Exploring Interface Design for Independent Navigation by People with Visual Impairments

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ABSTRACT
Most user studies of navigation applications for people with visual impairments have been limited by existing localization technologies, and appropriate instruction types and information needs have been determined through interviews. Using Wizard-of-Oz navigation interfaces, we explored how people with visual impairments respond to different instruction intervals, precision, output modalities, and landmark use during *in situ* navigation tasks. We present the results of an experimental study with nine people with visual impairments, and provide direction and open questions for future work on adaptive navigation interfaces.

Categories and Subject Descriptors
K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities.

Keywords
Non-visual navigation, interface design, visual impairment.

1. INTRODUCTION
People with visual impairments have unique navigation strategies, spatial understanding, and information needs. Prior work has examined navigation systems for people with visual impairments [5]; however, most studies focus on the effectiveness of a single system, and do not provide interface alternatives for users to choose amongst. Other work has explored the information that people with visual impairments desire while navigating independently [1, 4]; but these studies relied on interview data instead of exploring different navigation interfaces in practice.

To bridge the gaps between these related works, we performed experimental evaluations of navigation interfaces with nine users with visual impairments. We used Wizard-of-Oz design, where a human *wizard* triggered navigation commands by hand (instead of via automation) as the user reached specific landmarks or needed to make path adjustments. The Wizard-of-Oz design allowed us to test multiple interfaces in practice in a low-cost, flexible way.

2. RELATED WORK
There are differences in how people with visual impairments and sighted people perceive and understand spatial information. People with visual impairments can learn spatial information via audio or tactile cues in the environment, but their spatial understanding is not complete [2], and route-based, turn-by-turn instructions are more useful for them, while overhead, birds-eye descriptions are more useful for sighted people [3].

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Both research and commercial tools have been built to provide navigational instructions for people with visual impairments. These tools often use localization techniques to direct the user to a target [5]. But studies of these navigation tools often focus on the efficacy and ease-of-use of a single tool, rather than comparing two or more interfaces to find the best way to present information.

Many features of navigation interface design have been explored through interviews with people with visual impairment, including how they choose navigation aids [4] and their information needs during navigation [1]. However, these interview studies explore participants' high-level reflections on navigation, rather than their immediate reactions of how well different interfaces would work in real scenarios. We collected *in situ* experimental observations to complement and contrast findings from these interview studies.

3. EXPERIMENTAL DESIGN
We created a total of 14 interface variants: 13 interfaces testing navigation components (walking in direct paths, turning, and walking without veering), and one landmark-based interface. We tested interfaces with a mixture of output modalities (speech, non-speech audio, haptic), information specificity and frequency, and location. These features were chosen with input from one of the authors, who is totally blind, and a local O&M instructor. The 14 interface variants are described in more detail in Table 1.

For each interface variant, the participant wore bone-conduction headphones which played navigation instructions (except for the haptic interface, where participants wore mobile phones in armbands which vibrated directionally). A researcher serving as the *wizard* walked behind participants as they navigated through a university campus, manually triggering each command as participants passed landmarks or needed to course-correct.

After each navigation task, we asked participants to rank the ease of using the interface on a 10-point Likert scale, in order to explicitly compare the interfaces and prompt discussion. Between each set of interface types and in a closing interview, we asked participants for reflections on the different interface features.

4. RESULTS
Nine participants with visual impairments were recruited through personal connections and local organizations to test these interface variants. We sought participants with a variety of ages (from 22 to 73, avg. 54), genders (four female), and levels of vision (four totally blind, three legally blind, and two low-vision). Two had confounding hearing impairments, and one had cerebral palsy. Average ease-of-use Likert scores are shown in Table 1.

Interval and Specificity of Feedback: There was no consensus among participants about the appropriate feedback intervals. Four participants wanted as many instructions as possible during direct path navigation, to get continuous feedback that they were on the right path; two others preferred as few as possible to avoid missing ambient noises that provide clues about their environment. Intervals mattered more as participants approached a waypoint or destination; five participants wanted fixed

ID	Navigation	Modality	Output Type	Interval/Specificity	Location	AVG	STD.
1	Direct Path	Speech	*"50 feet to door"*	Every 10 feet	Indoor (empty)	**8.17**	1.70
2	Direct Path	Speech	*"40 feet to door"*	Every 20 feet	Indoor (empty)	**8.17**	1.27
3	Direct Path	Speech	*"30 feet to door"*	Every 30 feet	Indoor (empty)	7.00	**2.06**
4	Direct Path	Speech	*"30 steps to door"*	Every 10 steps	Indoor (empty)	7.28	1.68
5	Direct Path	Speech	*"20 steps to door"*	Every 20 steps	Indoor (empty)	7.33	1.87
6	Direct Path	Sonification	Fast clicks	1 click / second	Indoor (empty)	7.00	1.98
7	Direct Path	Sonification	Slow clicks	1 click / 2 seconds	Indoor (empty)	6.83	1.71
8	Veering	Speech	*"Move slightly right"*	N/A	Indoor (trafficked)	**8.17**	2.09
9	Veering	Sonification	Clicks on left or right	N/A	Indoor (trafficked)	6.50	2.32
10	Veering	Haptic	Vibration on left or right	N/A	Indoor (trafficked)	7.39†	**2.75†**
11	Turning	Speech	*"Turn to 11-o'clock"*	Clockwise	Indoor (trafficked)	**7.11**	**2.26**
12	Turning	Speech	*"Turk left 15 degrees"*	Degrees of turn	Indoor (trafficked)	5.28	1.89
13	Turning	Speech	*"Turn slightly left"*	Verbal	Indoor (trafficked)	6.72	1.64
14	Landmarks	Speech	*"This corridor is a wide area. The floor will be carpeted when you get closer to the door."*	At each landmark, (e.g. doors, stairs, railings, changes in floor type)	Both indoor areas, stairwell, lobby, and an outdoor quad	N/A	N/A

Table 1. Interface designs with average ease-of-use scores. Highest average score of each navigation type is bolded.
† *Two scores not given for haptic veering.*

instructions 5 or 10 feet before each point of interest, regardless of their preferred frequency for other instructions.

Exact specificity was not necessarily useful for participants. For turns, eight participants preferred clockwise or verbal instructions over degree of the turns, which were exact but took too long to parse. For long paths, an exact distance may be needlessly precise:

If I'm far away from something and it told me to walk 1400 steps, I would have no concept of how far it wanted me to go. (P6)

Modality of Feedback: All participants preferred speech for path navigation, finding it more distinguishable, more informational, and less distracting than non-speech, though tradeoffs existed:

The plus is, you don't have to think, you just listen to the beeps. But the minus is, you can't get a picture in your mind how far you're going to have to go. (P1)

Only two participants preferred vibrational interfaces over sound-based interfaces for veering, and both had some level of hearing impairment, which may have influenced their preferences.

Landmarks: While participants found many of the landmarks useful, some participants had trouble hearing all the landmarks as they tried to follow complex instructions while simultaneously dealing with surrounding noise from construction equipment and passing groups of conversing students. Though the information was valuable, the actual number of instructions received at any point may have been overwhelming and hard to keep track of.

5. DISCUSSION

Interviews with the participants revealed a variety of other information needs and how they could be used for navigation.

Seven participants said exploratory information about their surroundings, such as announcing which cross-streets they were currently between or what shops they were passing, could be useful for navigating to a target and confirming that they was on the correct path. However, five mentioned it would also be useful to announce important indoor locations, such as elevators or bathrooms, which may not be part of their route but would make the path easier to complete independently without asking for help.

Five participants mentioned that different levels of instruction are needed in familiar and unfamiliar spaces, also noted in prior work [1]. But many stated that familiar spaces can become unfamiliar due to obstacles, pedestrians, or environmental changes (snow in winter, outdoor café tables blocking a sidewalk in summer). While applications can offer different instructions for familiar and unfamiliar spaces, the definition of *familiar* should remain flexible, accommodating sporadic obstacles and other changes.

While participants had different preferences among the interfaces, all desired more information than was currently available to them. Even when they disliked an interface design, they felt the information provided could be useful. While she did not like using the step-counting interface, P7 still ranked it a 4, saying:

It's a little bit of help, so I'm not going to say it's a 1. (P7)

6. CONCLUSION

Navigation interfaces for people with visual impairments must be designed with appropriate flexibility, adaptability, and feedback. In this poster, we present the results of a user study with nine participants, exploring 14 experimental navigation interfaces. Though no specific interface emerged as perfect for everyone, participants identified a number of suggestions and criticisms, which we plan to distill into design recommendations and explore in a follow-up study with an adaptive navigation interface.

7. REFERENCES

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