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Research Report

Objective Mobility Documentation Using Emerging Technologies

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The development of the instruments used in this research was supported by grant C2489R, and current work is supported by grant C3732 from the Department of Veterans Affairs, Office of Rehabilitation, Research, and Development. On the basis of the results of this preliminary study, a three-year regional study to quantify the impact on travel of Veterans Administration--sponsored rehabilitation for people who are blind using GPS-GIS and accelerometer measurement technology has been funded and is in progress.

Historically, rehabilitation clinicians who work with people who are visually impaired (that is, are blind or have low vision) have relied on subjective checklists and clinical assessments to document the capacity of individuals to perform various tasks, including mobility, and to assess the impact of rehabilitation. Numerous instruments have been developed to measure functional outcomes and the quality of life of people who are visually impaired (De l'Aune, Williams, Watson, Schuckers, & Ventimiglia, 2004; Haymes, Johnston, & Heyes, 2001). The continued development and implementation of such instruments represents a major achievement in the coordination and standardization of measurements of functional outcomes.

This article highlights a unique, objective method for assessing the mobility of clients who are visually impaired by using a combination of GPS (Global Positioning System), GIS (Geographic Information Systems), and accelerometer technologies. The use of these technologies facilitates a highly objective and reliable measurement of both indoor (accelerometer) and outdoor (GPS and accelerometer) mobility and travel patterns. Moreover, measures of mobility can be used in conjunction with other commonly used self-report and clinician-assessed measures of mobility-related behaviors, including those that assess the impact of vision loss on mobility.

GPS AND GIS TECHNOLOGY

GPS technology, which provides information on the spatial coordinates of a given geographic location or traveler that is derived from signals received simultaneously from multiple GPS satellites, is often used in conjunction with GIS, which provides digital mapping and other important information about a specific location. In simple terms, GPS determines an individual's geographic location, travel paths, and speeds, while GIS provides a multilayered platform that is typically displayed in maps that can be used to interpret GPS data.

GPS technology has been used to investigate details about personal travel behavior (Wolf, Guensler, & Bachman, 2001; Wolf, Loechl, Thompson, & Arce, 2003) and the relationships between physical activity and travel patterns. By equipping participants who are visually impaired with GPS data loggers, investigators can process data on second-by-second GPS positions, time, and speed within a GIS framework to obtain in-depth information about various outdoor behaviors, including travel times, modes of travel, the duration of stops, the length of trips, speed profiles, routes, and types of travel environments. This information can then be augmented with information on the specific purposes of travel and levels of independence that is gathered from self-report travel diaries and assessment interviews. These behaviors are closely related to the goals associated with orientation and mobility.

GIS technology involves spatial analysis software platforms that are used to manage and evaluate geographically referenced data (Brainard, Bateman, & Lovett, 1995; Brainard, Lovett, & Parfitt, 1996; Lee & Stucky, 1998; Loh, Van Stipdonk, Holtfrerich, & Hsieh, 1996; Lovett, Parfitt, & Brainard, 1997). It can be used to generate detailed information on travel routes that an individual who is visually impaired has collected via GPS. In addition, extensive comments or notes about specific features of various GIS themes, such as bus routes, commercial and entertainment districts, and other relevant community information, can be integrated into the data system.

METHODS

This study was conducted by researchers at the Atlanta VA Rehabilitation Research and Development Center and at GeoStats (<www.geostats.com>) to evaluate the efficiency of the procedures, the quality of the data, and the effectiveness of the concepts of the three technologies. It was approved by the Emory University Internal Review Board, and the participants signed informed-consent forms before they participated.

The purpose of the study was to test the methodology and procedures for future use in a large-scale study. The sample size was intentionally small ($N = 4$), and the area of deployment was centered in the Atlanta, Georgia, metropolitan area. The GPS data logger and accelerometer equipment were sent via overnight courier to the four participants, along with written and audio instructions. The resultant GPS-GIS and accelerometer data that were collected included the number of trips that each participant made on each day of travel; the level of activity on each day of travel; and the distance, maximum speed, and average speed per trip.

Equipment

Two devices were used: the GeoStats Wearable GPS GeoLogger and an Actigraph Activity Monitor (see Figure 1). The Geologger, which is worn over one shoulder, similar to a camera bag or purse, records GPS data when a person is outside or in a vehicle. The device can log at either one- or five-second frequencies and can log all valid GPS points or only those valid points for which the speed is greater than one mile per hour (to screen out nonmovement events). The standard GPS data stream that is recorded by the GeoLogger includes the date, time, latitude, longitude, speed, heading, altitude, number of satellites, and horizontal dilution of precision (a measure of positional accuracy). These elements are stored in the GeoLogger in standard GPS units and are converted into user-specified units and formats when they are downloaded. The participants were asked to wear the GeoLogger whenever they traveled outside their homes.

To capture additional information on the participants' activities, the Actigraph Activity Monitor, a small, lightweight unit that is worn around the waist on a belt, was used. The participants were instructed to wear it at all times except when they were sleeping, bathing, or swimming. The Actigraph Activity Monitor is a multidirectional accelerometer that counts movement 10 times per second and sums the counts over one minute.

Protocol

The four participants were directed to wear these devices for 14 consecutive days. Supplementary travel information was collected every third to fourth day by telephone to provide additional and confirmatory details beyond the data that were collected by the GPS and accelerometer. To ensure the reliability and validity of the data that were being collected, all the data collected from the GPS, the accelerometer, and the participants' telephone reports on their travel were aggregated to confirm the participants' travel destinations and modes of travel. For the purpose of this study, relevant modes of travel included walking or running for exercise, walking for travel (to get from one place to another), use of public transportation, use of paratransit vehicles, and use of automobiles. To evaluate improved mobility, one could assume that an increase in miles in the first three modes would indicate greater confidence in independent travel, whereas an increase in the latter two categories would reflect increasing mobility with some assistance. The GPS trips that were identified in this study were tagged on the basis of these categories. Counts of trips for each participant were generated by the study day and the type of trip, as well as by the average mileage for the trips made by each participant by study day and travel destinations.

Data processing

After the researchers received the GPS second-by-second trace data, they converted the data into GIS-compatible formats and reviewed them for potentially bad or poor data points. A program was subsequently run on the GPS data stream to identify potential ends of trips that were derived from the intervals in time between the consecutively logged points. For this study, 120 seconds was defined as the appropriate initial interval between GPS-recorded trips. Next, the researchers evaluated each potential trip within an interactive GIS-based application to identify both missing and false ends of trips. Once this step was completed, the updated GPS-based trip file for a given participant was ready for analysis. The activity data were merged with the GPS data on the basis of the time and date, so the researchers could evaluate activity levels that were captured concurrently with the GPS data and could identify activities that occurred without the GPS data. The combination of the GPS and accelerometer data also enabled the researchers to map activity levels across time and space. The GPS trace data, combined with activity levels, were measured during daily jogging events for Participant 1, who was legally blind. The GPS data indicated that Participant 1 followed a regular jogging routine using two different geometric patterns, and may indicate that the participant used familiar paths and routines in the exercise regimes.

RESULTS

Analyses of travel behavior and activity levels

All but one participant, Participant 3, returned GPS data for all the days in the study. GPS data were missing for Participant 3 for the last four days of the study, yet accelerometer data for this participant were collected, indicating that the participant was active during this period. After the missing data for Participant 3 were reviewed, the researchers determined that either equipment failure or human error had occurred. The lack of complete data for Participant 3 could have been the result of no travel or the battery not being recharged properly. Furthermore, given the activity thresholds provided by the manufacturer of the Actigraph Activity Monitor, it appears that Participant 3 did engage in moderate activity on all days except two during the study period and at no time engaged in hard or very hard activities.

Table 1 presents a summary of the number of valid GPS-recorded trips made by each participant. Note that on some days, some participants took only one trip. These were round trips to and from their home locations that were probably made for exercise by walking or jogging in their neighborhoods. Table 2 summarizes the trip-making behavior of each participant. On average, the participants made 4.8 trips per day and traveled out of their homes 9.5 days out of the 14-day study period. Since the participants traveled more on weekends than during the week, their weekend trip rates were also higher.

IMPLICATIONS FOR PRACTICE

The GPS-GIS and accelerometer data that were collected in this study were gathered to assess the feasibility of deploying this technology and the reliability of this system for future use. On the basis of the findings, it is evident that GPS-GIS and accelerometer technologies are effective tools for both quantifying and depicting the travel behaviors of adults who are visually impaired. Furthermore, this article has proposed a method of reporting outcomes of travel characteristics using data on trips and activity levels and tracing the participants' living space to provide orientation and mobility instructors and other rehabilitation professionals with information on their clients' mobility and travel behaviors.

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