Volume 2 Number 3 Summer 2009

AER Journal

Research and Practice in Visual Impairment and Blindness

ISSN 1945-5569

AER

Association for Education and Rehabilitation of the Blind and Visually Impaired

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A quarterly journal in the field of education and rehabilitation of persons of all ages with low vision or blindness

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AER Journal: Research and Practice in Visual Impairment and Blindness (ISSN 1945-5569) is published quarterly by the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER), 1703 N. Beauregard Street, Suite 440, Alexandria, VA 22311-1744, (703) 671-4500, fax (703) 671-6391. AER, a 501(c)(3) tax-exempt organization, supports professionals who provide education and rehabilitation services to people with visual impairments, offering professional development opportunities, publications, and public advocacy. Publishing services provided by Allen Press, 810 E. 10th Street, Lawrence, KS 66044.

Periodicals postage is paid in Lawrence, KS.

Claims for copies lost in the mail must be received within 90 days (180 days foreign) of the issue date to ensure replacement at no charge.

The 2009 print subscription rate is $99 per calendar year for institutions in the U.S., $124 for institutions outside the U.S., including Canada and Mexico. Allow six weeks for shipment of first copy. Single copies are available at $30 in the U.S. and elsewhere at $40. All amounts are listed and payable in U.S. dollars. Contact aerj@allenpress.com for more subscription information.

POSTMASTER: Send address changes to AER Journal, Association for Education and Rehabilitation of the Blind and Visually Impaired, 1703 N. Beauregard Street, Suite 440, Alexandria, VA 22311-1744.

Cover Photo: Photographer, Alexander Shaw, www.alexshaw.ca.

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Special Issue: Wayfinding

I am very pleased to present the *AER Journal*'s first special theme issue. We selected the theme of wayfinding after I realized that there was little published on the subject, although it was of some concern among people in orientation and mobility. In other words, a great deal of work was going on by technological research experts and in universal design; yet, little was being published here in the field of vision rehabilitation. It was time to change that. We were gratified to have 12 papers submitted for this issue. Although only five could be accepted for the current issue, we had several others that have been positively reviewed and are being held for future issues of the *Journal*.

I would like to extend my sincere thanks to Dr. Richard Long, our guest editor for this theme issue. I do not think he quite imagined the amount of work coming his way when he said yes to me at the AER conference in Chicago last year. Nobody is better qualified to lead the way, and Dr. Long has done a superb job in overseeing the work of the reviewers and doing the editorial legwork to make this issue a success. Whereas wayfinding technology usually results in less dependence on guides, the same is not true of publishing. In publishing one always needs a guide, and Dr. Long has ably guided the authors featured here and their reviewers. My deepest appreciation and gratitude are extended to him for these efforts.

I sincerely hope you, the reader, enjoy this latest contribution of the *AER Journal*, and I look forward to hearing your responses by e-mail or in a "Letter to the Editor."

Until Next Time,

DGold.

Deborah Gold, PhD
Editor-in-Chief

Clear Paths and Pleasant Wanderings

There are common elements in serving for the first time as a guest editor for a journal and in finding one's way in unfamiliar territory. Each offers opportunities for creativity and inspiration. On the other hand, each is replete with opportunities for wrong turns that end in unanticipated places or, worse yet, in places that are best avoided. I trust that as you read the diverse set of articles on orientation and wayfinding that follow, you will be intrigued by the opportunity to explore a topic that, although somewhat neglected in our professional literature, is central to the field of orientation and mobility (O&M) and to the lives of individuals with blindness and low vision.

In my work in O&M, I've been intrigued by the fact that our mobility-related techniques and strategies are described in great detail in various "practice-oriented" books, but there is little of a similar nature related to orientation and wayfinding. I also know that children and adults can learn to think about space and about wayfinding in ways that allow for flexibility in route planning and efficiency in route execution. Good teaching and good technology are important ingredients in this learning process. The articles in this special issue will stimulate you to think about the research and instructional development work that could improve our efforts in this important area.

One thing will be clear as you read this issue—Technology plays a key role today, and its influence in wayfinding of individuals with blindness and low vision will grow dramatically in the future. Four of the five articles focus on technology in wayfinding, addressing topics such as cutting-edge technologies for sign reading and indoor navigation (Ross), the use of global satellite positioning (La Grow et al.), the role of neuroscience and virtual gaming in wayfinding (Merabet and Sanchez), and the role of accessible pedestrian signals to support street crossings (Feingold & Lorenz). The fifth article, by O&M specialist Diane Brauner, provides an excellent introduction for the practitioner to approaches that help young children acquire the spatial concepts and the confidence in wayfinding that is critical to independence in mobility.

I trust that this issue will be both enlightening and stimulating reading. Please feel free to e-mail me at richard.long@wmich.edu if you have comments about the issue. Good reading!

Richard G. Long, PhD
Guest Editor

User Perceptions of Accessible GPS as a Wayfinding Tool

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Abstract

The purpose of this study was to determine the extent to which a group of visually impaired persons who own GPS use it for everyday travel, their perceptions of the impact the use of these systems has on their ability to carry out specific wayfinding tasks, and the extent to which the use of GPS affects their view of themselves as travelers. Seventy-one persons who had completed a GPS training course run by Leader Dogs for the Blind were surveyed. The vast majority of the participants were found to agree with statements indicating that the use of GPS was helpful for carrying out each of the major wayfinding tasks canvassed. It also was found that the participants used GPS most of the time when traveling in most environments. A high percentage of travelers also agreed to statements that the use of GPS made them more capable, confident, and relaxed travelers. This study provides evidence of the efficacy of accessible GPS as a wayfinding tool.

Keywords: GPS, wayfinding, orientation, orientation and mobility, visually impaired

Introduction

Wayfinding, or environmental navigation, is a fundamental human activity involving purposeful and directed movement to reach predetermined destinations (Darken & Peterson, 2002; Mast & Zaehle, 2008). The process of wayfinding requires one to establish and maintain orientation to place, plan routes of travel along designated pathways (e.g., sidewalks or footpaths, pedestrian crossings, steps and stairs, bus routes, train and subway lines), and solve problems as they arise (Long & Hill, 1997). Though this is generally considered a visual task, those who are blind or have low vision may learn the skills required to successfully navigate environments (i.e., orientation and mobility) of varying levels of complexity to a high degree (Rieser, 2008). Yet, the quality of information available to them for doing so is often not of the same level as that available to others (Long & Hill) nor is it always possible to find other reliable sources of information when needed (Ponchillia, Rak, Freeland, & La Grow, 2007). For example, accessible place information for independent travelers with visual impairments, such as auditory cues provided by traffic on busy streets and distinctive intersections, or from buses entering or departing bus terminals, is simply not consistently available. Likewise, place information gathered from others is only as reliable as the source's knowledge of the locale or his or her ability to describe it. As a result, some limitations in wayfinding may continue to exist even for the most skilled travelers.

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Received February 11, 2009; Accepted May 22, 2009

User Perceptions of Accessible GPS

Accessible global positioning devices, however, may provide a way to overcome many of these problems by coupling global positioning systems (GPS) with geographic information systems (GIS) to allow users to easily and precisely locate themselves in the environment and plan routes of travel to their desired destination (Broida, 2004; El-Rabbany, 2002; Taylor & Blewitt, 2006). The types of information provided by these devices can be divided into four broad categories, including (a) "Where am I?" functions, (b) route functions, (c) points of interest functions, and (d) virtual functions (Ponchillia, Rak, et al., 2007). "Where am I?" functions, also referred to as user location functions, include such information as the name of the street of travel and the upcoming intersection and its distance, as well as estimated address and direction of travel. Route functions enable a user to create and travel routes to specified destinations and follow unit-generated directions that include turn-by-turn instructions. Route recalculation is generated automatically if the traveler fails to follow the directions given. Points of interest (POI) functions are of two major types: commercially available POI that include a database containing an array of businesses and services located in the area and self-generated POI that consist of a database created by the user. Virtual functions permit users to "look around" environments without actually traveling in them. Virtual functions may be used to preview routes to be traveled and even help one decide where to eat or stay once there.

Two studies have provided evidence that current, state-of-the-art accessible GPS technology provides information that is reliable enough to meet certain wayfinding needs (Ponchillia, MacKenzie, Long, Denton-Smith, Hicks, & Miley, 2007; Ponchillia, Rak, et al., 2007). Ponchillia, MacKenzie, et al. found that with training, the device they tested appeared to provide sufficiently accurate information to be of practical use. In their study, an experienced user was able to approach an unknown target within less than one-half meter on every attempt using the GPS. In a second study, Ponchillia, Rak, et al. (2007) reported that their subjects consistently used the accessible GPS device they tested to gain orientation and find objectives designated by street address and marked as a user-generated POI. The participants were able to use the device to quickly establish place orientation after purposely being disoriented and to successfully plan routes to and accurately locate specified destinations in a familiar residential environment. Success was found to be a function of the subjects' willingness to accept the wayfinding information available from the device and of one's ability to interact with the unit itself (Ponchillia, Rak, et al., 2007). Thus, training and practice in GPS use is thought to be important to the quality of the outcomes gained.

User performance, however, is also likely a function of the brand of accessible GPS device used, because they all do not have identical hardware and software components. As such, performance-affecting characteristics such as accuracy, usability, and data quality would be expected to vary. In addition, utility across various environments, particularly in those where access to satellites might be limited (i.e., urban and/or wooded) or in familiar versus unfamiliar environments is unknown. In addition, little is published about the impact GPS devices have on one's overall experience while traveling or wayfinding. The purpose of this study was to fill some of these gaps by surveying users to determine the extent to which they use the Trekker® GPS for everyday travel, the environments and conditions in which they find it most useful, and their perceptions of the impact it has on their travel.

Method

This study was conducted in accordance with the tenets of the Declaration of Helsinki and approved by the Human Subjects Institutional Review Board, Western Michigan University. A telephone survey was conducted with graduates from a series of GPS training sessions run by Leader Dogs for the Blind between June 2005 and August 2008. These programs, although designed to introduce accessible GPS to persons with visual impairments in general, were conducted using Trekker® GPS exclusively. Each program was 5.5 days in duration. Approximately 40 percent of the time was spent indoors in the classroom and 60 percent outdoors in the environment. The basics of using GPS, keyboard function, unit adjustment (i.e., volume and speech rate), and assembly were introduced in the classroom, as were the techniques required for navigating the software, browsing a map virtually, and using the device with a computer. During outdoor instruction, students were taught to travel in different types of environments (i.e., residential, semibusiness, business, college campus) by foot and as a passenger in vehicles while using GPS. They learned to use the system to maintain their orientation and find destinations, create and execute routes, reverse routes, recover when lost, create points of interest and navigate in areas away from the street grid. Each participant owned the Trekker® GPS unit used for training and took it home at the completion of the program.

Participants

In total, 85 persons attended these programs. Of those, 71 were located by a team of trained and independent telephone interviewers. All those contacted agreed to participate in this study.

Instrument

The survey instrument was designed in consultation with training staff from Leader Dogs for the Blind. It consisted of 56 items divided into seven major parts, including personal information, patterns of use, environments of use, perceptions of usefulness as a wayfinding aid, perceptions of its impact on one's everyday travel, features liked the most and least, and perceptions of the quality of training in the use of the aid. Personal information items included age, gender, amount of useful vision, age at onset of visual impairment, and living situation. Items relating to the pattern of use covered length of time it had been used, frequency of use, whether used while alone or with others, mobility device it is used with most, and whether used more on familiar or unfamiliar routes. Items under environments of use required the participant to select the response that fit best from the following response set: (a) every time I travel, (b) most times when I travel, (c) sometimes when I travel, (d) rarely when I travel, (e) never, or (f) I don't travel there often enough to say, was used for each environment identified. In all cases, each environment identified was listed separately as being either a familiar or unfamiliar environment (i.e., when traveling in a residential environment that is familiar to you). Items relating to perceptions of usefulness of GPS as a wayfinding tool had a forced-choice response set of (a) strongly agree, (b) agree, (c) disagree, (e) strongly disagree, or (f) I don't use Trekker® for this purpose. Examples of situations in which the device was judged for usefulness as a wayfinding tool included maintaining orientation during travel; planning a route of travel; identifying and finding shops and other businesses along one's route; knowing the name of the upcoming street; reestablishing orientation if lost; knowing when the destination is reached during travel by bus, taxi, or train; and providing for opportunities to make decisions about where to eat or stay when on trips with others. The response set for questions regarding one's perception of the effects of the use of GPS on everyday travel also ranged from strongly agree to strongly disagree but included a response of "undecided" (i.e., strongly agree, agree, undecided, disagree, strongly disagree). Participants were asked to respond to statements such as: The use of GPS has (a) made me a more capable traveler, (b) confident traveler, (c) relaxed/less anxious traveler, (d) increased the amount I have traveled, and (e) increased the amount I venture into unfamiliar environments. Using an open-ended format, participants also were asked to list their favorite and least favorite features of Trekker® and the things they liked most and least about the unit. Similarly, subjects were asked, "Please identify the things that Trekker® cannot do that you wish it could." The final section of the instrument was aimed at evaluating the training program. The results of this last section will not be included in this report.

Procedures

Letters were sent from Leader Dogs for the Blind to all those who had attended their GPS training programs during the targeted period. These letters explained the purpose of the study, how the data would be used, and the rights of the recipients to refuse to participate, answer any specific question posed, or to withdraw from participation at any time they wish. Recipients of these letters also were informed that a telephone interviewer would call to follow up the letter, as well as the dates and times when calls could be expected. Calls were made during evenings and weekends within a 2-month solicitation period (December 2008 and January 2009). Upon contact, the interviewer reiterated the purpose of the project and the rights of the individual in relation to the project and extended a fresh invitation to participate.

Prior to beginning the study, the interviewers were trained and a trial interview was conducted. The wording of some questions was modified to eliminate confusion. In addition, one of the researchers was present to observe the early calls in order to aid the interviewers in clarifying or interpreting items and to ensure that questions were posed as written.

Data Analysis

Descriptive data were collected and reported for questions with defined response sets using frequency and percentage of response. Dummy variables were created for age at onset (early onset and late onset), amount of usable vision (none and some), and length of time of Trekker® use (less than a year and more than a year). Cross tabulations using chi-square were run to determine whether gender, age at onset, amount of usable vision, and length of time of use had an impact on user perception of (a) the effectiveness of Trekker® as a wayfinding tool and (b) one's travel. In each case, a Bonferroni adjustment to the alpha level used to judge statistical significance was applied to counter the increased risk of Type I error inherent in conducting multiple comparisons. To do so, the alpha level is divided by the number of comparisons made ($N = 4$) on each dependent variable (Pallant, 2001). Therefore, in this study, $p = .05$ was divided by 4 to obtain an adjusted alpha of .0125. Finally, responses to open-ended questions were grouped into categories and frequencies of responses were tabulated. The most common responses to the open-ended questions were reported.

Table 1. Personal Characteristics

	n[a]	%
Age	71	
Mean: 44.4 years		
Range: 16–78 years		
Gender		
Male	39	55
Female	32	45
Total	71	100
Amount of usable vision		
Have no usable vision	34	49
Have a little usable vision	30	43
Have a lot of usable vision	6	9
Total	70	101[a]
Age at onset		
At or before age 5 years	42	59
From age 6 to 65 years	29	41
After age 65 years	0	0
Total	71	100
Living arrangement		
Live alone	23	32
Live with others	49	68
Total	71	100

[a] *Does not add to 100% due to rounding*.

Results

The participants ranged in age from 16 to 78 years, with a mean age of 44.4 years. Fifty-five percent were males, 49 percent had no usable vision, 59 percent had early onset visual impairment, and 68 percent stated that they lived in a household with others (see Table 1).

All participants owned their own GPS unit, with 69 percent stating that they had owned it for more than a year. Fifty-one percent stated they used their GPS unit either every time they travel or most of the time; whereas, 11 percent stated they used it rarely and 4 percent, never. Eighty-seven percent said they used it mostly when traveling on their own. Fifty-nine percent reported using it mainly while using a dog guide; 30 percent, with a long cane; and 4 percent, both equally. Nearly 40 percent stated they use it when traveling on new routes mostly, 6 percent when traveling on routine routes mostly, and 53 percent on new or routine routes equally often (see Table 2).

Participants reported using GPS most often (either every time they travel or most times they travel) when traveling in unfamiliar residential (76 percent of the time), unfamiliar commercial (75 percent), and unfamiliar rural (48 percent) environments, followed by familiar commercial (41 percent), familiar residential (39 percent), and familiar rural environments (37 percent). In all environments, participants reported using GPS more often when they were not familiar with the environment in question (see Table 3). In addition, 77 percent ($n = 55$) reported they used GPS when traveling by bus; 46 percent ($n = 33$), when traveling by taxi; and 23 percent ($n = 16$), by train (see Table 4).

In terms of the usefulness of GPS as a wayfinding tool, 92 percent either agreed or strongly agreed with the statement that they found the use of their GPS helpful for "establishing or maintaining orientation while traveling in general." Similarly, 92 percent either agreed or strongly agreed with the statement that their GPS unit was helpful for "reestablishing

Table 2. Use and Ownership of GPS

	n[a]	%
Length of GPS ownership		
Less than 6 months	9	13
6 months to year	13	18
More than year	49	69
Frequency of use		
Every time I travel	15	21
Most times I travel	21	30
Sometimes when I travel	24	34
Rarely when I travel	8	11
Never when I travel	3	4
Use mostly when		
Alone	62	87
With others	9	13
Use most often when traveling		
With a guide dog	41	59
With a long cane	21	30
Both equally	3	4
Neither	4	6
Did not respond	2	3
The situation in which GPS is used most often		
When traveling new routes	28	39
When traveling routine routes	4	6
Both equally	38	53
Did not respond	1	1

[a] $n = 71$. *Percentages may not add up to 100 due to rounding*.

one's orientation when dropped off at an incorrect spot.'' Ninety-four percent either agreed or strongly agreed with the statement that the use of the GPS unit was helpful for ''planning a route of travel to a destination in an unfamiliar part of town.'' Ninety-three percent either agreed or strongly agreed with the statement that it was helpful for "knowing when I had reached my destination when traveling in an outdoor environment." Ninety-three percent either agreed or strongly agreed that GPS was helpful for "finding shops, restaurants, and other businesses along unfamiliar routes of travel." Eighty-three percent either agreed or strongly agreed that the use of their GPS unit "increased their opportunities for involvement in making decisions about where to eat or stay when on trips with others" (see Table 5). Of those who said they used GPS when traveling by bus ($n = 55$), taxi ($n = 33$), and train ($n = 16$), 89 percent, 88 percent, and 57 percent, respectively, either agreed or strongly agreed with the statement that the use of GPS was helpful for doing so (see Table 4).

In terms of the long-term effects on the participants' travel experience, 92 percent either agreed or strongly agreed with the statements that the use of GPS "made me a more capable traveler" and a "more comfortable traveler"; whereas, 90 percent either agreed or strongly agreed with the statement that using GPS made them "more relaxed and less anxious" when traveling. Seventy percent and 73 percent either agreed or strongly agreed with the statement that the use of GPS increased the amount they traveled in and outside of their immediate neighborhood, respectively (see Table 6). Comparisons were made across the dummy variables of gender, age at onset, amount of usable vision, and length of time one owned his or her GPS unit to determine whether these variables had any impact on user perception of the usefulness of GPS as a wayfinding tool or on user perception of the travel experience. These comparisons were not extended to travel by public transportation, because many of the participants stated that they did not use GPS for doing so. No significant differences ($p < 0.125$) were found on any of the questions assessed by gender (male vs. female), amount of usable vision (none vs. some), age at onset (at or before 5 years vs. after 5 years), and length one had owned his or her GPS unit (a year or less vs. more than a year).

When asked what they liked the most about their GPS unit, the most common replies included the route planning function ($n = 20$), the "Where am I?" function ($n = 19$), and POI function ($n = 10$) (see Table 7). When asked what they liked the least, the most common replies included the life of the unit's battery ($n = 9$), complexity of use ($n = 7$), tendency to crash ($n = 7$), difficulties encountered with acquiring a signal ($n = 6$), and difficulties encountered with programming POI ($n = 5$). When asked what they wished it could do that it does not currently do, the most common replies were: provide more accurate location information ($n = 9$) and work indoors ($n = 8$).

Discussion

The results of this study indicate that the accessible GPS unit under investigation was seen

Table 3. Frequency and Percentage of Use of GPS by Environment

	Familiar		Unfamiliar	
Environment of Travel	*n*[a]	%	*n*	%
Industrial				
Every time I travel	5	7	9	13
Most times I travel	6	8	11	15
Sometimes when I travel	0	0	3	4
Rarely when I travel	4	6	2	4
Never	0	0	0	0
Do not travel in this environment	46	65	46	65
Commercial				
Every time I travel	14	20	24	34
Most times I travel	15	21	29	41
Sometimes when I travel	24	34	10	14
Rarely when I travel	10	14	1	1
Never when I travel	5	7	2	3
Do not travel in this environment	3	4	5	7
Residential				
Every time I travel	11	15	27	38
Most times I travel	17	24	27	38
Sometimes when I travel	24	34	10	14
Rarely when I travel	13	18	1	1
Never when I travel	3	4	3	4
Do not travel in this environment	3	4	3	4
Campuses or schools				
Every time I travel	5	7	8	11
Most times I travel	7	10	10	14
Sometimes when I travel	11	15	4	6
Rarely when I travel	4	6	2	3
Never when I travel	11	15	3	4
Do not travel in this environment	33	46	44	62
Rural				
Every time I travel	10	14	17	24
Most times I travel	16	23	17	24
Sometimes when I travel	15	21	3	4
Rarely when I travel	8	11	5	7
Never when I travel	5	7	2	3
Do not travel in this environment	17	24	27	38

[a] n = *71. Percentages may not add up to 100 due to rounding.*

as being helpful for all major wayfinding tasks (i.e., establishing and maintaining orientation to place, planning routes, and locating travel destinations) and was said to be used most of the time in most travel environments by those who own it. Not surprisingly, GPS is seen as being most helpful in unfamiliar environments and is used more often there than in places well known to the user. It also was said to be used by the vast majority in combination with a mobility device (cane or dog guide), which indicates

Table 4. User Perception of the Usefulness of GPS When Traveling by Public Transport

I find the use of my GPS helpful when	n^a	%
Traveling by bus		
Strongly agree	44	80
Agree	5	9
Disagree	4	7
Strongly disagree	2	4
Total	55	100
Do not use it for this purpose	16	
Traveling by taxi		
Strongly agree	27	82
Agree	2	6
Disagree	2	6
Strongly disagree	2	6
Total	33	100
Do not use it for this purpose	38	
Traveling by train		
Strongly agree	7	44
Agree	2	13
Disagree	3	19
Strongly disagree	4	25
Total	16	101
Do not use it for this purpose	55	

[a] *$n = 71$. Percentages may not add up to 100 due to rounding.*

that users do not consider it a replacement for their traditional mobility aids. In addition, it was used to a large extent when traveling on buses, but less so on trains and in taxicabs. This finding could be due to a perceived need for more control over identifying their stop when traveling by bus than by other means. It also may be seen as offering a solution to a common problem, because presetting user POIs at regularly used stops would eliminate any need to rely on drivers to know when to disembark. The low usage of the device when in taxis likely stems from the fact that drivers generally know local travel routes and can be relied on to drop the traveler at the desired location. The low usage while on trains is less easy to explain, because it may be due simply to the fact that fewer people travel by train. However, when coupled with a lower percentage of agreement as to its usefulness, it may be that GPS units are used on trains less frequently because they are not seen to be terribly useful for that mode of transportation. Further study would be required to discover more about this topic.

The impact of using the GPS unit seemed to positively affect the overall travel experience, because an overwhelming majority of participants agreed to statements that using GPS made them more capable, confident, and relaxed travelers, and more than two thirds said that using it had increased the amount they travel both within and outside of their immediate neighborhood. Perhaps over time, the apparent increase in confidence and decrease in stress associated with GPS-aided travel could result in an even greater willingness to venture out, particularly into unfamiliar areas. However, time of ownership was not found to have a significant impact on these factors. This, of course, could be due to the fact that the difference in the amount of time may not have been that great (i.e., more than a year vs. less than a year). Further study over a longer time frame would be required to test this hypothesis.

Gender, age at onset, and amount of usable vision did not prove to have a significant impact on participants' responses to statements concerning either the effectiveness of GPS as a wayfinding tool or its impact on their travel experience. This was somewhat surprising, yet could be due to the fact that the participants in this study were all dog guide travelers and therefore may have been a relatively homogeneous group of travelers.

When asked what the participants liked the best about their systems, they most frequently noted the route planning functions, the "Where am I?" function, and the POI function. This would appear to reflect the overall value of these functions to travelers who are visually impaired. For example, focus group feedback reported by Ponchillia, Rak, et al. (2007) indicated that the major wayfinding information not readily available to travelers with visual impairments included reorientation after becoming lost en route, route planning, and knowing what businesses were being passed while walking through both familiar and unfamiliar environments. The features listed here as most liked met these needs and are apparently appreciated by the study group.

The least liked characteristics of the device were apparently not considered to be serious by a significant group of users, because the largest percentage of subjects responding negatively to the interview item "What do you like least…?" was never more than 13 percent ($n = 9$). However, there were

User Perceptions of Accessible GPS

Table 5. User Perceptions of the Usefulness of GPS as a Wayfinding Tool

I find the use of my GPS unit helpful for	*n*[a]	%
Establishing or maintaining orientation while traveling in general		
Strongly agree	55	77
Agree	11	15
Disagree	2	3
Strongly disagree	1	2
Did not answer	2	3
Reestablishing orientation when dropped off at an incorrect spot		
Strongly agree	60	85
Agree	5	7
Disagree	1	2
Strongly disagree	1	2
Did not answer	4	6
Planning a route of travel to a destination in an unfamiliar part of town		
Strongly agree	61	86
Agree	6	8
Disagree	1	2
Strongly disagree	1	2
Did not answer	2	3
Knowing that I have reached my destination when traveling in outdoor environments		
Strongly agree	56	79
Agree	10	14
Disagree	2	3
Strongly disagree	1	2
Did not answer	2	3
Identifying shops, restaurants, and other businesses along unfamiliar routes of travel		
Strongly agree	60	85
Agree	6	8
Disagree	1	2
Strongly disagree	1	2
Did not respond	3	4
Increasing my opportunities for involvement in making decisions about where to eat or stay when on trips with others		
Strongly agree	50	70
Agree	9	13
Disagree	3	4
Strongly disagree	1	2
Did not answer	8	11

[a] n = *71. Percentages may not add up to 100 due to rounding.*

a number who considered the life of the unit's battery, complexity of its use, its tendency to crash, difficulty with acquiring the signal, and difficulty programming POIs as device weaknesses. These perceived problems could result from either technological or human factors. Further research would be required to identify any difficulties and their source.

Table 6. User Perception of the Impact of GPS on Travel

Statement: I would say that using my GPS unit has	n^a	%
Made me a more capable traveler		
Strongly agree	48	68
Agree	17	24
Undecided	0	0
Disagree	3	4
Strongly disagree	3	4
Did not answer	0	0
Confident traveler		
Strongly agree	55	77
Agree	11	15
Undecided	0	0
Disagree	2	3
Strongly disagree	2	3
Did not answer	1	1
Relaxed and/or less anxious traveler		
Strongly agree	54	76
Agree	10	14
Undecided	2	3
Disagree	3	4
Strongly disagree	2	3
Increased the amount that I travel within my immediate neighborhood		
Strongly agree	33	46
Agree	17	24
Undecided	1	1
Disagree	16	23
Strongly disagree	4	6
Increased the amount that I travel outside my immediate neighborhood		
Strongly agree	37	52
Agree	15	21
Undecided	3	4
Disagree	14	20
Strongly disagree	2	3

[a] n = *71. Percentages may not add up to 100 due to rounding.*

Table 7. Reponses to Open-Ended Questions about the GPS Unit

Response	*n*
Features users like most	
Route planning function	20
"Where am I?" function	19
Points of interest (POI) function	10
Motorized mode	9
Maestro	5
Pedestrian mode	4
Browse offline	3
Overall design of unit	3
Texting capacity	2
Total	75
Features users like least	
Battery life	9
Complexity of use	7
Tendency to crash	7
Difficulty acquiring signal	6
Difficulty programming POI	5
Difficulty resetting	3
Size of unit	2
Wish it could do that it can't	
Provide more accurate location information	9
Work indoors	8
Other	7

The findings of this study may be limited by the approach taken during this investigation, particularly because participants were asked to respond to statements posed about frequency of use, helpfulness of the device for carrying out a number of wayfinding tasks, and the impact of the GPS on travel in general. In-depth interviews were not conducted to get greater detail than that nor were participants asked to indicate the degree to which they felt the device was helpful or how much it impacted on their travel. These questions need to be raised in future studies.

The findings also may be limited by the fact that all participants used a Trekker® GPS. Thus, it is not known whether their responses are reflective of accessible GPS devices in general or limited to the specific system used. Although we would guess that most of what we report here is indeed reflective of current state-of-the-art accessible GPS, particularly because all the modern electronic wayfinding systems share the major functions described by the study group as most helpful. There is, of course, no way to know that without further study. Furthermore, the study population would not be considered representative of all people with visual impairments because all participants were guide dog users, they were relatively young, a high percentage had early onset vision impairment, and most had either no usable vision or just a little. As such, the sample used in this study may be more mobile and technology astute than a more general sample of people with visual impairments. We would conclude, however, that for this group of users at least, using GPS was perceived as highly advantageous and as having had a positive impact on the overall travel experience of those using it.

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Importance of Information Selectivity in Navigating the Community

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Abstract

Concepts of community psychology are merged with rehabilitation engineering design methods in the development and evaluation of three orientation and wayfinding technologies for persons with vision loss. A rationale emphasizing information-selective and effort-selective design considerations is developed as a basis for assistive technology design and evaluation and is applied in the design and evaluation of three orientation and wayfinding technologies. Results support the value of employing information-selective and effort-selective criteria in design.

Keywords: orientation and mobility, assistive technology, rehabilitation, navigation

Introduction

A variety of technologies are now in development, with the potential to provide orders of magnitude more information for persons with visual impairment than previously possible: huge geographic information system (GIS) databases linked to specific locations; radio frequency identification (RFID) tags with the potential to inexpensively label every sign, landmark, and object in the environment; and wearable artificial vision systems. For years, the desire of persons with visual impairment has been to gain access to all the information available to persons who have sight. However, it should be understood that information availability and information accessibility are two very different things. Without an easy means of selecting specific pieces of information from the mass of information that may become available, the time and effort involved may preclude reasonable access.

This became particularly evident during the course of a 3-year project to develop and evaluate Talking Braille signs—signs that provide access to their information at a distance. Over this same 3-year period, two other information-based navigation projects were conducted: SeeStar (videoconferenced remote assistance) and SeeScan (an object recognition system). As this research progressed, a critical research question surfaced: "What information selection strategies can be developed to provide easy access to specific pieces of information needed for successfully navigating an environment?" The results of these three research projects, as described herein, have begun to answer this question.

Academic Foundation

Our research team developed an academic foundation with which to frame the above question—a foundation built on concepts of community psychology, where community comprises schools, government, the workplace, stores, businesses, hospitals, churches, service organizations, transportation systems, utilities, communications systems, neighborhood organizations, assistants, friends, relatives, and so forth, as well as the architectural structures and technological systems that are an integral part of community and community activities.

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Received February 2, 2009; Accepted May 22, 2009

Information Selectivity in Navigation

Factors impacting functioning within a community with a disability were developed in G.W. Kelly's thesis, "The Participants' Description of the Personal Adjustment Process to the Disability Experience" (Kelly, 1993). Through a series of ethnographic interviews of 40 participants, Kelly gained insights into two generic areas of concern: (a) effort selectivity issues and (b) information selectivity issues. Kelly describes *information selectivity issues* as relating to an inability to selectively access needed and valued information when and where it is of import for the task at hand. This was described as a primary disabling factor by participants with sensory loss—especially those with vision loss.

Being dependent upon other sensory channels with far less capacity, a person with severe visual impairment must be highly selective in choosing the information that he/she wishes to acquire. This problem of limited sensory channel capacity makes the following factors of great import:

- An intermediary (assistant or assistive technology) must be employed for obtaining needed and valued information
- This intermediary constitutes a loss of primary information access and a lessening of control, because the person must now trust an intermediary to provide needed information
- The intermediary is in effect a secondary "channel," now in series with the person's own primary sensory input channels (e.g., auditory, tactile), over which the person has only secondary control

Effort selectivity was described as a need to select information sources and strategies of information acquisition that minimize the amount of effort required to participate in valued activities. That is, participants felt that their ability to participate in community activities was largely based on the time and effort required to obtain the information needed for traveling to and participating in desired activities. In many cases, a choice not to participate was based on an inability to easily access orientation and wayfinding information for traveling to the location of a valued activity. Participants felt that such "forced" choices drastically curtailed their interactions with community.

Furthermore, Kelly found that time and effort are always a concern when intermediaries (whether human or an assistive technology) are employed as information channels, because

- They may degrade information and/or not focus well on relevant factors
- They may have availability limitations
- They may have limited specificity of access, being helpful in one area but not another
- They may require specialized expertise for successful access to information
- They may have limited capacity, transferring far less information per unit time than might be accessed directly
- They may require a high degree of maintenance (e.g., frequent system updates, etc.)

The Project Research

The three projects described below were conducted within the conceptual framework of the above academic foundation and with two goals in mind: to determine (a) what information is most useful in varied settings and circumstances and (b) how persons with vision loss can most easily select desired information from an information surround. The SeeStar and SeeScan projects were both 1-year projects that began and were completed within the 3-year span of the Talking Braille project. The results of these two shorter projects helped to focus our Talking Braille design effort and our analysis of the results. As such, the results of Talking Braille, in many ways, act as a summary of the results for the three projects.

SeeStar

SeeStar (Dorcey, 2005) was a Phase I National Institutes of Health (NIH) grant awarded to iVisit LLC to develop an OnStar-like system for persons with visual impairment. This system is based around the use of iVisit's videoconferencing system, which places live video from the user's cell phone camera onto a remote assistant's computer monitor. In addition, the remote monitor shows the user's location and movement on a Google Earth satellite image of the area. Using this information, the remote assistant answers whatever questions the user may have, which may include planning a route to a particular destination. The impetus for this project came from consumers reporting that often their only recourse when erroneously stepping off a bus at the wrong stop was to call 911.

The SeeStar prototype was evaluated by eight participants who were dropped off near the Atlanta Veterans Affairs (VA) Medical Center at an unfamiliar location and told to use the SeeStar assistant to find the front entrance. During these evaluations, the prototype demonstrated all the above-listed issues related to the use of an intermediary: loss of video signal and/or voice communications at random times as a result of high data traffic or signal degradation, loss of GPS information or very degraded GPS accuracy at various times, "blinding" of the remote assistant when the user was walking facing the sun, communications issues related to aiming the camera in a useful direction, difficulty determining how best to describe surrounding environmental elements, difficulty determining what surrounding elements were of real import to the person, an inability of the assistant to judge distances when looking through a camera lens, and random time delays of up to 3 seconds of both video and voice communications that made it difficult at times for the assistant to stay in touch with the user and remain fully cognizant of the user's progress along the route.

As a result of these issues, investigators concluded and recommended (a) that assistants not attempt to provide information while the user is in motion, (b) that in future prototypes, a means of acquiring panoramic images would be most useful so the assistant can obtain a wider field of view and greater awareness of the user's surroundings, and (c) that interactive user-assistant protocols be developed for quickly determining the types of descriptive information most useful to the person being helped.

In other words, the authors discovered that it is necessary to first understand what information the user really needs and then to provide it before the person starts walking. Providing information "on the fly" did lead to potentially dangerous situations. During the evaluations, an orientation and mobility (O&M) instructor had to intervene at least once with each participant to ensure his/her safety, because with a limited field of view and intermittent data losses it was impossible for the remote assistant to remain aware of changing environmental situations while the user was moving. The authors predict that the system will work far better if the user is able to obtain information on demand at locations where he/she can stop and orient to the setting/situation and then move on using his/her own skills to follow a described route.

SeeScan

SeeScan (Dorcey, 2007) was another Phase I NIH National Eye Institute project. Investigators employed Evolution Robotics' Object Recognition (OR) software to identify objects and settings as imaged through a computer webcam. Investigators installed this software on a handheld computer manufactured by OQO, Inc., called the "OQO." The webcam was plugged into a USB port to provide live video for the OR software. The webcam was placed on a lanyard around the user's neck facing forward, and the OQO placed in a specially-designed vest pocket so the person could hear its auditory output.

This OR software has two main modes of operation: (a) learn and (b) identify. In learn mode it captures a picture when a button on the webcam is pressed. After a number of pictures have been taken, each picture can be selected from a menu and linked either to a sound file or text that is to be played/synthetically spoken when the OR software recognizes the pictured image.

To test this system for use in wayfinding, investigators took pictures at regular intervals facing forward along a route through several hallways in the Atlanta VA Rehabilitation Research and Development Center. This was done without aiming the camera at any particular object, but rather at the view down the hallway at 20-foot intervals. The investigators then labeled these pictures "20 feet," "40 feet," "60 feet," and so on, and then put the software into recognition mode and repeated this route through the hallways. The result was very encouraging. The software announced our position 83 percent of the time with accuracy ± 5 feet and never gave us an incorrect response. Furthermore, after the OR software was trained to recognize pictures of standard universal signs (e.g., men's room, ladies' room, trash can), it was able to identify each sign when the camera was brought to within 7 feet of it.

Two test routes of comparable length and complexity were then established by an O&M instructor. The OR software was trained to recognize multiple images along these routes to provide enough redundancy that the system would be fully reliable despite its 17 percent failure-to-recognize rate. Each image was assigned a spoken phrase stating (a) the distance to the next turn or destination, (b) to make a left/right turn, or (c) the name of a universal sign (e.g., men's room).

Investigators then recruited 24 participants to evaluate the use of this system. None had vision better than light perception, and none had any familiarity with the area of the hospital where the test routes were located. They were given two tasks to perform: (a) find a restroom and (b) then move on to a specific destination office. Routes were assigned randomly as either baseline or intervention routes. Furthermore, "baseline" was assigned randomly as either the first or second route traveled. A baseline route consisted of an O&M instructor giving an overview of the route and directions for reaching the destination. For the intervention route, the camera was hung around the participant's neck and the participant was told to follow the directions provided by the system. The key differences between baseline and intervention routes were (a) on the baseline route, participants were provided an overview of the route and instructions for finding the destination but no help along the way, and (b) on the intervention route, the prototype provided just-in-time turn-by-turn directions but no overview of the route prior to starting out.

The results were impressive. None of the participants missed or made a wrong turn when using the OR prototype, though two misunderstood the verbal direction given indicating the destination door and passed by it. However, on the baseline routes 87.5 percent of the participants missed or made at least one wrong turn, and 75 percent of them had to give up and restart the route.

However, although the objective results were excellent, participants did have two major complaints: (a) It provided more information than was desired in most cases, which was perceived as annoying and a waste of their time, and (b) the quality of the synthesized speech was criticized as difficult to understand and certainly not as good as the speech on their home computers.

Talking Braille

The purpose of Talking Braille, a VA Merit Review funded project (Ross, 2005), was to make braille signs accessible from a distance so as to further our goal of populating environments with information that is easily detected and accessed. Given the results of the OR project, highly rated Acapela Mobility 7.0 speech synthesis software was purchased for use in the Talking Braille prototype. Furthermore, to avoid issues of divided attention, we wished to provide an awareness of available information in a manner that draws minimal attention away from other conscious processes. To this end, and for the purposes of this particular research, we developed six categories of indoor information: (a) entrance, (b) office, (c) elevator, (d) restroom, (e) stairs, and (f) emergency exit. A 1-second characteristic sound then was assigned to each type of information. For instance, "entrance" was assigned a traditional doorbell sound, "elevator" an elevator ding sound, and "office" a soft ringing telephone sound. Thus, walking down a hall, the user becomes aware of every office, restroom, stairway, and exit without having to attend to verbal descriptions. Knowing the type of information available, the person can then choose to read the sign by pressing a "read" button on the user device, which then provides synthesized speech output.

Over the 3 years of the project, this technology was extended beyond typical braille signage locations to hallway intersections and other salient indoor landmarks as suggested by participants. In the final evaluation of the Talking Braille project, we placed a transmitting device (Infra-Red Digital Association transceiver) by every door, restroom, hallway intersection, elevator, cubicle, water fountain, and exit sign, and other landmarks.

Investigators recruited 24 participants to evaluate the final Talking Braille system and used a protocol identical to that described above for evaluation of the OR system, with two exceptions: (a) an O&M instructor established two new comparable test routes, and (b) participants received 15 minutes of training in the use of the Talking Braille prototype prior to navigating the test routes. Again, participants were asked to first find a restroom and then move on to a destination office.

Results

The objective results were actually better than the OR prototype results, with no missed turns and everyone finding the destination office door. What was of real interest, though, was the diversity of the comments provided by the participants. These comments were obtained via interviews a few weeks after the actual use of the system so the participants had time to absorb their experience in using the system and to consider it in the context of their normal daily activities in navigating their communities. Interview comments were grouped by topic and categorized. No specific groups were preestablished. The result was eight rather self-evident categories.

Ergonomics

Four categories were grouped to describe the ergonomic parameters of the prototype: physical factors, sounds, speech, and information delays. Physical factors were related to carrying and manipulating the user interface. In the test protocols, the participants kept the tactile keypad interface in hand for quick access to functions as they walked the course. However, for everyday use many had comments similar to this:

> I think if I had one and was using it all the time, it would be a little awkward, because my one hand is using the cane, the other is holding the device. If I had my briefcase or my laptop along, it would be very difficult. It needs to be able to clip to a belt, or purse strap. I like mostly hands-free devices—something that would either clip on over the breast pocket or belt.

With respect to the sounds, the respondents had less agreement.

> I thought the sounds were cute, funny, and I did not have to listen hard to know what they were. I could react faster to the sounds without having to concentrate as much. I liked them more than the verbal speech, as I could respond faster while still concentrating on my wayfinding. The sounds were easy for me to learn, too. The sounds matched up well with what they were supposed to signal—They were distinctive. There was no mistaking one landmark for another. The sounds were easy to learn and made a lot of sense to me.
>
> I'd rather have a mix of both sounds and speech. You have an advantage if both are possible, as they complement each other. I think it would be good to alternate between sounds or speech. I have more difficulty with speech in a noisy environment. It would be nice to switch to sounds then.
>
> The sounds threw me off. I just was not thinking about them in that way. I just like the speaking part better than the sounds. I remembered some of the sounds, and some I did not.
>
> I preferred the speech. There are so many sounds in our environment that sounds can be confusing. Even though the sounds were clear and crisp, I would rather have the information.
>
> I was not enthusiastic about the sounds. I prefer verbal directions. I want to hear the verbal statement of where I am and not have to hope I remembered the correct sounds.

Respondents found the speech to be highly acceptable. It was clear from all participants that speech is less controversial than the sounds.

Information delay, or timing, was referred to in both positive and negative terms in the comments of nearly all the participants. This is the delay between the time that directions were given and the opportunity to carry out those directions.

> The delay from the time I got voice direction and the upcoming turn or whatever was right for me. It gave me the confidence to move about more quickly. I didn't feel like I needed to trail a wall or look for a doorway—All that was gone. It was amazing.
>
> I am a fast walker, so sometimes I would overshoot the turns. If there was a way it could sense my presence, and better let me know when to turn. The delay was too short for me. By the time I was turning, I had passed the turn.
>
> When I got to the point where I had to make a turn, I turned too quick. The delay was too long for me. It would be nice if it adjusted.

Thus, overall, there was a desire to control the timing of information being presented to suit their personal gate. However, this is not a parameter that can be customized given the existing Talking Braille hardware that simply presents information as it is acquired at a distance.

Amount and Extent of Navigation Directions

The research team optimized the messages presented by the prototype and limited them to specific simple statements. These were organized as a turn-by-turn presentation. The respondents reacted favorably to this presentation, both in terms of the minimal message length and the logic of a step-by-step presentation.

> The navigation directions given were just right—not too much, and not too little, and they were clear to me. I had no problem following them.
>
> If I was already familiar with the route or building, I would probably want to not use the system, [would] turn it off and on as I needed it.

Participants also commented on the difference between step-by-step instructions and the type of overview directions provided by the O&M instructor on the baseline route, and suggested that a combination of these might be ideal.

> For me, the step-by-step instruction was best. When you get an overall description of a place, you have to memorize it in certain sections. In other words, you say you give it to me all at once, you are not going to memorize all of that, depending on how good your memory is. I believe in giving it to you in increments. I like it better step-by-step.
>
> While the turn-by-turn directions worked OK, I would also like to get the overview directions first so I know where I am, too, because that helps. I might forget them halfway through, but that's when the turn-by-turn directions can help. So I would like a combination of both.

"Bonus" Information

Participants commented a great deal on the "bonus" information provided by the prototype—information not needed for the immediate task of finding a restroom or a specific office, but useful for learning more about the building and what is located where. In these terms, some suggested that the system is not only helpful while using it in the present, but it has a future impact, too. It helps in "learning" a new facility or building a cognitive map that may be used later. This is not a feature that can be measured through ordinary quantitative methods.

> Even if you go by a place that you did not need at the time, say a water fountain, then later I would know where that was if I wanted it. It helps me form a more complete map in my head. I would not have to ask or mention it to anyone else to get help, as I might normally have to do.
>
> The system is good for learning a building—but I would not need it later, if I was going to be there often enough. It would be very good for places I do not know at all, like when I go the first time. It is hard to go to a place cold.
>
> It gave me more information as I traveled that I could then make use of later. It gave me an additional bonus, in that what it told me the first time was something I might make use of later.

The bonus factor does not save time and effort on the first use, but it may on later uses. The respondents did think in terms of the time and effort the system use requires.

Time and Effort

This research was formulated, in part, to further our understanding of time and effort parameters—to learn their import in mobility and orientation tasks. Participants were clear in their personal understanding of the relative importance of time and effort involved in their personal mobility. The respondents' statements below make it clear that the reduction in time and effort are what makes this system so attractive to them.

> I think this device would save me time. My cane picks up a lot of things, but this system can tell me a lot without taking as much time. It would reduce searching time to find things. I would have to go to each door with my cane, but with this device, I could just keep going, until I got to the right door. This system will save time and effort.
>
> It would save me from effort.... It would have saved me effort, and maybe some time, too. That would be very important to me. I do a medium amount of travel. Mostly I am alone when I travel. So, this system would be especially good for me.
>
> There was hardly any effort in using the system. I thought it was fantastic. Because there again, I either have to be shown by an O&M instructor, or I could have this device and learn it on my own, which is really nice.
>
> The system definitely, absolutely saves time. It is very helpful at saving time. The function of it is saving me travel time, and effort, too. Even if one knows the facility already, it gives great reminders. If you were going somewhere where you did not need it, it would still help. I just like that extra confirmation to help me feel more confident.

Additional Requested Features

Finally, participants requested a number of additional features for the system:

- An indication of which stairway goes up and which goes down, or if only one stair direction is available; an indication as to how many levels of stairs there are to the building exit
- The addition of soda machines as an element in a facility identified by the system
- An indication of doorknob locations and the direction in which a door opens—push or pull

- An auto-updating feature, so that the system reflects current facility usage patterns; some facilities change in their use over time, such as museums, schools, universities, and office buildings
- The device should give its operational status, battery check, and relevant update information

Recommendations and Conclusions for Future Research

With the completion of the above three projects, investigators have reformulated their information provision infrastructure concepts and have begun a project to develop the use of RFID tags and long-range (15 feet) readers as sources of information for orientation and wayfinding. The idea is that 10-cent RFID tags are inexpensive to place on every sign and salient feature of interest. Making use of what has been learned in the above-described projects will be crucial to the success of this new RFID project. The basic concepts evaluated by the research team across all three projects establish a solid foundation for use of RFID technology as well as any other future technology used for the provision of information. In this regard, future projects should investigate the following points:

- Methods to offer users a device that they can program with their own personal settings for as many options as possible: speech versus sounds, the nature of sounds or speech messages, the volume, speech rate, and possibly the type of voice used by the device. Easily accessed user menus for selecting options should be made available. Furthermore, the interface should include "fast switch" keys that will provide a quick means of switching between favorite modes based on changing circumstances.
- Given participant requests for a combination of step-by-step directions and a building overview/route preview, we recommend further study on how these two types of information might best be mixed and controlled by the user, including selections of various levels of output detail and the "chunking" or grouping of route information.
- Given time and effort comments and the desire to limit information to just what is wanted for the task at hand, valued information types should be delineated further. Once these are established, they should be categorized in such a way the users can easily switch on or off specific types of information according to their immediate needs. Then appropriate sounds/phrases should be established for each category of information.
- Because participants do not want to carry the user device in their hand, we recommend that various other possibilities for carrying/wearing the device be investigated that will leave hands free for mobility needs.
- We recommend implementing the additional useful features suggested: providing door handle locations and door swing direction, up/down stairway information, and methods for conveying device operational status.

These are all navigation technology challenges for the future that can and should be addressed to take best advantage of new technologies that will likely become ubiquitous in the next 5 to 10 years.

Acknowledgments

Talking Braille research was funded by the Department of Veterans Affairs Rehabilitation Research and Development Service, with research facilities provided by the Atlanta VA Medical Center. SeeStar and SeeScan research was funded by NIH National Eye Institute.

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Audio-Based Navigation Using Virtual Environments: Combining Technology and Neuroscience

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Abstract

For individuals who are blind, navigation requires the construction of a cognitive spatial map of one's surrounding environment. Novel technological approaches are being developed to teach and enhance this cognitive skill. Here, we discuss user-centered, audio-based methods of virtual navigation implemented through computer gaming. The immersive, engaging, and heavily interactive nature of the software allows for the generation of mental spatial representations that can be transferred to real-world navigation tasks and, furthermore, promotes creativity and problem-solving skills. Navigation with virtual environments also represents a tractable testing platform to collect quantifiable metrics and monitor learning. Combining this technology with neuroscience research can be used to investigate brain mechanisms related to sensory processing in the absence of vision.

Keywords: blindness, orientation and mobility, navigation, neuroplasticity, gaming

Introduction

It is crucial for individuals who are blind to develop good navigation skills in order to remain functionally independent. Surprisingly, very little work has been done to elucidate how the brain itself carries out this task in the absence of sight. Orientation and mobility (O&M) training represents the formal instruction of these skills and is geared at developing strategies to assist with orientation, route planning, updating information regarding one's position, and reorienting to reestablish travel (Blasch, Wiener, & Welsh, 1997). To navigate effectively, a person needs to develop sensory awareness (i.e., acquire information about the world through remaining sensory modalities) and searching skills (so as to locate items or places efficiently) and to keep track of the spatial relationships between objects within the environment (Blasch et al., 1997; Loomis, Klatzky, & Golledge, 2001; Welsh & Blasch, 1980). The mental representation of an external space is referred to as a cognitive spatial map (Landau, Gleitman, & Spelke, 1981; Strelow, 1985; Tolman, 1948). In contrast to the sighted, individuals with profound visual impairment cannot rely on visual cues to gather this information and visually order and classify their physical environment. Instead, an individual who is blind has to rely on other sensory channels to obtain

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 Received February 2, 2009; Accepted May 22, 2009

appropriate spatial information regarding their surroundings (Thinus-Blanc & Gaunet, 1997). Indeed, it is generally believed that an individual who is blind (both early and late onset) develop compensatory behavioral strategies through the use of their remaining senses (Carroll, 1961; Wagner-Lampl & Oliver, 1994).

The theoretical underpinnings related to navigation skills in the absence of sight have been the subject of intense debate. It has been classically assumed that because of this high reliance on visual cues, individuals who are blind (particularly, early blind children) must in turn have cognitive difficulties in representing spatial environments and, consequently, impaired navigation skills. However, a review of literature reveals contradictory results (particularly in relation to the role of prior visual experience), calling into question the conclusions of these earlier interpretations. In fact, some studies have reported that no differences exist in terms of how well individuals who are blind are able to mentally represent and interact with spatial environments (Landau et al., 1981; Morrongiello, Timney, Humphrey, Anderson, & Skory, 1995; Passini & Proulx, 1988), and in certain spatial navigation tasks, individuals with profound blindness have been shown to exhibit equal (Loomis et al., 2001) and, in some cases, even superior performance (Fortin et al., 2008) when compared to sighted control subjects.

Given these contradictory reports regarding behavioral performance and the ability of individuals who are blind to compensate for the lack of visual sensory input, one has to ask whether differences in spatial mental constructs and navigation skill are solely due to *visual deprivation itself* (and related developmental factors such as the timing and profoundness of vision loss) or whether they reflect an impoverished or incomplete *acquisition* of necessary spatial information through other sensory channels. From a rehabilitation standpoint, perhaps what is missing is a better way to access, manipulate, and transfer acquired information—a gap that could be potentially closed through the use of appropriate technology. Here, we propose how the combination of computer-based virtual environments and neuroscience research may help answer these questions by developing scientifically testable training strategies aimed at improving navigation skill in individuals with severe visual impairment. The approach can be described as a user-centered, audio-based immersive and interactive strategy with the goal of developing novel and tractable rehabilitative approaches for improving spatial navigation, problem-solving skills, and overall confidence. Second, by observing brain-related activity associated with virtual navigation (using modern-day neuroimaging methodologies), we can begin to potentially uncover the mechanisms associated with navigation performance as well as how the brain adapts and carries out this task in the absence of sight.

Navigating Using Audio-Based Virtual Environments

With respect to navigation, information captured through sound is very important for developing a sense of spatial orientation and distance as well as obstacle detection and avoidance (Ashmead, Hill, & Talor, 1989; Rieser, 2008). Previous work with individuals who are blind has shown that spatial information obtained through novel computer-based approaches using sound (Ohuchi, Iwaya, Suzuki, & Munekata, 2006; Riehle, Lichter, & Giudice, 2008) as well as tactile information (Johnson & Higgins, 2006; Lahav, 2006; Pissaloux, Maingreaud, Velazquez, & Hafez, 2006) may prove useful for developing navigation skills. In parallel, many advances in computer technology have improved information accessibility in general. For example, many individuals with visual impairment are familiar with speech-based systems (e.g., screen readers or text to speech interfaces [TTS]) as well as contextual nonspeech information (e.g., alerts using associative and realistic sounds). With respect to contextual learning, virtual environments and simulations (e.g., flight simulators for pilot training) have received considerable interest as a novel means to interact with complex information using multiple frames of reference (e.g., egocentric vs. allocentric perspectives) and for the transfer of knowledge from one situation to another (Dede, 2009). In a series of ongoing studies, we have extended these concepts with the goal of developing audio-based virtual environments as a means to teach, motivate, and develop spatial navigation skills in individuals with severe visual impairment. Specifically, by interacting with auditory cues that describe and characterize a particular environment (e.g., using TTS to provide heading information or identifying an encountered obstacle) and the conceptual alignment of spatial features using audio-based information (e.g., using stereo spectral cues to help localize the spatial location of an object), a user with profound blindness can learn to navigate a relatively complex route (Sanchez & Saenz, 2006). Key to this approach is the fact that auditory-based spatial information is acquired sequentially, within context, and through a highly interactive interface that greatly engages a user to actively explore a given environment and construct a cognitive spatial map effectively and efficiently. Taken further, this then leads to the intriguing possibility that the spatial information acquired through virtual simulation can then be translated to overall enhanced navigation skill within real-world scenarios. In the subsequent sections, we describe a series of software-based applications that have been developed with these goals in mind as well the thought process that has evolved into our current lines of collaborative research in this arena.

AudioDoom

AudioDoom is an auditory-based computer game developed as a means to engage children with blindness in play and improve spatial navigation and problem-solving skills (Sanchez & Lumbreras, 1998). The game is loosely based on a popular "first-person shooter" computer video game called *Doom* (Id Software, Mesquite, TX). In this game, a player navigates through a predetermined labyrinth of walls and corridors, locating various items and avoiding monsters so as to find his or her way to an exit portal and start the next level. Key to succeeding in this game is to maintain an internal mental map regarding the spatial location of objects encountered and keep track of areas explored. Briefly, the auditory version of the game ("AudioDoom"; Sanchez & Lumbreras, 1998) works much the same way but involves the use of sound spectral cues (e.g., door knocks and footsteps) as a means to acquire contextual spatial information regarding one's surroundings during game play. Using a keyboard, mouse, or joystick, a gamer can move in any direction (stepping forward or turning right or left) and interact with the environment in a step-by-step fashion (i.e., through a series of sequential "encounters") so as to pass through a corridor, open a door, pick up treasure, and so on. The gaming structure organizes the level into several predetermined corridors, dead ends, and pathways, giving a sense of the entire area laid out over a three-dimensional space (Figure 1A). As the paths to be explored are constrained by the use of corridors rather than true open spaces, a player is able to maintain his or her sense of orientation and heading. Thus, played out in a corresponding three-dimensional auditory virtual world, the user builds a spatial mental representation based on these sequential and causal encounters within a goal-directed navigation framework (Sanchez & Lumbreras, 1998).

In an early study, Sanchez and Lumbreras (1998) found that children who are blind ($n = 7$, aged between 8 and 11, all with early-onset and profound blindness) who played *AudioDoom* found the game very enjoyable (as assessed through the use of subjective questionnaires). Interestingly, supervising teachers also subjectively reported that blind gamers demonstrated improved cognitive abilities, problem-solving skills, and overall sense of self-confidence transferring to other areas of their course work (Sanchez & Lumbreras, 1998). However, perhaps even more interesting, was the fact that following play, the gamers were able to create tactile representations of the route they navigated in the game (e.g., using Lego® blocks; Figure 1B). Comparing their final constructions with the target virtual environment revealed that they were able to accurately represent the encounters and navigation route they followed (Figure 1C), suggesting a great degree of fidelity in the spatial cognitive maps generated following game play.

These observations reported during initial field testing of *AudioDoom* are important in terms of our overall discussion of navigation skill. Specifically, they demonstrate, first, that auditory information can provide for accurate cues that describe spatial environments and the relationships between objects and, second, that users of the game who have profound blindness can generate accurate spatial cognitive maps based on auditory information using an interactive and immersive virtual environment. Furthermore, the interactive and immersive nature of the game not only provides for a strong motivating drive but also demonstrates that spatial cognitive constructs can be learned implicitly and rather simply through causal interaction with the software.

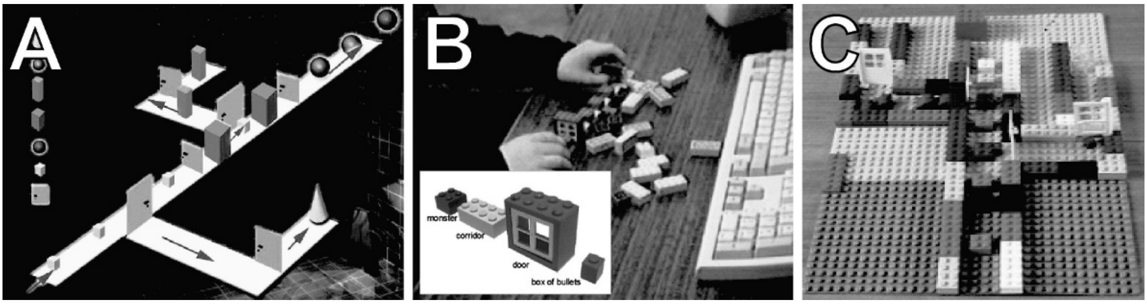

Figure 1. *Interacting with* AudioDoom*. (A) Figure depicting a target game level with corridors, doors, dead ends and objects. (B) After interacting with* AudioDoom*, a child is asked to create a model of the explored level using Lego® pieces representing different objects (inset figure). (C) The child's reconstruction of the level is an exact match of the target level depicted in (A). Figures modified from Sanchez and Saenz (2006).*

AudioMetro

In parallel to *AudioDoom*, another audio-based software interface has been developed with the goal of assisting users with visual impairment to organize and prepare a travel route before riding on the actual subway. This interactive software called *AudioMetro*, is based on the urban subway system of the city of Santiago, Chile, though, in principle, any subway system can be rendered (Sanchez & Maureira, 2007). Interacting with *AudioMetro* is based on a metaphor that simulates travel through a subway car. The metaphor considers notions of consecutive, transfer, and terminal stations and allows the user to simulate the experience of the entire voyage from start to finish. As with most urban subway systems, travel between two stations is sequential and along a specific line that covers both directions. Transfer stations consist of different levels with each specific line having its own level. In a typical session, the user has to first choose the departure and arrival stations of the voyage using an interactive menu (keyboard input and TTS interface; Figure 2). The software then automatically calculates the optimal route from the departure to the arrival station. In the second stage, the user travels virtually through the subway network, starting at the departure point, passing through consecutive stations, and making appropriate transfers until finally arriving to the desired destination. The software has an inherent sequential and unidirectional flow, allowing the user to explore the subway network and associated landmarks provided through audio feedback. As a result, users can familiarize themselves with the basic organization of the subway system and reinforce important concepts, such as the relative distance between stations, appropriate transfer points, platforms associated with each line, and key landmarks and facilities present at various stations.

To evaluate the usability and validity of this software, Sánchez and Maureira (2007) recruited seven participants (aged between 15 and 32, all legally blind and with varying degrees of residual visual function). In summary, the authors found that users of *AudioMetro* were able to initially plan their voyage and, over time, construct a mental representation of the overall organization and layout of the subway system and the interconnections of the various lines (as verified by tactile model construction). Furthermore, users were able to implement the knowledge gained by traveling independently throughout a series of test scenarios without the need of a guide present. Users also reported a greater sense of autonomy and competence in using the subway network (assessed using subjective rating scales) (Sanchez & Maureira, 2007). The results with *AudioMetro* suggest that audio-based interactive software can be used to access information as well as simulate and play out hypothetical scenarios that can potentially translate into enhanced navigation skills. Furthermore, these generated mental representations can be large scale and correspond to real-world environments. Finally, as with the case of *AudioDoom*, the use of gaming metaphors and the interactive and immersive nature of the software serve as powerful motivating incentives for their use.

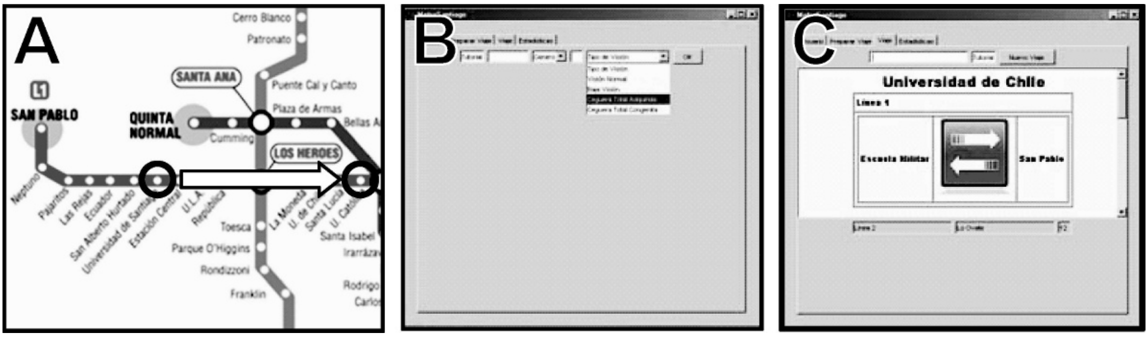

Figure 2. *Interacting with* AudioMetro*. (A) Section of the Metro map of Santiago, Chile. Travel from Universidad de Santiago to Santa Lucia station is indicated. (B) A user interface to select the desired origin and destination of travel. (C) Simulation of travel though the subway. Figures modified from Sanchez and Maureira (2007).*

Audio-Based Environment Stimulator

Building on and combining the strengths of the aforementioned software approaches, we then hypothesized that users with profound visual impairment who interact with a virtual environment that represents a real place (e.g., a building in a individual's school) can not only create an accurate cognitive spatial map of that place but may also potentially transfer this acquired spatial information to a large-scale, real-world navigation task. Key to demonstrating this premise would be to develop a flexible and modifiable software platform that leverages the advantages associated with both gaming metaphors and interactive virtual navigation. Following through with these notions, we are currently investigating the feasibility and effectiveness of using an audio-based virtual navigation software called *Audio-Based Environment Stimulator* (AbES) (Sanchez, Tadres, Pascual-Leone, & Merabet, 2009). This software is similar to those previously described in terms of its audio-based navigation and interactive capabilities but has the added feature of a floor plan editor that allows an investigator to generate virtually any physical space desired, including open rooms and corridors, multiple floors as well as furniture and obstacles (Figure 3). The software also incorporates various data collecting methods that can be used to assess behavioral performance (e.g., reconstruction of the route traveled, including the time taken to navigate to target, distance traveled, and errors made). The virtual environment is scaled so that each step is meant to represent one typical step in real physical space. Using a keyboard, a user explores the building virtually, moving through the environment and listening to appropriate spectral cues after each step taken (e.g., a knocking sound in the left stereo channel is heard as the player walks past a door on the left, and walking up stairs is associated with sequential steps of increasing pitch). Orientation is based on cardinal compass headings, with "north" defined in relative terms as the direction of forward movement as one enters the virtual space. Users have reported that they perceive their movement as "forward" in the virtual space, and thus the use of cardinal terms of direction is appropriate. The user also has a "where am I?" key that can be pressed at any time to access TTS-based information that describes his or her current location in the building, orientation, and heading as well as the identity of objects and obstacles in their path. As a proof of principle, pilot data from one test subject (early blind and aged 32 at the time of study) suggests that after approximately 40 to 60 minutes of interacting with AbES, the user was indeed able to survey and explore the layout of the building and locations of the target objects virtually. Furthermore, the subject was able to demonstrate a transfer of cognitive spatial knowledge in a real-world navigation task by locating objects found within a room in the actual physical building.

Another unique feature is the fact that AbES can be played in two modes: "directed navigation" or a "game" (or "open exploration") mode. In directed navigation mode, a facilitator places the user in any location in the building and directs the individual to a target destination so as to simulate the navigation and exploration of the building. In the game mode, the user interacts with the virtual world on his or her own (i.e., without a facilitator) with the goal of exploring the entire building in order to collect hidden gems while avoiding roving monsters that can potentially take the gems away and hide them elsewhere (Figure 3B). Thus, in either mode, users interact with the virtual environment to gain spatial information and generate a cognitive map of the spatial surroundings. However, given the implicit nature of acquiring spatial information through gaming, we have speculated that the construction of these cognitive spatial cognitive maps may prove to be different, depending on the mode of play. In other words, AbES played in game mode is in effect designed to promote full exploration of the building, thereby maximizing creativity and to encourage the development of "higher-level" spatial skills (Blasch et al., 1997). By comparison, we hypothesize that individuals who interact with AbES in directed navigation mode will generate spatial constructs that are limited to the actual routes encountered and as defined by the facilitator. This latter point is of particular importance not only in terms of generating cognitive spatial maps but also with regard to safety. It would be reasonable to assume that individuals who have a more "robust" cognitive spatial map of their surroundings are more likely to be flexible in their spatial thinking and thus can come up with alternate routes for navigation when needed as opposed to relying on rote memory alone. Current work is now aimed at investigating these hypotheses by assessing how well individuals are able to transfer their acquired spatial information from the virtual to the real physical environment and as a function of the mode of acquiring that information.

Combining Technology and Neuroscience: Watching the Brain in Action

As mentioned in the introduction, it is generally believed that in the absence of sight, an individual develops compensatory strategies by using their remaining senses more effectively so as to remain functionally independent (Carroll, 1961; Wagner-Lampl & Oliver, 1994). In line with this view, mounting scientific evidence now suggests that these adaptive skills develop in parallel with changes occurring within the brain itself (Bavelier & Neville, 2002; Pascual-Leone, Amedi, Fregni, & Merabet, 2005). It is now established that these changes implicate not only areas of the brain dedicated to processing information from the remaining senses such as touch and hearing but also regions of the brain normally associated with the analysis of visual information (Merabet, Rizzo, Amedi, Somers, & Pascual-Leone, 2005; Theoret, Merabet, & Pascual-Leone, 2004). In other words, understanding how the brain changes in response to blindness ultimately tells us something about how individuals compensate for the loss of sight. This "neuroplasticity" or "rewiring" of the brain may thus explain the compensatory and, in some cases, enhanced behavioral abilities reported in individuals who are blind, such as finer tactile discrimination acuity (Alary et al., 2008; Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000), sound localization (Ashmead et al., 1998; Gougoux et al., 2004; Lessard, Pare, Lepore, & Lassonde, 1998), and verbal memory recall (Amedi, Raz, Pianka, Malach, & Zohary, 2003).

Evidence of functional and compensatory recruitment of visual areas to process other sensory modalities in the absence of sight has resulted largely from neuroimaging studies (Theoret et al., 2004). Modern brain imaging techniques such as functional magnetic resonance imaging (fMRI)[1] can identify areas of the brain that are associated with a particular behavioral task. Navigation skill, for example, has been extensively studied in sighted individuals (Maguire et al., 1998), and key brain structures that underlie this skill have been identified (such as the hippocampus and parietal cortical areas). However, very little is known as to how these

[1]Neuroimaging techniques such as fMRI allow us to follow more closely and objectively phenomena related to behavioral performance at the level of the human brain. Unlike standard MRI images that give high-quality anatomical images of the brain, *functional* MRI takes advantage of the fact that when a region of the brain is highly active, there is an oversupply of oxygenated blood to that region. By measuring the relative amounts of oxygenated and deoxygenated blood, it is possible to determine which regions of cortex are more active for a given task over a time scale of a few seconds. This signal is then analyzed to generate images of the brain that reflect regions of the brain implicated with the behavioral task being carried out (see Logothetis, 2008).

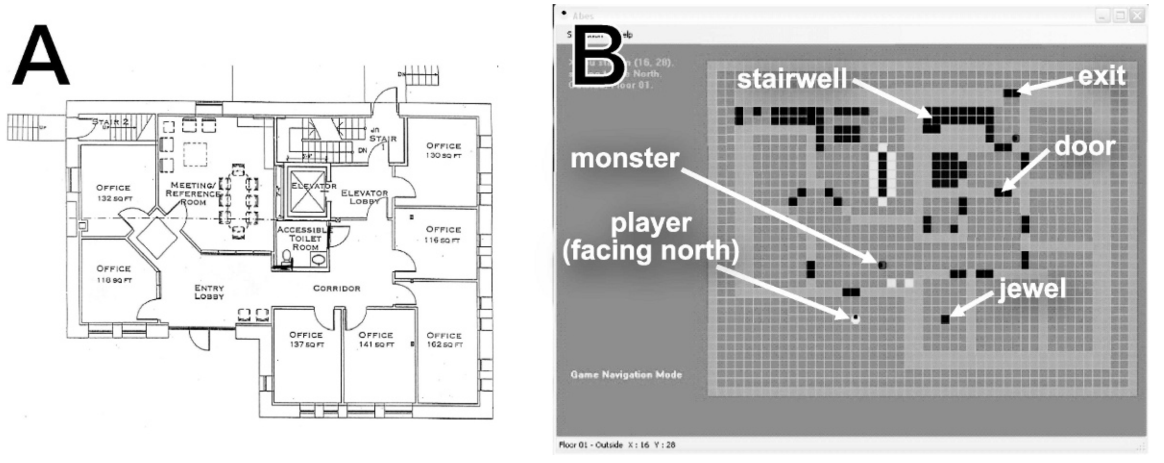

Figure 3. *Real and virtual worlds with AbES. (A) Actual floor plan of a target building. (B) Virtual rendering of the floor plan in AbES game mode showing various objects the user interacts with.*

same corresponding areas of the brain relate to navigation performance in individuals who are blind and as a result of the neuroplastic changes that follow vision loss. To help uncover this issue, we have adapted the AbES game so that it can be played within an fMRI scanner (Figure 4A). Again, as a proof of concept, we have shown that interacting the AbES within the scanner environment (testing with a sighted individual) leads to selective task activation of specific brain areas related to navigation skill. Specifically, when the subject listens to the auditory instructions describing his or her target destination, we observe brain activity localized within the auditory regions of the brain. When that same person is asked to randomly walk through the virtual environment (i.e., without any goal destination), we find brain associated activity within sensory-motor areas related to the key presses of the hand. However, when the same person is now asked to navigate from a predetermined location to a particular target, we see a dramatic increase in brain activity that implicates not only the auditory and sensory-motor regions of the brain but also regions of the visual cortex (to visualize the route) and frontal cortex (implicated in decision making), parietal cortex (important for spatial tasks), and hippocampus (implicated in spatial navigation and memory) (Figure 4B). As a next step, work is currently under way comparing brain activation patterns associated with virtual navigation in sighted (through sight and through hearing alone) with that in individuals with profound blindness (early and late onset). Of particular interest will be the role of the visual areas as they relate to plasticity and overall navigation performance. For example, does greater visual cortex activation correlate with strong navigating performance regardless of visual status and/or prior visual experience? Furthermore, how do activation patterns and brain networks change over time as subjects continue to learn and improve in their overall navigation skills? Are there specific areas or patterns of brain activity that can help identify "good navigators" from those patterns that typify poor navigation? These as well as many other intriguing questions await further investigation.

Conclusions and Future Directions

O&M training remains a mainstay in blind rehabilitation, and with systematic and rigorous training, individuals with visual impairment can gain functional independence. It is important, however, that training strategies remain flexible and adaptable so that they can be applied to novel and unfamiliar situations. Further, training must be tailored to a person's own strengths and weaknesses to address their particular challenges, needs, and learning strategies. The creative use of interactive virtual navigation environments such as the software approaches presented here, as well as other strategies (e.g., tactile representations; Ungar, Blades, & Spencer, 1995; see also Blasch et al., 1997), may provide for this flexibility and supplement

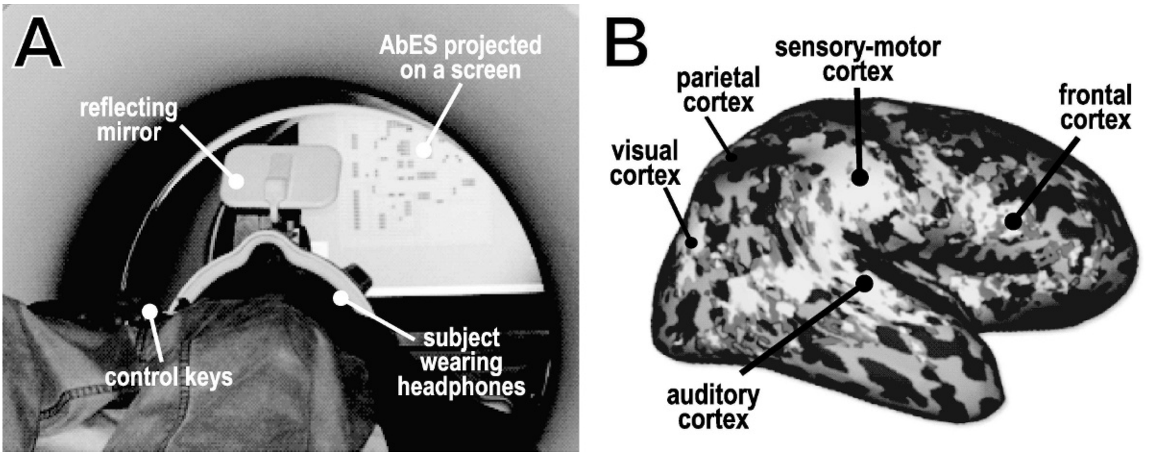

Figure 4. *Brain activity associated with navigation. (A) Sighted subject lying in the scanner and interacting with the AbES navigation software. (B) Activation of cortical areas while actively navigating with AbES. Areas implicated with active navigation include sensory-motor areas and auditory cortex as well as frontal, visual, and hippocampal (not shown) areas.*

current O&M training curricula. Certainly, that there may be substantial differences between the behavioral gains obtained though virtual compared to real physical navigation. For example, virtual navigation training within a controlled environment allows for the opportunity to play out multiple scenarios while potentially alleviating associated stress and risk issues. Conversely, there may be inherent advantages associated with the actual execution of physical movements in real-world situations that ultimately translate into enhanced motor planning and eventual consolidation of O&M task-related skills. We reiterate that we are not advocating for a replacement of current rehabilitative techniques with virtual training. Rather, we propose an adjunctive strategy that not only draws on the benefits of high motivational drive but also provides for a testing platform to carry out more controlled and quantifiable studies, including neuroscience-based investigations.

We have described a series of interactive audio-based computer software and virtual environments designed to serve as novel rehabilitative approaches to improve spatial navigation, problem-solving skills, and overall confidence in individuals with visual impairment. We continue to investigate the feasibility, effectiveness, and potential benefits of learning to navigate unfamiliar environments using virtual auditory-based gaming systems. In parallel, we are developing methods of quantifying behavioral gains as well as uncovering brain mechanisms associated with navigation skill. A key direction of future research will be to understand what aspects of acquired spatial information are actually transferred from virtual to real environments and the conditions that promote that transfer (Peruch, Belingard, & Thinus-Blanc, 2000). Furthermore, understanding how the brain creates spatial cognitive maps as a function of learning modality and over time as well as an individual's own experience and motivation will have potentially important repercussions in terms of how rehabilitation is carried out and, ultimately, an individual's overall rehabilitative success.

Moving forward, future work in this arena needs to continue employing a multidisciplinary approach drawing in expertise from instructors of the blind, clinicians, and technology developers as well as neuroscientists, behavioral psychologists, and sociologists. By further promoting an effective exchange of ideas, we believe that ultimately this will lead to an enhancement of the quality of life of individuals living with visual impairment and enhance our understanding of the remarkable adaptive potential of the brain.

Acknowledgments

Support for the work presented here is from a K 23 EY016131 award from the National Eye Institute (to L.B.M.) and the Chilean National Fund of Science and Technology, Fondecyt 1090352, and Project

CIE-05 Program Center Education PBCT-Conicyt (to J.S.). The authors would like to thank Rabih Dow, Maria Goldstein, Joe Quintanilla, and the staff at the Carroll Center for the Blind in Newton, Massachusetts, for their continued enthusiasm and support. The authors also thank Mark A. Halko with assistance with the neuroimaging studies and Darick Wright and Richard Long for helpful comments in preparing this manuscript.

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Practice Report

Putting Orientation Back into O&M: Teaching Concepts to Young Students

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Abstract

Orientation skills are the tools that should be in every student's toolbox. Orientation skills are learned skills; orientation techniques can be broken down into simple steps and should be systematically taught to all preschool/early elementary students with visual impairments. As orientation and mobility instructors, we need to be aware of not only what to teach but also how to teach orientation skills.

Keywords: orientation and mobility, preschool students, elementary students

Introduction

Have you ever wondered why some cane travelers are independent on all routes while others tend to be rote route travelers, unable to determine new routes and frequently unable to make corrections if lost? The independent cane traveler has numerous orientation and mobility (O&M) skills or tools in his or her toolbox and knows when to pull out and use a specific tool. Rote travelers tend to focus on specific directions on a route, often without a mental map of the whole area. Orientation skills are the tools that should be in every student's toolbox. Orientation skills (knowing where you are, what is around you, where you are in relationship to other things, and where you are going) are learned skills; orientation techniques can be broken down into simple steps and should be systematically taught to all preschool/early elementary students with visual impairments. Most students with multiple disabilities (developmental age equivalent to preschool/kindergarten) can also benefit from these same orientation concepts with little or no modifications. Students with multiple disabilities may need additional time to learn these orientation concepts and more repetition to learn the concepts and may be limited in their abilities to generalize these concepts to other environments.

As O&M instructors, we need to be aware of not only what to teach but also how to teach O&M skills. Focusing on cane techniques and learning specific routes are important; however, this method, when used in isolation, tends to encourage rote route skills for many of our O&M students. Focusing on orientation skills promotes the student's ability to be able to develop spatial concepts and a mental map, to develop helpful routines when lost, and to generalize skills learned in one environment to other environments.

When Do We Teach Orientation Skills?

The first step is to start teaching orientation skills early. There are wonderful (and simple) orientation activities that can be done with infants and toddlers. As a preschooler begins to walk, his or her world immediately begins to expand; with systematic instruction from an O&M instructor, the preschooler's orientation skills as well as mobility skills will take off. (In the United States, public school O&M instructors are responsible for students 3 years old and older, so this article addresses orientation skills for preschoolers and older.)

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 Received January 18, 2009; Accepted May 22, 2009

Observing older O&M students can be enlightening when they identify and analyze what types of orientation problems/issues these students demonstrate, along with their O&M strengths. By breaking down these habitual problems into simple steps, it is then possible to begin teaching the basic foundation skills to younger students in order to build strong lifelong orientation skills. It is easier to systematically teach good foundation orientation skills to young students (in small, age-appropriate steps) than to try to retrain entrenched bad habits in teens and adults.

What Are Foundation Orientation Skills?

Good directions are an essential part of successfully completing a route. What if you were given the following directions? We are going to "that place." To get there, you "go this way," then "turn by the thingy." Go until you get to "that street." It is beside the "what-you-ma-call-it."

These directions are ineffective because they lack all the crucial information, such as street names, landmarks, and which direction to turn. O&M students need to know all this information in order to travel independently. O&M students should be able to locate, identify, and then use this information—all part of their "foundation orientation skills."

The four foundation orientation skills are the following:

- Naming and labeling (name hallways, rooms, landmarks, streets, and so on)
- Landmarks and clues (identify and use landmarks and clues)
- Intersections and turns (identify intersections and have spatial awareness of turns)
- Directions (understand the spatial concepts of right, left, straight ahead, and behind)

These are the four basic things that a student with visual impairments must master in order to have good orientation.

How to Teach Foundation Orientation Skills

Naming and Labeling

O&M instructors cannot successfully teach routes if the student does not know the specific names for important landmarks, hallways, streets, and so on. Remember the previous directions where you were supposed to turn by the "thingy" and go until "that street"? In order to successfully follow the directions, you must know what "thingy" means (landmark such as McDonald's) and the name of the street (Franklin Street).

With younger students (preschoolers and older), O&M instructors should consistently name all classrooms, doors, areas around the school, and hallways. (Teachers/parents should also be recruited to help follow through with naming skills.) Be sure to use names that make sense to the student, such as calling the room by their teacher's name. There are multiple doors in most school hallways; naming a door "door" does not help distinguish one door from another door. Be sure to teach adjectives along with the noun (Mrs. Jones's door, glass front door, and so on). Be sure to name the hallways as well (cafeteria hallway, front door hallway). Naming hallways and learning the concept that the hallway is linear, not just one point like a specific door, are crucial prerequisites to teaching school intersections and street concepts. Students should also identify and name important landmarks around the school (kindergarten bathrooms, front door rug). Preschoolers can begin naming objects (teacher's desk, cubbies) and areas in their classroom (writing center, housekeeping center). These kids can also begin to learn to categorize what might be found in each center (writing center = crayons, brailler; housekeeping center = dishes, sink). Students can also categorize rooms at home (family room = couch, TV; kitchen = stove, refrigerator). When orienting a student to the playground, be sure to name the play structures (tunnel slide, curvy slide). Also name streets and stores—name everything in the school, home, and community environments that the student has contact with.

A typical preschool/kindergarten skill is to identify shapes and colors. Our students with visual impairments should learn to identify and name shapes, colors (if appropriate), and textures. This is not only a typical preschool/kindergarten goal but also a prebraille/literacy skill and O&M prerequisite for "tactile markers," "tactile door markers," and tactile maps. Tactile markers are textured symbols that are used to help the student distinguish specific areas (student's cubby, table). Use different shapes, textures, and colors when making tactile markers, as one student might focus on the texture to distinguish the marker, and another student might focus on the shape. Tactile markers should be small—a student can identify the shapes best if it fits in his or her small hand. Tactile door markers are similar textured markers that are used to distinguish doors/classrooms. The tactile door markers are adhered to the wall at the child's eye height (if there is some vision) or hand height (if no vision), close to the door frame (student finds the wall, searches for the frame, and then follows the frame up/down until he or she locates the marker), and on the same side of the door as the doorknob (safety reasons). Initially, the student should be encouraged to reach up and touch the tactile door marker every time he or she enters the classroom. Tactile door markers are used to teach basic orientation concepts (by helping the student easily identify a specific door); however, tactile door markers are also foundation orientation concepts, as they help the student have goal-directed routes (vs. wandering), are motivating, and are symbols that can also be used to label the same locations on a tactile map. Simple tactile maps are an easy, concrete way for young students to understand a big environment.

By kindergarten, most academic students are ready to learn and use basic "self-familiarization" skills. Self-familiarization is a mental mapping technique in which a room (or business) is systematically described. Most rooms/businesses are basically in the shape of a square/rectangle. Each of the four walls is numbered, and the main characteristics (or departments) are associated with each wall. Wall #1 is always the main entrance door. For example, in the classroom, Wall #1 has the hallway door, coat hooks, and bathroom door. Wall #2 (to the right) has the whiteboard and circle area. Wall #3 (back of room) has the windows and centers. Wall #4 (to left when back is to the hallway door) has the teacher's desk and cubbies. When initially self-familiarizing the room, the student should start by walking along the edges/walls (if possible) of the room before learning the interior of the room. Remember the difference between teaching rote routes versus tools that can be generalized to other areas? The self-familiarization technique is a prime example of teaching "O&M tools." If the student is exposed only to specific routes in the interior of the classroom, he or she will be caught up on locating the next specific landmark; the student will not be thinking about where he or she is in relationship to other main areas within the classroom (no mental map). For example, on a rote route from the circle area to the coat hooks, the student will be looking for a desk to trail through the open space but will ignore the sounds coming from the open door on Wall #1. The student will not be able to compensate if there are unfamiliar obstacles in his or her path, nor will he or she be able to independently determine new routes.

Each main characteristic along the wall should be named. From each characteristic, have the student point to the other main characteristics. If in the kitchen center, have the student listen for the hallway door and point to it. Ask the student to point to and name the various walls (#1, #4). Help the student name the direction as well (straight ahead, behind, right, left). Ask the student to turn, then repeat naming and pointing. In a business (such as Wal-Mart), the student will associate the four main walls with departments. Wall #1 has the front doors, cash registers, and pharmacy; Wall #2 (right side of store) has grocery department; Wall #3 (back of store) has electronics, camera counter, and toys; and Wall #4 (left side of store when back is to the front doors) has automotive, hardware, and lawn and garden.

Teaching self-familiarization should start in preschool with the concept of a square (square has four sides). Find a small room in the school (such as a teacher's lounge) to reinforce self-familiarization skills. In a teacher's lounge, Wall #1 is the door, Wall #2 has the refrigerator and microwave, Wall #3 has the bathroom door and table, and Wall #4 has the couch. Have the student explore the office, fort/playhouse on the playground, elevator, and so on. Be creative—self-familiarization techniques can be taught almost anywhere. Self-familiarization skills can easily lead to and be reinforced by the use of simple tactile maps. When making a tactile map of the classroom, be sure to encourage the same spatial (mental map) techniques that have already been introduced. With all maps, have the "bottom" of the map (edge closest to the student) as Wall #1; Wall #3 is the "top" of the map ("back" of the room"; the edge farthest from the student). Do not have the student rotate the map as he or she "travels" along map routes. Encourage the student to develop a mental map of the area and verbalize directions by walking toward a wall/department rather than saying "turn left/right." (Go to Wall #1, front doors.) There are always landmarks within the store that help the student find specific areas. (When looking for the front door—on Wall #1—the student can hear the cash registers and, using his or her mental map, can remember that the cash registers are also on Wall #1 by the front doors.) Remember how the student pointed to the main areas and named the walls when walking around the room from different locations? This helps the student establish specific locations in relationship to other locations as he or she moves through space versus rote routes. When a young student reverses the route, he or she becomes confused as the left/right directions change. (The cash registers that were on the left when walking toward Wall #4 are now to the right when walking toward Wall #2.) It is easier for a young student to develop good mental maps and spatial concepts using these techniques. As the student matures, he or she will frequently be able to use right/left directions (reversing the directions as he or she reverses more complex O&M routes).

Landmarks and Clues

As discussed, all landmarks and clues should be named. The next step is to teach the student to identify these landmarks when traveling routes. Initially, preschoolers want to touch everything with their hands. There are numerous opportunities for a young student to touch and explore with their hands; however, it is important to teach the student to locate and identify the landmark with an adaptive mobility device (AMD; commonly known as a precane) or long cane rather than his or her hand. It is easy for most preschoolers to learn to identify objects by the auditory sound when their cane bumps the object, especially a familiar object. The term "cane" is used to mean either AMD or long cane. Preschoolers are overwhelmed when asked to simultaneously focus on learning orientation skills and trying to use a safe long cane technique. It is recommended to teach orientation concepts early (while the student is using the less challenging AMD) and switching to the long cane after foundation orientation skills are mastered. It is harder for a young student to notice subtle flooring differences, such as when the cane locates a rug—the student will often be startled when his or her foot finds the rug. It is very important to teach the student to pay attention to surface changes (vs. locating objects), as this is a safety skill for locating drop-offs.

Teach the student to "bump and walk up" when the cane locates an object (vs. reaching out with their hands). After the cane "bumps" the object, the student should "walk up" to the object until the cane is upright in front of his or her body. This helps the student learn the spatial distance between the end of the cane and his or her body—how many steps he or she will take before actually reaching the object with his or her body. It is also a critical safety issue, especially when locating doors. If kept in the correct position, the cane will help stop a door from unexpectedly being opened and crashing into the student. "Bump and walk up" also prepares a student for locating and walking safely toward a drop-off. As the student learns the spatial concept of how far the cane is out in front of him or her, the student will be more comfortable when locating drop-offs, as he or she will understand how much reaction time the cane truly gives.

Landmarks can be auditory (hearing the noisy cafeteria, echo in bathroom), tactile (touching objects), and/or olfactory (smelling leather in shoe department, food in the cafeteria). Again, landmarks should first be named, then the student should be able to locate/identify the landmark, and, finally, the student should use the landmark for orientation purposes (at the bathroom, turn right).

Intersections and Turns

Most students appear to travel routes successfully as long as they do not have to consciously make a turn. Understanding the concept of an intersection is often the main issue. Naming hallways and understanding that the halls are linear are critical concepts when teaching intersections. Teach the student that an intersection is where two hallways (sidewalks, aisles, or streets) meet. If the student is in an intersection, ask him or her to name the two hallways (main hallway and cafeteria hallway; initially, noisy hallways, such as the cafeteria or gym, are best) and then have the student point to specific areas (noisy cafeteria, squeaky front door). Remember to reinforce spatial relationships by having the student turn and repeat naming and pointing to the various hallways/areas.

Most preschoolers do not realize when they have made a turn. They will frequently shoreline a wall (or hand trail a desk) and follow it around the corner without realizing they have completed a turn. The concept of a turn can be taught by having the student put his or her back to the wall, then turn and put his or her right shoulder to the wall, turn and face the wall, and turn and put his or her left shoulder to the wall. Be sure and have the student point to and name various areas while practicing turns. When teaching a turn in an intersection, have the student initially make the turn by shore lining; stop just after the turn and have the student name and point to the two different hallways and then name and point to various areas down each hallway. At the same corner, have the student "hop" into the main hallway, then "hop" back to the cafeteria hallway. Practice having the student make the same turn in the middle of the hallways—without shore lining the wall. Initially, ask the student to hop every time he or she encounters an intersection—kids are very motivated to hop, and it allows the O&M instructor to instantly know if the student is aware of the intersection. Initially, when traveling through intersections, teach the phrase "hop, stop, and figure it out." Have the student identify the intersection and hop, stop in the middle of the intersection, and then figure out where he or she is and where he or she needs to go. "Figure it out" is a verbal prompt to determine "what's here?"—identify things and sounds nearby (cafeteria sounds to the left, office to right)—and "what's next?"—where you are going and how do you get there (turn left in cafeteria hall). This routine encourages the student to develop critical thinking skills as he or she travels along routes (vs. wandering down the hallway). "Figure it out" can be expanded to encourage independence when the student becomes lost. The student can be prompted/referred back to "figure it out" by asking "what's here?" (gym sounds), "what's different?" (identify what should be along the route versus what *is* along the route, e.g., gym sounds instead of kindergarten hall), and "what's next?" (where you are going and how to correct your route to get there, e.g., square off from the gym and go to the kindergarten hallway intersection).

Directions

Naming, identifying intersections, making turns, and directions are all intertwined. Always include the terms "right," "left," "front," and "behind." Sighted students know these directional concepts in kindergarten; our students typically know right/left concepts as preschoolers. Young students first learn to raise their right/left hand. Pointing right/left is the next step. Have the student raise the right/left hand, then point right/left. Pointing is typically difficult for our students, as they tend to point using limp arms/hands. To teach how to physically point, start with the student's back against the wall. Have him or her reach out and touch an object (or the O&M instructor) that is also against the wall. The student should be encouraged to have a straight elbow and to press his or her arm against the wall at shoulder height. The student should make a fist; using an index finger only, he or she should touch the object/instructor. The object/instructor should move away, and the student should point again, pretending that he or she is about to touch the object. Later, when the student is waiting to cross a street and wants a car to go, he or she can firmly point to the car and then forcefully move his or her hand to point out the direction the car should go. (Many of our students have ineffective, limp-handed waves when trying to tell a car to go.) "Distance right/left" is a more abstract concept. Teach distance right/left by having the student put his or her back against the wall with the O&M instructor on the student's right. Have the student point to the O&M instructor and verbalize "right." The O&M instructor can move around the student (left side, front, behind—possibly using a motivating, noisy toy). Gradually move farther away from the student (out of arm's reach) and repeat. Then have the student point to distant auditory landmarks (noisy cafeteria) and name the distant direction.

There is a limited window of opportunity in which to easily teach spatial concepts to young students with visual impairments. When foundation orientation concepts—especially spatial concepts—are introduced early, preschoolers effortlessly incorporate these concepts into their expanding world. As a young student's world expands from the home to the preschool classroom, school building, and community, his or her orientation concepts should also expand. For most congenitally blind travelers, these orientation skills have to be introduced as the student is first exploring new environments so that "tuning in" to landmarks becomes as natural as walking with a cane. Each foundation orientation skill is a tool in the student's toolbox—enabling the student to travel in a variety of environments successfully and independently. A good traveler is aware of multiple landmarks and knows how to use these landmarks for orientation purposes. He or she has mental maps of familiar areas and is able to use self-familiarization techniques to develop mental maps of new areas. By naming hallways, streets, and landmarks and developing a mental map of these landmarks, along with other established orientation skills, a student can independently figure out shortcuts and develop new routes. This good traveler listens and develops new landmarks to help travel old and new routes. A rote adult traveler tends to "tune out" (is unaware) of landmarks and/or does not use the landmark for orientation purposes; he or she rarely has a mental map of the surrounding environment. It is very difficult for an established adult rote traveler to relearn the way to process orientation concepts in order to become a more independent traveler. Introducing students to foundation orientation concepts early, in a systematic, step-by-step, age-appropriate manner, will maximize each student's potential to become a successful, independent traveler.

Accessible Pedestrian Signals in San Francisco: Example of Successful Advocacy

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Abstract

This article is a case study of accessible pedestrian signals (APS) in San Francisco. APS provide audio and vibrotactile information to visually impaired pedestrians to assist in safe street travel. The article summarizes the advocacy efforts that led to an historic settlement agreement between the blind and visually impaired community and the city. It describes the elements of that agreement, including the technical specifications to ensure that APS are up to date and as safe as possible for visually impaired pedestrians. The article brings the reader up to date by discussing how the settlement is being implemented and how many APS are currently installed in San Francisco.

Keywords: accessible pedestrian signals, advocacy, pedestrian safety, mobility, legal rights

Introduction

Pedestrian safety is a cornerstone of an independent life. Pedestrian safety enables people to get to work; volunteer; engage in family, social, and religious activities; and generally live fully in any community. Yet today, quiet cars, complex intersections, sidewalk barriers, right-turn lanes, and other factors combine to make safe, independent travel by blind or visually impaired pedestrians more and more challenging.

Accessible pedestrian signals (APS) can help change that. APS are an important part of ensuring that people who have visual impairments are able to travel independently. The signals—with both an audible and a vibrotactile method of informing pedestrians when the visual "Walk" signal is displayed—are something that every pedestrian with a visual impairment and every AER member should be familiar with.

The purpose of this article is to share information about the APS advocacy effort in San Francisco. We hope this information will help increase the number of effective APS installations across the country. The authors invite AER members to share stories of successful APS advocacy in their communities.

Summary of San Francisco APS Installations and Related Legal Advocacy

Three years ago, the City of San Francisco had one intersection equipped with an APS. As of May 2009, San Francisco has 690 APS devices installed at 69 intersections—putting it with a handful of cities in the United States that have made a serious

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 | Received February 9, 2009; Accepted May 22, 2009

commitment to pedestrian safety for the blind and visually impaired community.

The devices in San Francisco are the result of a successful, multiyear advocacy campaign by the California Council of the Blind, the San Francisco LightHouse, and others. Using the structured negotiations process instead of litigation, the blind and visually impaired community and the city hammered out an agreement in 2007 that is now being carefully implemented. Structured negotiations is a process that avoids litigation and allows potential adversaries to work collaboratively to resolve accessibility issues. The process was a particularly useful advocacy method for the San Francisco blind and visually impaired community's need for APS because advancing technology and new safety research demand that the parties have an ongoing constructive relationship to resolve issues as they arise. Too often, litigation prevents such a relationship from developing.

The APS structured negotiations with San Francisco began when a detailed letter was sent to the city attorney on behalf of a blind San Francisco resident, the California Council of the Blind, and the San Francisco LightHouse for the Blind and Visually Impaired. The letter explained that the absence of APS was a violation of the Americans with Disabilities Act and California law and invited the city to work with us to find a solution that was acceptable to all. In the years leading up to sending the letter, community advocates had tried valiantly to convince San Francisco to install APS, but it had become apparent that legal advocacy was necessary.

Once the city agreed to participate in the structured negotiations process, there were meetings, testing of various devices, information sharing, and much back-and-forth as the terms of the final agreement were worked out. Among the issues that needed to be addressed the cost of the installations, whether all new intersections would include APS installations, means by which the public could request APS, and the nature of the audible walk indicator. The structured negotiations process, which allows the parties to work out thorny issues together rather than submit them to a judge for resolution, created a collaborative environment to resolve even the most challenging issues. In this effort, all parties were greatly assisted by APS expert and local orientation and mobility specialist Linda Myers and by APS experts Beezy Bentzen and Janet Barlow.

As a result of the structured negotiations effort, the city signed a binding legal agreement requiring it to install APS at a minimum of 80 intersections and to spend a minimum of $1.6 million on APS over a two-and-a-half-year period. The agreement also provides that the city will seek additional funding for more installations during the two-and-a-half-year term of the agreement. Since the agreement was signed, additional funding has in fact been secured. Details about the specifics of the San Francisco plan are at the end of this article.

San Francisco's APS Units

The state-of-the art signaling devices being installed in San Francisco are manufactured by Polara Engineering, Inc. (http://www.polara.com), and are being installed and maintained by the city's Parking and Traffic Department. The devices have been installed at various types of intersections equipped with pedestrian signals. Intersections with transit islands, "scramble" intersections (where pedestrians cross in four cross walks at the same time), intersections with a right-turn lane set off by an island, and standard midblock crossings have been equipped with APS since the city signed the APS agreement in 2007.

The APS devices assist blind and visually impaired pedestrians by emitting a rapid ticking sound in tandem with the familiar "Walk" symbol displayed for sighted pedestrians. A large arrow on the push button also vibrates during the "Walk" phase. The devices also have "locator tones"—audible beeps to enable persons with visual impairments to know of their presence and to locate the devices as well as vibrating push buttons during the "Walk" phase. Many installations provide other audible information, such as street names, when pedestrians press the push button for 1 second or longer. Pressing the button also increases the volume of the device. At intersections where a sighted person does not have to press a button to get the "Walk" sign (fixed time intersections), the audible and vibrotactile features are activated without a button push.

These details are included in the technical specifications that were negotiated as part of the APS settlement agreement. The specifications also include information about pole placement, volume settings and other installations, and operational guidelines for successful APS placements. The design specifications are particularly important because they allow for consistency for blind travelers in San Francisco. In San Francisco, all APS units operate in the same manner, and there are not multiple types of units configured in various ways throughout the city as is the case in some other locations where APS have been installed. The APS details set forth in the San Francisco technical specifications are critical to ensuring that APS provide effective information in as safe a manner as possible for pedestrians with visual impairments.

Other APS Issues

In addition to installing the devices, San Francisco representatives are meeting twice a year with blind and visually impaired community representatives to discuss implementation issues as well as any new technology, legal, or safety developments in connection with APS. The city has also committed to maintaining the new devices and has adopted a policy for San Francisco residents to request accessible pedestrian signals. (The policy is available online at http://www.sfmta.com/cms/wproj/aps.htm.) San Francisco has also adopted a detailed checklist to enable it to fairly prioritize APS requests based on safety factors and other criteria. This checklist, known as the Prioritization Tool, is available by contacting the authors. It was based on the tool available at http://www.apsguide.org/appendix_d.cfm.

When the APS program was announced, city officials praised the community advocates and the structured negotiations process. San Francisco's city attorney said in the press release that "this agreement reflects far more than our commitment to public safety—it represents San Francisco's commitment to engage the disability community in a manner that is cooperative rather than confrontational on matters involving accessibility and compliance with the Americans with Disabilities Act…. [I am] thankful for the positive approach taken by advocates for the blind and visually impaired community." The full press release is available online at http://lflegal.com/2007/06/aps-press-release.

Learn More

Everyone reading this article is encouraged to share the information and the following resources with other community members, certified orientation and mobility specialists, students, clients, and local traffic engineers and other state and local officials. Pedestrian safety is a critical issue for the blind and visually impaired community, and APS should be a significant part of all pedestrian safety programs.

AER members interested in learning more about San Francisco's APS program can find the settlement agreement and related documents on Lainey Feingold's Web site at http://LFLegal.com. Lainey, along with civil rights lawyer Linda Dardarian (http://www.gdblegal.com), represented the blind community in negotiations with the City and County of San Francisco.

The direct link to the settlement agreement is at http://lflegal.com/2007/05/sf-aps-agreement. The APS technical specifications can be found at http://lflegal.com/2007/05/sf-aps-agreement/2/.

Jessie Lorenz, director of public policy and information at LightHouse for the Blind and Visually Impaired, is the principal advocate helping the City and County of San Francisco implement the historic APS agreement. Jessie can be reached at 415-694-7361 or jlorenz@lighthouse-sf.org.

Eugene Lozano, Jr., California Council of the Blind's first vice president and chair of the Access and Transportation Committee, was instrumental in formulating the technical specifications used in San Francisco. Gene can be reached at 916-278-6988 or eugene.lozano@ccbnet.org.

A wealth of information and research about APS can be found on the Web site of Accessible Design for the Blind at http://www.accessforblind.org/aps_abt.html.