since some users expressed the need and preference for that [1].
R2. Response time for output device should be within 1 second, since otherwise it was reported to cause users to lose the feeling of operating [6, 9].
R3. Feedback should not disturb user's auditory senses, e.g. to allow using echolocation [2].
R4. Precise object detection at short distances, since indoor areas may be relatively small.
R5. Detection of objects at various heights.
R6. Object detection without touch to avoid knocking or hitting objects.
R7. Provide feedback only upon user's request to avoid discomfort due to prolonged use.

from 10-51. Two respondents were visually impaired from birth, one lost their vision between 11 and 15 years old, and three during adulthood. All informants were unable to navigate independently in unfamiliar spaces and had experiences with using a white cane.

The types of help used in navigation reported by participants include: assistance from a sighted person, a white cane, a guide dog and passive and active echolocation. Assistance at home was frequently mentioned as unnecessary as in these spaces the layout and object placement is known. Nonetheless, participants reported that detecting where people might be standing or whether a furniture or item was moved can be challenging even in these home environments. One person reported to use passive echolocation at home, and either a white cane or a guide dog in even familiar places if they are larger.

When asked about objects that are crucial to be detected participants reported: *"things overhead like shelves left open*, *"objects that are moved around"*, *"most larger objects, notably higher up (...), objects that are harder to hear with passive echolocation"*, *"things that you could knock over (or) break"*, hot drinks, doors and tables especially in unfamiliar situations.

Fig. 4 narrates our findings. These suggest that navigation in unfamiliar indoor places needs better support, since VI people are unlikely to navigate in them independently. White canes were praised for being great at detecting *"large objects sitting on the floor"*, *"simple to use"*, and notifying about *"dangerous situations such as stairs, (...) holes in the ground"*. They also hold advantages over guide dogs as they allow one to *"have a conversation with somebody else (...) and not have to tell the dog what to do"*. Apart for practical advantages, white canes were also reported to be *"useful in non-verbal communication to others"*, suggesting that they prefer to be recognised by others as visually impaired.

When asked about inconveniences with white cane devices used and anything that could be changed about these, three participants mentioned the same issue: white canes cannot be used to detect objects that are higher from the ground such as letterboxes, overhanging branches or (road) signs. Other usability issues include: tip of the cane frequently getting caught in cracks and cervices or other uneven surfaces, *"causing a halt, pain"*, hitting other people with a cane, and discomfort from prolonged use.

DESIGN OF *EYER*

Using the surrounding body of literature and the questionnaire we formed seven requirements for VI people (Sidebar 1). From these we built our prototype device for object detection coined *EyeR*. *EyeR* is a glove prototype which vibrates on a users wrists when an object is detected when a user directs the glove. We attached the device to a user's hand, to allow the user to freely adjust the direction and height at which an area to be examined is (R5). The main components of *EyeR* are listed in Sidebar 2.

In line with prior research to implement vibration, two vibration modes (*Speed* and *Pattern*) were used to provide different types of vibration given a distance from an object. To shape the interaction

Sidebar 2: Main components of *EyeR*.

Two important criteria in the choice of the components were the affordable price and mobility.

SHARP IR proximity sensor (GP2Y0A-02YK0F) is attached on the glove to detect objects from 20cm to 150cm (R1, R4, R6) and its latency is controlled under 300ms.

Shaftless vibration motor (POULU#1636) supports R3 and is attached to inner wrist.

Force sensitive resistor (FSR) serves as an on/off button at the the index finger to minimise the prolonged discomfort (R7) and prevent mistouch.

Arduino Uno board (A000066) was used to integrate the components being attached to the arm.

Table 1: Distance levels in *Speed* mode

Range (cm)	AV	Output
20 - 40	0	continuous
40 - 80	100	continuous
80 - 120	175	continuous
120+	255	none

Table 2: Distance levels in *Pattern* mode. The milliseconds (ms) values in *Output* indicate the length of vibration and pause in a pulse.

Range (cm)	AV	Output
20 - 40	0	continuous
40 - 80	0	100 ms
80 - 120	0	250 ms
120+	255	none

around the end-user, we left both modes for user testing to determine which is preferred. In the first mode, *"Speed"*, the intensity of vibration changes with the distance from the device to the detected object (Table 1). In the second mode, *"Pattern"*, vibration output pulses with the pulses getting shorter as the object gets closer (Table 2). *EyeR* prototype can be seen in Fig. 2.

To detect objects, IR was chosen. We initially tested ultrasonic proximity sensor but this did not give accurate results due to being sensitive to vibrations in the air and we were worried if these sounds could potentially be heard by guide dogs. We also considered attaching the device to the head, but the variety of heights at which objects can be detected may be more limited since the head typically has lower rotation capabilities than arm (R5). Whilst the design decisions discussed above are based on a small user group, there are later queried through the end users testing for validity.

PART II: USER TESTING

To evaluate the usability of *EyeR* we gave our device to VI participants to see how participants interact with and use the device, reflecting on our initial requirements (Sidebar 1). Participants were recruited through the Finnish Federation of Visually Impaired in Helsinki, Finland. Two VI people, a man (participant A) and a woman (participant B), aged between 40-60, volunteered to participate in our study. Neither participant can see objects within a short distance. Participant A uses a white cane to navigate whilst participant B mainly uses an assistance of a guide dog, and occasionally a white cane.

Procedure

At the beginning, participants were introduced to the concept with the main components and usage of *EyeR* being explained, and the two vibration modes (*Pattern* and *Speed*) introduced. This introduction was conducted by moving the participant's arm with the device on at a slow pace towards and away from an object. To test our initial requirements (R1, R4-R6) the first task was to try to detect typical items found at various heights that can not be detected with a white cane (R5).

The objects were two laptops with their lids open at an approximately 90° angle and a paper holder of size approximately 30cm x 40cm. After the required task, participants were allowed to test the device in free form within the building, to allow more daily and ordinary usage. At the end, a group interview was conducted to further investigate validity of original requirements. The interview questions were focused on the following topics identified in our initial requirements: current experience with navigation and object detection techniques; usability and usefulness of *EyeR*; and issues they experience in navigation and object detection that have no feasible support available yet.

The entire experiment took 2 hours, where each participant took approximately 15 to 20 minutes to test the device and the interview lasting 50 minutes. The participants' interaction with *EyeR* was video recorded for analysis. All forms were provided in text and audio format to support the participants disability, where both participants consented verbally.

RESULTS

Participant A in the first task successfully detected all objects on the table with *Pattern* mode. The participant was able to tell where an object starts and ends without touching the item, where there is no object, and whether an object was near or far (R1, R4-R6). In case of the *Speed* mode the ease of object detection was similar. However, participant A expressed that they preferred *Pattern* mode, as *"it is easier to think, for me, how far the obstacle is if I'm using the first type (pattern)"*. Participant A moved the arm that had *EyeR* attached at a significantly slower pace while keeping the arm and hand in parallel to the table and thus having no issues with detecting the objects. In contrast, Participant B moved their arm very quickly, often pointing at the table, which resulted in a constant feedback from the device as such they noted that *"it is difficult to separate table from objects"*.

We then explained how the IR sensor is angled relative to the hands direction and Participant B was able to detect objects placed on the table, as shown in Fig. 2. However, Participant B struggled to distinguish the distance with *Pattern* mode, reporting that *"it feels continuous"* and expressed preference of *Speed* mode, because it was not perceived to give constant feedback.

In the free-form testing, participant A voiced their enthusiasm in being able to detect whether the door in the room is shut or open. Participant A was also able to detect more objects, including a floor lamp (Fig. 3), and whether a chair is occupied or not. Participant A commented that the device *"reacts very quickly, changing the type of vibration (pattern)"* (R2), concluding that *EyeR* is *"an interesting idea"*. In case of *Speed* mode, Participant A tested detection of the door opening while walking (Fig. 1)not encountering any problems being able to almost immediately tell a wall from the open space. Participant B, walked around significantly faster resulting in while testing *Pattern* mode, bumping into furniture multiple times and not being able to detect the door opening. However, when the mode was switched to *Speed*, participant B was able to avoid obstacles more efficiently and detect the door opening while maintaining the fast pace.

Outcome of the free-form and tasks testing confirmed R1-R6. Participants were able to detect arbitrary objects that were higher from the ground level, above 30cm and within 1 meter distance, without physically touching them reporting that *EyeR* responds quickly and does not disturb their hearing. R7 could not be confirmed, because the on/off button was not used by the participants due to the short duration of the experiment and confines of the situation, however they did not report feeling discomfort caused by vibration.

In the interview participants agreed that *EyeR* works as described. Both noted that the main strength of *EyeR* is its speed in recognising objects, but they expressed that detecting objects on a table with their own hands would still be easier and faster. They described that currently to avoid knocking objects they tend to place a hand on a table and move it around slowly.

Sidebar 3: Scenarios of usage based on suggestions from VI participants.

1. Avoiding objects on head-level, e.g. low ceiling lamps or open doors of higher cabinets.
2. Recognising small objects, e.g. differentiating dropped coins from the floor or distinguishing between products with similar packages.
3. Saving points of interest in unfamiliar places, e.g. identifying location of a toilet at a cocktail party or detecting borders of a swimming pool.

DISCUSSION AND FUTURE WORK

Each vibration mode was favoured by a different participant and performed better in certain cases: *Speed* can ensure accuracy while moving at a fast pace yet the distinguishing between different distance levels requires more practice. On the other hand, *Pattern* has more precise distance differentiation although its feedback is not as fast as *Speed*. This suggests that *EyeR* needs to allow for personalisation, including integrating two types and customising the vibration levels in an environmental-aware manner. Although *EyeR* is currently capable of detecting objects accordingly there were also some limitations in our initial requirements and design decisions, discovered through user testing. Concepts moving forward are described in Sidebar 3.

CONCLUSIONS

In this paper we present *EyeR*, an assistive device designed from a user-centred perspective to support visually impaired (VI) people in object detection and indoor navigation. We used questionnaires to gather seven requirements in which VI participants identified various opportunities for technological support. From these we built *EyeR*, tested our prototype with two VI volunteers, who found that the device allowed them to easily detect objects higher than the ground level. *EyeR*'s main strength was found to be its quickness in detecting obstacles, making it useful for navigation. However, hands were still considered more efficient than *EyeR*, thus more iterations are required to improve our prototype.

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