

# Accessible GPS: Reorientation and Target Location Among Users with Visual Impairments

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**Abstract:** This article presents the results of two single-subject experiments that were designed to determine consumers' ability to use a BrailleNote GPS. The participants decreased their mean orientation time from 6 minutes to 45 seconds and increased their target- location efficiency fourfold with BGPS than without BGPS. Additional results and implications for the field are presented.

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The authors thank the following student researchers, who carried out a portion of this project in partial fulfillment of their master's degrees: Geo Athappilly, Linda Chung, Patricia Tassie, and Michael Work. The research on which this article was based was supported by National Institute on Disability and Rehabilitation Research grant SB020101, awarded to Sendero Group and partners.

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The recent explosion in the use of global positioning satellite technology has significantly increased people's ability to maintain place orientation and to store and retrieve information about specific locations, such as businesses, recreational facilities, and geographic attributes (Broida, 2004; El-Rabbany, 2002). Rather than relying on the floating bubblelike compass that once sat on the dashboard and gave a rough estimate of the direction of travel, when a person prepares for a trip to grandmother's house in 2007, he or she now may use a Global Positioning System (GPS) unit that can plan a route to grandmother's house, keep the user on route while traveling there, continually update how much farther

away the house is (and provide the estimated time of arrival), and announce "arrived" when the house comes into view.

The power of GPS technology persuaded Loomis (1985) to speculate on its wayfinding applications for travelers with visual impairments (that is, those who are blind or have low vision). Loomis and his colleagues developed the first GPS-based system adapted for people with visual impairments, called the Personal Guidance System, over the next few years (Golledge, Loomis, Klatzky, Flury, & Yang, 1991).

Another team, which ultimately formed the Sendero Group, began working on a GPS product in 1994, released the first commercially available adapted device (GPS Talk) in 2000, and currently partners with Pulse Data International and the HumanWare Group to offer several wayfinding devices under the general name BrailleNote GPS (BGPS) (Golledge, Marston, Loomis, & Klatzky, 2004). Sendero Group, in partnership with researchers at the University of California at Santa Barbara, Carnegie Mellon University, the University of Minnesota–Twin Cities, and Western Michigan University (WMU), was awarded a grant from the National Institute on Disability and Rehabilitation Research in 2000. The collaborative project was designed to develop and integrate several outdoor and indoor navigation devices into a single system. The task of the team from WMU was to determine users' needs by conducting a series of focus groups and a national telephone survey that were designed to identify wayfinding problems and preferences for products and to conduct users' evaluations of products as they were developed. The findings of the first evaluation study that reported users' ability to locate targets accurately using a technique known as Geotracking will be reported in a subsequent issue of the *Journal of Visual Impairment & Blindness* (Ponchillia et al., in press). The findings of the second evaluation project are reported here.

The purposes of Experiment 1 in the study presented here were to determine the effect of the BrailleNote GPS on the ability of the

participants to regain reorientation in a familiar neighborhood after being deliberately disoriented and to locate a target house in a familiar neighborhood. The experiments were conducted in a familiar neighborhood to give the participants the knowledge required to wayfind in the "no-GPS" treatment regimens. The purpose of Experiment 2, the follow-up to Experiment 1, was to measure the ability of an experienced user of BGPS to locate a target house in each of three levels or degrees of electronic intervention.

## **What is GPS?**

GPS is comprised of a series of 24 operational satellites that circle the earth in six planes and transmit radio signals (El-Rabbany, 2002; Garmin, 2000). When GPS is coupled with a Geographic Information System (GIS), the two can be used to pinpoint the location of someone who is carrying a GPS receiver (Mendoza, 2002; Taylor & Blewitt, 2006). A GIS stores georeferenced materials, including spatial features, such as roads, rivers, and mountains; and attributes, such as text, photographs, and numbers (Taylor & Blewitt, 2006). The GPS-GIS combinations, which have come to be called "GPS units," can also be used to give people random access to names, locations, and services that are provided by millions of restaurants, hotels, banks, car dealerships, bowling alleys, and the like (Taylor & Blewitt, 2006).

## **The wayfinding problem**

Long and Hill (1997) described the wayfinding skills that travelers who are visually impaired use and some of the barriers to successful wayfinding, such as the lack of accessible environmental information and the unreliability of locational information that is solicited from the general public. They also noted that some people with visual impairments have difficulty using certain of these wayfinding skills, including understanding spatial relationships, using mental maps, and soliciting aid.

The WMU research team conducted focus groups on the

wayfinding problem in Raleigh, North Carolina; Lansing, Michigan; Chicago, Illinois; and Minneapolis, Minnesota, during the first year of the National Institute on Disability and Rehabilitation Research project. Ethnicity, age, vision, the use of canes and dog guides, and levels of experience were all well represented among the 38 participants in the groups. The participants were asked to imagine and discuss the problems they would face if they had to travel from their residences to a physician's office in an unfamiliar part of town. The most serious concerns they expressed were with the planning phase of a trip, but they were also dissatisfied with the lack of information available to them during travel and when crossing intersections. In spite of their success in everyday travel, the participants expressed concern about their nearly total dependence on others for information about planning routes and with the lack of reliability of the information that they generally received from the people they asked for information on routes. Not having access to street or storefront signs, the lack of a reliable way to get back on route if they became disoriented, and a desire for more information about the stores and businesses they passed on their familiar day-to-day routes were among their most critical en route concerns. The participants were also keenly aware of the lack of specific information that was available to them at intersections regarding lanes, signal phases, islands, and so forth. It is interesting that the concerns of those with low vision did not differ markedly from those who were functionally blind.

## **Adapted GPS**

Wayfinding technology became commercially available to people with visual impairments in 2002 (Golledge et al., 2004), primarily because the version of Braille-Note available at the time was the first accessible personal digital assistant (PDA) that was powerful enough to run a GPS program (May, in press). The BGPS Version II, issued in 2003, contained GIS software with street maps for the first time and was, as a result, vastly more useful than its predecessor (May, in press). Two other commercial products

containing maps have been introduced since 2003: HumanWare's Trekker (for more information, visit: <[www.humanware.com](http://www.humanware.com)>) and Freedom Scientific's Street Talk (for more information, visit: <[www.freedomscientific.com](http://www.freedomscientific.com)>). These products were not included in this research, since it was initiated before their introduction to the market. However, future plans include studies of both products.

The BGPS, the focus of this study, has five major functions: (1) standard functions, (2) automatic routes, (3) manual routes, (4) points-of-interest files, and (5) virtual functions, as follows:

- Standard functions are those that operate with little or no input from users; that is, they function nearly automatically as the user moves along a route. There are many standard functions, but the most important are intersection, address, and heading. The *intersection* commands name the travel street, the nearest cross street, and its distance; *address* gives the user an estimated street address; and *heading* gives compass directions while moving.
- Automatic routes allow the user to input an address or intersection and then have the device create a route, which can be followed turn by turn to the destination.
- Manual routes are designed by the user to be used in places that do not have streets and thus do not appear on GIS maps, such as in parks and points on college campuses. A user can leave a set of electronic "waypoints" along a route to use later to follow to a destination.
- Points of interest are, simply put, electronic addresses for businesses and other significant places that the device keeps in databases. They are available to the user and include locations of automated teller machines, banks, coffee shops, intersections, motels, restaurants, and used-car lots.
- Virtual functions are those commands that let users stay in one place, but virtually look at or travel through an area that is some distance away.

## Status of GPS and visual impairment

Adapted GPS technology does not yet appear to be widely embraced by professionals who teach travelers with disabilities. There have been few articles, interest in the GPS course at WMU has been relatively low, and the devices do not appear to be taught to a great extent in rehabilitation or educational programs. Perhaps acceptance of GPS technology has been slowed by the relatively disappointing performance of the electronic travel devices that preceded it.

## **Method of experiment 1**

### **PARTICIPANTS AND SITE**

Three participants were selected by purposive sampling (Robson, 2002). Since we focused more on qualitative performance over several trials than on group performance at a given measurement point, we thought that the purposive sampling technique that is often used in qualitative research to ensure a range of characteristics offered advantages. As can be seen from the following description, the three participants represented three distinctive types of consumers who are visually impaired. Note that although all of the participants were not female, they are all referred to as "she" or as Participant 1 (P1), Participant 2 (P2), or Participant 3 (P3) in an attempt to protect their identities.

P1, aged 25, used a dog guide, was totally blind from an acquired cause, had good mental mapping skills, used environmental cues well, had an aggressive information-solicitation style, and had experience using the BrailleNote PDA. P2, aged 52, used a dog guide, was totally blind from a congenital impairment, had difficulty with mental mapping, used environmental cues well, was a reluctant solicitor of information, and had only seen the BrailleNote PDA in a demonstration. P3, aged 38, used a dog guide, had enough vision to use a telescope to read street signs and house numbers, had good mental mapping skills, generally ignored environmental cues and depended nearly exclusively on house numbers for wayfinding, solicited information when

needed, and had been introduced briefly to BGPS as a participant in another study.

Experiments 1 and 2 were conducted in a two-by-four-block residential neighborhood that was bordered on the west by a busy commercial street and on the other three sides by streets with a relatively low volume of vehicles. The residents of the neighborhood are accustomed to seeing travelers who are blind, since the neighborhood is used for orientation and mobility (O&M) training by a local rehabilitation agency.

## **APPARATUS AND DESIGN**

The BrailleNote with Keysoft 6.11, running GPS Version 3.1 using a Magellan receiver (Model IEC-529 IPX7), was used for both studies. Updated software and receivers are now available and are considered to be more accurate than those used in this study. Thus, newer versions would be expected to yield more positive benefits than are reported in this article.

Experiment 1 used a single-subject alternating-treatment design (Gay, 1987), which resembles a within-subjects group design. The design required the participants to complete two trials per session. The paired trials (or sessions) consisted of one using BGPS and one using only natural and trained navigational skills. The order in which the conditions were offered was determined by random selection each day. The number of sessions that were held was determined by the consistency of performance that the participants demonstrated after a minimum of three sessions. P1 and P2 clearly demonstrated consistency in three sessions; P3 required four sessions to do so.

## **PROCEDURE**

Training began after the official consent form provided by WMU's Human Subject Institutional Review Board was read to, discussed with, and signed by each participant. Training was aimed at teaching the functions required of the BGPS that are required to

help a user reorient herself when lost and to locate a given target house in a familiar neighborhood. These functions included the standard commands of intersection and heading and the manual-route function of locating a waypoint. The training consisted of three parts: (1) eight hours of pretest familiarization with the device and its functions; (2) two hours of on-site pretest practice trials; and (3) on-site remediation of skills, as needed, between test sessions. All the participants received training after the first test session, but training was withdrawn as each participant became competent with BGPS, and no training was provided after the second test session.

We established a series of 15 standard routes to be used during the testing. Each route began at a residence and ended at another residence, consisted of similar length, had one turn, and contained two street crossings. After a participant demonstrated a complete knowledge of the names of the streets and the street-numbering system in the neighborhood, she was randomly assigned to either the BGPS or no-BGPS condition. Then a pair of routes was selected from the list of predetermined routes, and the participant was disoriented by being taken by vehicle to the starting address of the first route to be used for the first trial.

Before each trial began, the participants were asked if they knew where they were. If they did not, they were told the address of the target house they were to locate, that a spotter would protect them from safety hazards, and that they should use all their O&M skills during the test (including soliciting aid). In addition, they were told that they would be stopped when they successfully located the target by stepping onto either the sidewalk or driveway of the target house or if 15 minutes had elapsed. Just before the trial began, they were informed that immediately upon becoming reoriented to their location in the neighborhood, they should hold up a hand and say, "I'm reoriented." After they were asked if they had questions, they were told to begin whenever they were ready. We timed the period from start to reorientation, stopped the watch while reorientation was confirmed by asking for the names of the



street and cross street, then reminded the participant of the target address, and restarted the timing when she began walking again. Efficiency rate was used as an objective measure of the participants' ability to locate the target and was calculated by dividing the actual distance in the route by the number of seconds taken from start to finish. The efficiency rate measure, rather than simple elapsed time, was used to compare target data in order to correct for the slight differences in the length of the test routes. The results were analyzed and presented graphically, as is traditional with single-subject research. In addition, overall means were calculated and presented in tabular form. One-third of the timings were recorded by a secondary observer to establish reliability. The reorientation results were analyzed by comparing the elapsed time to reorient between the two conditions, while the target-location data were analyzed by comparing the efficiency rate across the conditions.

## RESULTS

### *Reorientation*

[Figure 1](#) presents the data regarding the three participants and graphically demonstrates the effect of BGPS on reorientation. The graphs of all three participants show a separation between the two horizontal lines (level) that connect the data points of the BGPS and no-BGPS conditions. The BGPS line falls lower than does the no-BGPS line, indicating that it took the participants a consistently shorter amount of time to reorient when using BGPS. Note that P2 was unable to reorient two of three times and that when she did, it took more than 850 seconds to do so. It should also be noted that when P1 and P2 reoriented without BGPS, they always did so by soliciting aid from a sighted resident of the neighborhood and never by using other orientation skills. Data from P3 are less dramatic because P3 was able to reorient in the no-BGPS condition by quickly moving to the nearest intersection and reading the street sign with a telescope. However, her elapsed time to reorient with BGPS was less than without it overall in three of four trials, and she corrected the onetime problem of forgetting to

use BGPS encountered in Session 2 in subsequent trials.

### ***Target location***

The results of the target-location portion of Experiment 1 are shown graphically in [Figure 2](#), which contains the data on the three participants. Note that on the graph, the level or relative height of the BGPS line for all the participants is higher than the no-BGPS line, demonstrating an increased efficiency rate of finding the target location. The graph for P2 shows a remarkable improvement, since P2 was never able to locate the target house without BGPS, but was always able to do so when she used it. Note that when the participants were unable to locate the target within the 15-minute time limit, the efficiency rate was represented by 0 in the graph. The data for P3 are represented in four sessions. As can be seen, P3 was unable to locate the target in Session 1 and Session 2 when she did not use BGPS and did not reach efficiency rates of 2 feet per second in either Session 3 or Session 4, but did locate the target at the rapid rates of 2.5 to 4 feet per second in the BGPS trials. Numeric comparisons yielded similar results to those of the single-subject graphs (see [Table 1](#)). Agreement between the two observers who recorded the data was calculated to be 93%.

## **Method of experiment 2**

### **PARTICIPANT**

By design, there was one participant in Experiment 2. The participant was also one of the designers of the study because he was the only sufficiently skilled BGPS user in the geographic region and was highly familiar with the study area. The participant, aged 62, is a dog guide user, has an acquired visual impairment, has good spatial skills, and is functionally blind.

### **DESIGN**

A single-subject design with A-B-BC-B-BC interventions was used, in which A = baseline or no BGPS, B = BGPS with no

electronic waypoint marker at the target house, and BC = BGPS plus an electronic waypoint marker at the target house. The test was designed to compare the ability of an efficient traveler to locate a target house with his own O&M skills alone, with those skills and the standard functions of BGPS, and with those skills and the manual route–waypoint functions of BGPS. The practical questions to be answered by the study were as follows: (1) Is using BGPS advantageous to an efficient traveler even in a familiar area? (2) Are the standard address and intersection functions of BGPS useful for finding the target location, and are they superior to natural navigation skills for that purpose? and (3) Is using a manual route (that is, marking a target house with an electronic waypoint marker) superior to using natural skills and standard functions for finding the target location?

This single-subject design establishes the superiority of a treatment on the basis of repeated demonstrations of increased performance of an intervention. Theoretically, the B phase (standard functions) demonstrates increased performance over A (natural skills), BC (standard functions plus the electronic waypoint marker) demonstrates increased performance over B, a return to B demonstrates decreased performance, and then another BC repeats the initial increase over B, completing the evidence of the superiority of BC over B. The final return to A is optional, depending on the power of the increases demonstrated by B and BC. In our case, we opted not to use a final A phase, since the data were so compelling.

## **PROCEDURE**

To establish his baseline performance, the participant was asked to locate five target houses using only O&M skills (the baseline phase) (see Phase A in [Figure 3](#)). Five waypoints were used because it was demonstrated graphically that there was a drop in performance from baseline point 4 to baseline point 5 (A4 to A5), meeting the requirement for the implementation of the first treatment phase. The subsequent phases were initiated using the same criteria, which is why the number of data points differs

among the phases.

The research began by taking the participant to an intersection near the center point of the same research area used for Experiment 1. An address was selected from a list of preestablished routes; then the participant was given that address, asked if he had any questions, told that he would be stopped when he successfully located the target by stepping onto the sidewalk or driveway of the house, and instructed to begin walking to the target whenever he was ready. The elapsed time and the actual distance to the address were recorded to calculate the efficiency rate. A secondary observer recorded one-third of the trials to establish reliability. Data were analyzed graphically and are presented in Figure 3.

## **RESULTS**

Figure 3 demonstrates that the line connecting the data points in the baseline Phase A is the lowest, that both the B1 and B2 lines are midway in level between the A and BC lines, and that the BC1 and BC2 lines have the highest level. These differences in levels indicate increasing efficiency in using the BGPS standard functions (B) over no BGPS (A) and greater efficiency using BGPS with electronic waypoints (BC) over the use of standard functions (B). The data show few inconsistencies overall. For example, the participant's performance during A2, B1–3, and B2–2 were higher than in the other points in these phases. On the other hand, the participants' performance in the BC phases showed relatively good consistency over all the points, indicating the control offered by using electronic markers.

## **Discussion**

With the exception of the participant with low vision (P3) in the orientation test of Experiment 1, the data in both studies demonstrate the marked improvement in wayfinding performance when the participants used BGPS than when they used only O&M skills. The results of Experiment 1 indicate the practical use of

BGPS for orienting oneself and for locating houses in a neighborhood. Although Experiment 1 used a single-subject design and, by definition, the results cannot be generalized, each of the three participants represented three distinctive sets of skills that may be viewed as "type cases"--(P1): no vision, good spatial awareness, and good use of the other senses; (P2): no vision, poor spatial awareness, and good use of the other senses; and (P3): low vision, good spatial awareness, and little use of the other senses. Because P1 used mental mapping well, her strategy for locating the house was based on asking the device for her location, placing herself mentally in the neighborhood grid, walking to the street on which the house was located, and then using the device again to pinpoint the electronic marker at the target house. P2's strategy differed from that of P1 in that P2 did not use the standard function information to place herself mentally in the neighborhood grid and then to walk to the street on which the house was located. Rather, she followed the electronic waypoint marker from the beginning. For example, at the midblock starting point, the device reported, "Target is 11 o'clock 632 feet"; P2 began to walk straight ahead and listened to the clock-face feedback until she came to a street where the device said, "Target is at 9 o'clock," indicating that she should turn left. P2 turned left to make the device say, "Target is at 12 o'clock" and then walked straight ahead until she found the target house.

P3 used the same method as P1, completely trusting the device and ignoring the residual vision she always used during the no-BGPS trials. In summary, three people with widely different skills and vision benefited from using BGPS. One established her place in a mental map of the area with BGPS and moved quickly to the target; another used BGPS to follow a route more or less to the target; and the third forsook her functional vision and did not read house numbers and instead followed the BGPS instructions to the target.

Experiment 2 demonstrated that GPS technology is advantageous even in extremely familiar areas. Although the participant knew

the area well, he traveled to the targets more efficiently with BGPS than by using just his knowledge and skills. Also, although the complex functions of using electronic markers got the participant to the target most efficiently, the simple standard address function also increased his target-location efficiency over his own skills. The participant was able to conceptualize the spatial layout of the area, so he traveled much like P1 in Experiment 1. While searching for the house designated by an electronic marker, he used the device to determine the nearest intersection, used his cognitive map to reach the street on which the target house was located, and then used the device to find the target house. In the condition of using the house address to locate the target, the first two steps were identical, but he found the target by walking to an address just before the desired address and then stepped into every drive or walkway until the researchers indicated that he had found the correct house. As we noted earlier, the participant was part of the team that designed the study. We recognize that his familiarity with the study could have had confounding effects on the results and acknowledge this weakness, but we believe that the risk was acceptable, since no other users with sufficient BGPS skills were available for the study. Furthermore, we recognize that additional research is required to support these findings and to examine numerous other aspects of the use of GPS technology.

## **Implications for practitioners**

The results clearly show that BGPS was advantageous to the participants. However, because these were single-subject experiments and the participants did not represent the entire population with visual impairments, the advantages provided would not be expected to be as strong across the entire population. However, it should be noted that these experiments were designed to demonstrate the possibilities provided by the accessible GPS, not to establish the degree of that advantage to those in the population. Therefore, the conclusions described next are based on the people who were studied and on a good deal of personal

experience with the device.

There are two strong implications from this research: (1) Adapted GPS technology appears to be sufficiently reliable to become part of the rehabilitation and educational programs of individuals who are visually impaired, and (2) the devices can be useful for the simple functions that require little training, as well as the more sophisticated ones. Experiment 1 demonstrated the usefulness of GPS technology in the everyday lives of people with visual impairments. The ability for an individual to reorient her- or himself in a neighborhood with 100% accuracy in less than one minute after being disoriented was an extremely significant finding. In essence, a single keystroke told users the name of the street they were on, the direction they were facing, the name of the nearest intersecting street, and its distance and direction. This function would enable users who are dropped at the wrong bus stop by a driver or turned around by confusing environmental information while on route to a destination to regain their position in space in the amount of time it takes to make a keystroke. This device eliminated the participants' need to ask, "Could you tell me the name of this street, please?" and consequently eliminated the problem of the lack of reliability of solicited information.

Similar empowerment came from using the GPS device to locate houses in a neighborhood. Because the device reported the map locations of the participants and of the target house, it enabled the participants to plan their trips independently. In addition, the findings demonstrated that one participant never became oriented or located a target house independently without the device, but did both every time with it. It was apparent to her and the research team that BGPS enabled her to maintain orientation regardless of her difficulty with spatial cognition. In essence, the device appeared to be the only option she had for traveling independently to the neighborhood targets.

Experiment 2 indicated that some of the simpler functions of the BrailleNote GPS technology are not only useful for what they

were designed for, such as the intersection function's identification of the locations of the user's street and nearest cross street, but for more sophisticated wayfinding tasks. For example, the standard functions of intersection, address, and heading were shown to be useful for locating houses in a familiar neighborhood as well. The significance of this finding is that the training regimen that is offered in an O&M program does not always have to include all the functions of a GPS device to be helpful. Rather, many people who do not have the ability or desire to learn the more elaborate route functions could gain the orientation power that these devices provide with just a few hours of training.

Experiment 2 also demonstrated that the GPS device was advantageous to a traveler who was already highly familiar with the neighborhood. The participant performed better with the GPS (see Figure 3), indicating that his travel was more efficient using the GPS than using his own skills and knowledge. This finding does not necessarily have strong implications for rehabilitation or education, but more efficiency may be equated with more success, more comfort, and less stress for the traveler.

Perhaps the important issue at hand is the effect that the findings will have on the instructional community. Will it matter that the participants in these studies performed highly efficiently with GPS technology, and will these results help quicken the acceptance of the technology? Certainly, the usefulness of the product is not the only variable that determines its popularity. For example, the relatively high cost of GPS technology has likely been a significant barrier to its integration into programs, which has been confounded by the general lack of knowledge about it. As in all things, cost is relative to value. Now that the value is becoming clear through research and increasing use, perhaps the cost will seem more reasonable. In addition, GPS products from all three U.S. suppliers are relatively new, and it is likely that their prices will decrease, to some extent, as the cost of the hardware that houses them goes down. We sincerely hope that these factors combine to increase access to these powerful wayfinding tools.



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