Stated Preferences for Components of a Personal Guidance System for Nonvisual Navigation

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Abstract: This article reports on a survey of the preferences of visually impaired persons for a possible personal navigation device. The results showed that the majority of participants preferred speech input and output interfaces, were willing to use such a product, thought that they would make more trips with such a device, and had some concerns about the cosmetic acceptability of a device and the use of a single or stereo headphone interface.

For almost two decades, collaborative multidisciplinary research on the problem of navigating without sight has, been conducted by researchers at the University of California-Santa Barbara (UCSB) and Carnegie Mellon University (CMU). Led by psychologist Jack Loomis at UCSB, the group includes legally blind geographer Reginald Golledge (UCSB); psychologist Roberta Klatzky (CMU); and a number of graduate students, postdoctoral fellows, and technicians who are associated with the various departments. In 2002, this group was joined by James Marston, a geography postdoctoral fellow whose interests lie in the areas of accessing information without sight in cue-poor environments and in enabling navigation via remote infrared auditory signage. The aim of this research has been twofold: (1) to conduct basic research on spatial perception, spatial cognition, and wayfinding in both visual and nonvisual domains (for an overview of this research, see Loomis, Klatzky, & Golledge, 2000) and (2) to design and develop a personal guidance system for travelers who are visually impaired (that is, those who are blind or have low vision) using the Global Positioning System (GPS) (Golledge, Klatzky, Loomis, Speigle, & Tietz, 1998; Golledge, Loomis, Klatzky, Flury, & Yang, 1991; Loomis, 1985; Loomis, Golledge, & Klatzky, 1998, 2001; Loomis, Golledge, Klatzky, Speigle, & Tietz, 1994). More information on the project is available at the project's web site, <wwwgeog.ucsb.edu/pgs/main.htm>.

The GPS was developed by the U.S. Department of Defense as a precise means of locating features of the terrain,

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vehicles, people, and other entities. A receiver on the ground, in the air, or on water receives signals from multiple satellites in space that convey the precise locations of the satellites at every moment. Using these positions, the receiver is able to compute a location with high precision. Sometimes, the technique of differential correction is used to enhance the precision of .localization, using signals from other receivers at fixed known locations. Differential correction permits the localization of a mobile receiver with an error that is often less than 1 meter, a value that makes GPS suitable even for travel by pedestrians.

The idea of using GPS to guide people who are visually impaired was first proposed by Collins (1985) and Loomis (1985). Since then, many projects, in addition to ours, have pursued the idea. Studies by other groups have included those by Brusnighan, Strauss, Floyd, and Wheeler (1989), Helal, Moore, and Ramachandran (2001), LaPierre (1993, 1998), Makino, Ishii, and Nakashizuka (1996), Petrie et al. (1996), and Talkenberg (1996), and recently there has been a proliferation of such projects reported on the web, in the popular media, and in announcements of products. Two commercial products are now being sold. VisuAide sells Trekker, a personal digital assistant (PDA) with voice output. Sendero Group and Pulse Data have developed and are now marketing the BrailleNote GPS, which uses a portable computer (PDA) with voice and/or braille output to provide accessible location information.

The practical result of our work has been the development of a series of research prototypes, all variants of the original UCSB Personal Guidance System (PGS). An early model was developed in 1993 and has been the basis for much of our experimental research since then. Prototype devices have included a laptop computer, GPS antenna and receiver, speech synthesizer, and assorted peripherals (Loomis et al., 1994), elements that are common to most of the guidance devices just mentioned. One difference was that we obtained high levels of accuracy of location using a differential correction signal that originated initially from a campus base station and later from a commercial supplier. Technological change in the GPS industry and the development of a more powerful wearable computer re-

Figure 1. The UCSB Personal Guidance System. This system has a head-mounted fluxgate compass. The GPS- antenna is shoulder-mounted, stereo headphones provide the auditory interface, speech access to the computer is via a microphone attached to the headphones, and the shoulder bag contains batteries and the microcomputer.

suited in considerable miniaturization so that the product could be carried in a shoulder bag (see Figure 1).

The survey

DESIGN

To further the development of a PGS, a telephone survey of persons who are visually impaired in the Santa Barbara community and the San Francisco Bay Area was designed to examine preferences for different types of possible navigation aids and for the components of a possible guidance system. As background information and possible discriminatory variables, some personal information was gathered, including visual acuity, reported pathologies, and the use of mobility or obstacle-avoiding devices. In addition, data were gathered on

- the frequency of learning new routes to familiar and new places
- self-ratings of proficiency in various travel skills and types of independent travel
- self-ratings of the difficulty of performing eight navigation tasks
- the type of information required to make a walking trip in an unfamiliar area and how that type of information was obtained
- preferred methods to assist with pretrip planning.

After these preliminary data were obtained, the participants were read the following description of a GPS-based personal navigation system:

> We are designing a navigational system for the blind and vision impaired that will give informed guidance throughout the environment. Perhaps you have heard of Global Positioning Systems (GPS) used in cars and other vehicles to produce a map or vocal output that tells people where they are and how to get to where they want to go. We are developing a system in which GPS is our locating and tracking component. This device uses the global system of satellites that circle the earth to pinpoint the location of the user. A computer receives a signal, plots your location on a database to pinpoint your location, and then computes a path to a selected destination and tells you how to get to it and what features are encountered on the route or near it. The device can tell you when to turn, what is around you, and how far it is to your destination.
>
> We want to develop this kind of system for people without vision to give them greater independence when traveling. Because we can't use the typical cartographic map display, we would like to get your opinion on the best ways to present information to a user, how best to input the necessary information to begin travel, and how best to give instructions or assistance while traveling.

Opinions were requested about various ways to input the destination and other information that would be required to start a trip and how best to relay the instructional information to the user. Finally, questions were asked about the perceived frequency with which users would travel in the future if this type of navigation device were to become available.

PARTICIPANTS

The participants were 30 persons who were legally blind, 24 men and 6 women (with a mean age of 48; *SD* = 16.2). Of the 30 participants, 21 had no useful vision (no perception or only light perception) and 9 could see some objects at arm's length and reported that they could see enough to avoid obstacles while traveling. Twenty-one could read braille, including 4 people with some vision. The etiologies of the participants' visual impairments varied: 10 had retinitis pigmentosa; 4 had retinopathy of prematurity; 4 had glaucoma; 3 had optic nerve damage; several had retinal blastomas; and others had macular degeneration, burns, brain tumors, and various other eye diseases. To avoid obstacles, 21 used canes, 7 used guide dogs, 1 used echolocation, and 1 used no assistive device. Because we were looking for reactions to possible interfaces that were different from traditional ones, we contacted a variety of people who had previous experience with a new device, the Talking Signs Remote Infrared Audible Signage (RIAS) system (Crandall, Brabyn, Bentzen, & Myers, 1999). Of the 30 participants, 24 had some experience with the RIAS system.

Results

PRELIMINARY MOBILITY, TRAVEL, AND SKILLS ASSESSMENTS

The survey first asked the participants to self-rate their mobility in several areas using a 5-point scale (1 = well below average, 2 = below average, 3 = average, 4 = above average, and 5 = well above average). The scaling procedure was explained and discussed with each participant before the participant answered any questions. The results are shown in Table 1.

The participants generally rated themselves well above average or above average on concepts, such as a sense of direction, independence of movement or mobility skill, knowledge of local street systems, and basic travel skills. Self-ratings dropped when they were asked about various well-recognized problems of traveling without sight, including the ability to deal with street crossings or intersections, to deal with unknown obstacle hazards, to learn routes to new places, and to take shortcuts. What was needed to deal with each of these problems (with the exception of street crossings) was real-time information about the travel environment and the route-two types of information that can be specifically incorporated into a PGS. (A PGS could provide only the names of intersecting streets and whether or not crossings were controlled by lights.)

Following up on the problem of relevant and timely access to information, the next phase of the survey focused on obtaining evaluations of how difficult it was for the participants to get information about new environments, including heading to a new destination, maintaining directional and orientation knowledge, and obtaining street names or place names. Again, a 5-point self-assessment scale was used. The results are presented in Table 2.

The participants rated knowing the current location, identifying nearby features, and obtaining guidance on turns and stops as the most difficult information to obtain. These results imply that a PGS system needs to be designed explicitly to provide this information.

Table 1
Participants' self-ratings of mobility.

Mobility task	Mean rating	Well below average (1)	Below average (2)	Average (3)	Above average (4)	Well above average (5)
General sense of direction	4.1	0	0	9	8	13
Independent travel	4.0	1	2	5	11	11
Local streets	3.9	0	2	8	10	10
Basic travel skills	3.8	0	1	11	11	7
Street crossings	3.5	0	5	12	7	6
Learning new shortest paths	3.5	2	2	10	12	4
Making detours around unknown hazards	3.4	0	3	12	14	1
New environment	3.3	0	4	13	12	1
Shortcutting	3.0	1	8	11	10	0

Note: Entries are the number of participants who gave the rating value.

The next phase of the survey concentrated on independent methods of pretrip planning. This aspect of travel is of fundamental importance to visually impaired travelers, for only the most confident and experienced travelers are prone to take novel walks, particularly in unfamiliar environments. The options to be considered included conventional tactile maps or speech-based information. Again, a 5-point self-assessment scale was used. The results are presented in Table 3.

The participants rated a pretrip virtual experience with a speech-based information system that outlined the trip and gave instructions on the lengths and num-

Table 2
Participants' self-ratings of difficulty in gaining access to information about new environments.

Type of information	Mean rating	Very difficult (1)	Difficult (2)	Neutral (3)	Easy (4)	Very easy (5)
Knowing which way to walk to the destination	3.2	1	12	3	9	5
Keeping track of the direction to the destination	3.2	1	8	9	8	4
Knowing which way you are facing	2.6	4	12	7	5	2
Knowing which street corner you are at	2.5	6	12	4	6	2
Knowing when and where to turn	2.4	2	19	5	3	1
Finding a new store or office destination	2.4	4	17	4	4	1
Learning about new bus-stop locations	2.0	8	15	5	2	0
Learning about new locations you are passing	2.0	7	18	4	1	0

Note: Entries are the number of participants who gave the rating value.

Table 3
Participants' ratings of methods to assist with pretrip planning.

Types of pretrip planning input	Mean rating	Very unacceptable (1)	Unacceptable (2)	Indifferent (3)	Acceptable (4)	Very acceptable (5)
Pretrip virtual experience ("talks" you through the route)	4.6	0	0	3	6	21
Auditory-tactile map (NOMAD)	4.0	0	3	4	14	9
Tactile map	3.2	2	9	5	9	5

Note: Entries are the number of participants who gave the rating value.

ber of segments, the number of turn angles, and the direction and angles of turns, as being very acceptable. They considered auditory-tactile maps, such as Nomad (Parkes & Dear, 1989), to be more acceptable than others and rated simple tactile maps as much less acceptable, although they still regarded such maps as acceptable devices.

TYPES OF INFORMATION NEEDED

Before we mentioned the navigation system, we collected data to determine what types of information the participants would need when making a walking trip to an unfamiliar area. The responses were categorized as follows (the numbers refer to the number of mentions of an item in the category, with multiple responses combined by the same subject):

- Landmarks (35): landmarks, obstacles, auditory and sensory cues, surface and tactile cues.
- Street information (26): the names and number of streets to cross, traffic and crossing information, side of street, and sidewalk information.
- Route information (26): paths and routes, travel directions, cardinal directions, how far and long.
- Destination information (14): address, corner, and block information.
- Building information (8): names and layout information on doors and entrances.
- Transit information (7): transit information and stops and route information. (Note: The question focused on a walking trip, but some participants wanted transit information. This is important information that a good navigation system could provide.)

When asked how they normally got this kind of information, almost all the participants stated that they asked others for information, with only a few indicating they could search for and find relevant guidance information independently.

PREFERRED TYPE OF INPUT FOR A PGS

The survey next asked the participants to express their preferences for selected input interfaces to a navigation device, including speech, a QWERTY keyboard, a telephone keypad and a braille keypad. A 5-point scale was used. The results are presented in Table 4. The question used to obtain reactions in this section was, "How would you like to input your destination, such as `Go to 1234 Main Street' or `Go to the closest bus stop for line 11?'"

Table 4

Participants' ratings of preferences for inputting a destination.

Types of en-route input	Mean rating	Very unacceptable (1)	Unacceptable (2)	Indifferent (3)	Acceptable (4)	Very acceptable (5)
Voice input	4.8	0	0	0	6	24
Standard telephone keypad	3.7	2	4	6	8	10
Miniaturized regular QWERTY keyboard	3.4	0	7	8	10	5
Portable braille keypad	3.1	2	12	4	6	6

Note: Entries are the number of participants who gave the rating value.

The preference for voice input was strong (all 30 participants rated it very acceptable or acceptable). No one was indifferent or negative about speech input. A surprising finding was that a braille keyboard for inputting was rated indifferent or unacceptable by 18 participants. To clarify the impact of nonbraille users on this count, we broke down the participant group into braille and nonbraille users. Of the 21 braille users, 11 rated a telephone keypad as very acceptable or acceptable, 12 rated a braille keypad as very acceptable or acceptable, and 8 rated a QWERTY keyboard as very acceptable or acceptable (all other answers were indifferent or unacceptable). Of the 9 nonbraille users, 7 rated a QWERTY keyboard as very acceptable or acceptable; 7 rated a telephone keypad as very acceptable or acceptable; and, as expected, all 9 nonbraille users rated a braille keypad as unacceptable.

PREFERRED TYPES OF OUTPUT FOR A PGS

The defining question in this section was, "How would you like to get your travel instructions?" Having obtained some reactions to different styles of inputting destination information, the survey next examined how the participants would like to receive their travel instructions (i.e., output information). Because the list of alternatives included some that the participants might not have known or previously experienced, the participants were asked to respond on the basis of how they thought they might like such a product to be. Specifically, the instruction given was this:

> Some of these devices will give route information, and others will also give directional cues to locations. If you are not aware of some of these devices, try to respond by telling us how you *think you* would like such a product to be.

The list of output alternatives for route and spatial language information included options for locating the output device (such as head-, shoulder-, neck-, or collar-mounted devices that could host speech or sound or tactile displays or braille) (see Table 5). The second part of this question offered more specific alternatives for receiving guidance information (see Table 5). Again, a 5-point scale was used.

The most acceptable output device was a collar-or shoulder-mounted speech or

Table 5
Participants' preferences for output features.

Types of output	Mean rating	Very unacceptable (1)	Unacceptable (2)	Indifferent (3)	Acceptable (4)	Very Acceptable (5)
Route and spatial language information						
Clip-on shoulder- or collar-mounted small speaker to get directions via speech or sound	3.8	0	7	2	12	9
Speech via headphones worn near the ears (bone phone)	3.7	0	6	4	13	7
Single headphone worn over one ear	3.4	1	10	2	10	7
Tactile raised-dot display	2.8	4	10	6	9	1
Speech via small tubelike headphones worn in the ears	2.7	3	15	3	7	2
Braille output	2.6	5	14	2	7	2
Speech via headphones worn over the ears	2.1	7	17	3	3	0
Guidance information						
A small handheld device (the Talking Signs product) that identifies objects by speech and uses speech to guide you to the locations in the direction to which it is pointed	4.5	0	0	2	12	16
A small shoulder speaker for receiving relevant travel information and information about nearby objects and a small handheld receiver to scan for specific directional cues	4.0	0	3	3	15	9
Speaker on a collar with a wristwatch-type receiver to scan for specific directional cues	3.7	0	7	3	11	9
Speaker worn on a neck strap (like the Talking Signs product); you can also scan for specific directional cues	3.7	0	5	4	15	6
Speaker worn on eyeglasses; you can also scan for specific directional cues by moving your head	3.1	2	10	5	8	5
Headphones with stereo directional cues that produces an audio-virtual reality, since the speech appears to come from different locations in the surrounding space	2.7	2	16	5	4	3
An array of vibrating stimulators that are placed around the torso to give directional information	2.4	5	14	6	5	0
An array of vibrating stimulators that are placed around the neck to give directional information	2.3	5	15	6	4	0

Note: Entries are the number of participants who gave the rating value.

sound device. Judged as least acceptable were output via headphones worn over the ears and braille output. Again, however, this evaluation was partly the result of scaling by nonbraille users. When the data were split between braille and nonbraille users, the overall results were similar, except for the rating on braille output. Braille users gave a mean rating of 3.0 (indifferent) to a braille output interface, while nonbraille users gave a mean rating of 1.7 (unacceptable). Of the braille users, 9 out of 21 rated braille output as very acceptable or acceptable, while the rest were indifferent or rated it as unacceptable. All 9 nonbraille users rated braille output as unacceptable.

Those who had no vision had much stronger negative feelings about headphones that blocked ambient sounds than did those who had some useful vision. The proliferation of cell phones and wireless PDAs may change this perception in the future, but the value of good auditory environmental cues cannot be dismissed. Of the participants who were regular braille users, however, only 12 out of 21 rated braille input as very acceptable or acceptable, and only 9 out of 21 rated it that way as a preferred output device.

For devices that included extra directional cues, the participants rated speech or tonal sound output the most acceptable (Table 5). The top five preferred interfaces for gaining directional cues were all some type of pointing device, handheld, wrist-mounted, or attached to eyeglasses. As was noted previously, some participants had prior exposure to a RIAS system (Talking Signs), which may have affected their responses. Alternatives that were the least preferred included vibrating collars or bands on the neck or the torso that produced a localized vibratory cue to turn in a specific direction.

COSMETIC ACCEPTABILITY

The final question in the survey asked the participants to indicate, on a 5-point scale, their opinions about different types of new mobility aids. Essentially, this question focused on whether the participants thought they would actually wear and use a navigation device of the type described in this survey if one was made available to them. The results are presented in Table 6.

All 30 participants strongly agreed or agreed that a wearable navigation aid would be acceptable. There was considerable variation when assessing the cosmetic acceptability of such a device-even if it worked well. But there was overwhelming support for the idea of traveling more often if such a device were to be available (27 out of 30 participants).

ACTUAL AND POTENTIAL LEARNING OF NEW ROUTES

In this section, we report on the current exploratory habits of the participants that were obtained before the participants completed the survey and their postsurvey estimations of the extent to which a PGS navigational device would affect their explorations. In the preliminary stage of the interview, two questions were asked, one about exploring familiar destinations and another about exploring paths to new areas. After the participants had been exposed to the concept of a PGS, the same two behaviors were examined, but this time, the participants were asked to anticipate how

Table 6
Participants' opinions on equipment.

Opinions	Mean Rating	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly agree (5)
I would use a wearable navigation aid if one was available.	4.5	0	0	0	16	14
Even if it worked well, I would be concerned about my appearance while wearing it in public.	3.4	3	6	4	11	6
If this kind of system was available, and I could use it to find any destination and independently travel to it, I would travel more often.	4.5		0	3	9	18

Note: Entries are the. number of participants who gave the rating value.

the use of a PGS system might affect their frequencies of exploration. Responses to these before-and-after questions are summarized in Table 7. The "Current" row summarizes the responses to the question asked prior to the survey, and the "Anticipated" row summarizes the responses to the questions asked again after the survey had been completed. Data on episodic frequencies of exploratory travel to familiar destinations were collected in categories that varied from less than once a month to daily. The results clearly show that most participants believed they would increase their exploratory behavior in familiar settings if they were given access to a travel aid, such as a PGS.

With regard to traveling to a new place, the questions concerned how often the participants learned a route to a new place and how often they thought they would learn such a route if they used a navigational device, such as the one that was described to them (see Table 7). Again, the potential use of a guidance system produced a willingness to explore new environments more frequently. The participants' current exploration to new places using existing mobility aids appeared to be limited.

The overall results of this preliminary survey provide some interesting perspectives that need to be explored further. For example, voice input was widely desired; progress in this area has been rapid, with software, such as IBM Via Voice, Dragon, and Microsoft SAPI Speech Engine, leading the way. Braille input and output was not highly desired by most participants. Voice output was highly desired in various forms, and there was a strong indication that some type of haptic pointing device was desired for finding and providing directions to specific locations. It appears that a hands-free speaker, combined with a pointing device, may be the best way to deliver these data, and our current modifications and testing of the latest PGS prototype has incorporated these features.

Future research

A guidance device relies heavily on getting relevant information to people in a clear and acceptable way. Given the stated preferences for speech and sound, ongoing research needs to focus on what

Table 7
Participants' current and anticipated frequency of learning new routes.

Type of route	Mean rating	Less than once a month (1)	Once a month (2)	Several times a month (3)	Weekly (4)	Several times a week (5)	Daily (6)
New route to a familiar destination							
Current	2.6		11	4	2	3	2
Anticipated	4.1		0	10	9	8	3
Route to a new place							
Current	2.4	6	13	7	2	2	0
Anticipated	3.9	0	2	11	9	5	3

Note. Entries are the number of participants who gave the rating value.

form of spatial input-language, sound variations or another pointing or guiding device-should be used. Our ongoing research is, therefore, aimed at (1) designing tests and conducting field experiments to determine the best kind of spatial language to use to deliver information on routes and destinations and (2) designing and evaluating the use of body-mounted or handheld haptic pointing devices that aid wayfinding. We have begun experimental trials of a type of interface that is modeled after the handheld receiver that is used in conjunction with the Talking Signs system of remote signage, as proposed in a previous article (Loomis et al., 2001). In the Talking Signs system, the user holds a small device in the hand that receives infrared signals from transmitters that are placed in the environment. These signals consist of labeling and location information that is accessed by pointing the handheld device at a transmitter and intercepting the infrared transmitted signal. The user can readily locate the transmitter when the handheld receiver is pointed toward it. The UCSB/CMU group is developing and testing a "haptic pointer interface" (HPI) that functions in much the same way. For this interface, the user holds a lightweight pointer in the hand to which an electronic compass is attached. When the user's hand is pointing roughly in the direction of a waypoint along a route or a point of interest, the computer sends synthesized speech (or tones) to a loudspeaker that is mounted on the device or worn on the torso. The HPI creates the impression of *virtual* Talking Signs transmitters in the environment without the need for any such installation. The person can use this HPI to orient quickly toward the location of interest, just as a user can use the Talking Signs receiver to orient toward transmitters. However, since the HPI is tied to a location that is based on GPS signals, its usefulness in indoor environments remains questionable until existing access problems are solved.

Conclusion

Currently the group's research and development are oriented toward helping to produce a marketable guidance system and are being conducted in collaboration with the Sendero Group, along with psychologists at Western Michigan University (WMU), the University of Minnesota, and the Smith Kettlewell Eye Research Institute. More information about this project can be obtained from the Sendero Group's web site, <http://wwwwayfinding.org>. In conjunction with the WMU researchers, a new, more comprehensive survey is being designed that will extend the questions asked in this preliminary and localized survey to a nationwide sample. It is anticipated that the results from this wider survey will influence the choice of components that are used in future navigational systems for visually impaired travelers.

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