Travel Behavior of Blind Individuals before and after Receiving Orientation and Mobility Training

FINAL REPORT

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16. Abstract

In this pilot study, we devised, tested, and refined a protocol for evaluating the travel behavior of blind individuals. Preliminary analyses of our pilot study data suggest that our new method involving Global Positioning Systems (GPS), accelerometers, and Geographic Information Systems (GIS), will enable us to collect objective, quantitative, and valid measures of blind individuals' travel behavior and Orientation and Mobility (O&M) training's effectiveness. Preliminary analysis results from a small sample of blind travelers describe the individuals' trip distances, trip frequencies, trip destinations, trip modes, travel times, whether assisted or not, and perceived ability to get around. With the completion of the full-scale study (proposed for FY 2016-18), we may be able to recommend changes to current O&M training to allow more active, confident, and safe travel by blind individuals in their communities. We may also discover characteristics of the physical environment that inhibit access by blind pedestrians and are more amenable to mitigation through good transportation planning (e.g., geometric design of intersections) than through O&M training.

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EXECUTIVE SUMMARY

In this pilot study, we devised, tested, and refined a protocol for evaluating the travel behavior of blind individuals. Preliminary analyses of our pilot study data suggest that our new method involving Global Positioning Systems (GPS), accelerometers, and Geographic Information Systems (GIS), will enable us to collect objective, quantitative, and valid measures of blind individuals' travel behavior and Orientation and Mobility (O&M) training's effectiveness. Preliminary analysis results from a small sample of blind travelers describe the individuals' trip distances, trip frequencies, trip destinations, trip modes, travel times, whether assisted or not, and perceived ability to get around. With the completion of the full-scale study (proposed for FY 2016-18), we may be able to recommend changes to current O&M training to allow more active, confident, and safe travel by blind individuals in their communities. We may also discover characteristics of the physical environment that inhibit access by blind pedestrians and are more amenable to mitigation through good transportation planning (e.g., geometric design of intersections) than through O&M training.

1. Introduction

Orientation (understanding one's position within an environment) and mobility (purposeful, safe and efficient movement within an environment) are essential areas of skill for independent travel (Jacobson, 1993; LaGrow & Long, 2011). For persons with blindness and low vision, these skill domains have been adapted and are taught by O&M instructors (Jacobson, 1993). Adaptations include techniques such as the incorporation of one's remaining senses to understand a traveler's location and specific training in the use of the long cane (Jacobson, 1993; La Grow & Long, 2011).

A recent Cochrane Review (Virgili & Rubin, 2010) of research in the area of Orientation and Mobility (O&M) training for adults with low vision confirms the need for quantitative assessment of the effectiveness of O&M training. Despite the widespread acceptance of O&M instruction and belief in its value, previous studies that examined the functional effects of O&M training have reported mixed results (Engel, Welsh, & Lewis, 2000; Griffin-Shirley, Kelley, Matlock, & Page, 2006; Kuyk et al., 2004; LaGrow, Ebrahim, & Towers, 2014; Soong, Lovie-Kitchen & Brown, 2001). The use of new technologies in global positioning systems (GPS) may allow us to provide objective and quantitative measures of O&M training effectiveness (van der Spek, Schaick, Bois, & Hann, 2009).

Soong et al. (2001) found no improvement in mobility performance on an indoor obstacle course immediately after O&M training between two groups of participants with low vision: those who received O&M training ($n = 19$) and those who did not ($n = 18$). In addition, in a study of 70 individuals (60 and older) who received blind rehabilitation services including O&M, Engel et al. (2000) found little change in self-reported outcomes from O&M training. Participants reported no significant change in walking inside and outside of the house in terms of

difficulties with or confidence in these activities before and after the training. Significant decreases in difficulty and increases in confidence were found only in the area of the use of public transportation. On the other hand, in a study of 128 veterans with visual impairment, Kuyk et al. (2004) reported significant improvement in self-reported mobility functions (movement through doorways, detecting stairs and curbs, etc.) two months after mobility training. Similarly, LaGrow et al. (2014) found that a week-long O&M program at Guide Dogs Queensland significantly improved the training recipients' perceived overall O&M skills measured by *Difficulty with Mobility Questionnaire-23*. Participants reported a significant improvement in all but 3 of the 23 skill areas.

Such conflicting results might have resulted, at least partly, from some of the challenges encountered when studying functional effects of O&M training. First, visual impairment is a low-incidence disability. According to the American Community Survey of 2012, the prevalence rate for persons 18 to 64 in the U.S. reporting a visual disability—defined as a person who is blind or has serious difficulty seeing even when wearing glasses—is 1.8% (Erickson, Lee, & von Schrader, 2014). Therefore, studies that involve visually impaired individuals often used small convenience samples, which limited the generalizability of the study findings (Engel et al., 2000; Soong et al., 2001). Second, while there is some consensus concerning aspects or skills to include in an O&M training curriculum (Barlow, Bentzen, Sauerburger & Franck, 2010; Hill & Ponder, 1976; Jacobson, 2013; La Grow & Blasch, 1992; La Grow & Long, 2011), there has not been a widely used standard evaluative tool that measures all of the skills considered vital to O&M training (Virgili & Rubin, 2010; Whiteneck, 1994). Some of the critical components of O&M training include reliable orientation to the environment, safe street crossing, reliable drop-off and obstacle detection, and locating objectives in a reasonable period of time (efficiency of

travel) (Bentzen & Barlow, 1995; Blades, Lippa, Golledge, Jacobson & Kitchin, 2002; Kim, Wall Emerson & Curtis, 2009; Kim, Wall Emerson & Curtis, 2010).

Vigili and Rubin, in their 2010 review of the literature about O&M training for adults with low vision, emphasized the need for standard methods to objectively test O&M performance, measures which are valid and reliable. Recently, La Grow et al. (2014) developed and tested the validity, reliability, and sensitivity of the instrument to measure the effectiveness of O&M training: *Difficulty with Mobility Questionnaire* (DMQ-23). This instrument proposes to assess an individual's perception of difficulty with 23 skills typically included in O&M training and necessary for safe travel. These 23 skills include aspects of travel such as negotiating obstacles, crossing streets, identifying curbs and steps, and using public transportation.

Examination of the travel behaviors of pedestrians traditionally relied on subjective data supplied by the research participants in the form of travel diaries (van der Spek et al., 2009; van der Spek, 2009; Shoval & Isaacson, 2006). However, recent studies of pedestrian travel have found disparities between subjective and objective measures of pedestrian activity (Robinson, Shumway-Cook, Ciol, & Kartin, 2011; Hagstromer, Ainsworth, Oja, & Sjostrom, 2010; Chaudhury, Stamatakis, Roth, & Mindell, 2010). In a nationally representative cross-sectional survey of 4,507 adults in England, Chaudhury et al., (2010) found that people tend to overestimate their actual physical activity level. Similarly, in a study of 980 adults, Hagstromer et al. (2010) reported that a subjective measure of physical activity overestimates the participant's actual physical activity. In a cross-sectional study of 50 community-dwelling survivors of stroke, Robinson et al. (2011) also found subjective and objective measures of participation in community walking to be only weakly correlated. The complexity of relationship between O&M training and a person's experiences suggests that both subjective perceptions of

quality of life and objective measures of activity are necessary to explain variability in the effectiveness of O&M training (Virgili & Rubin, 2010; Robinson et al., 2011).

The appropriate use of Global Positioning Systems (GPS) technology for monitoring activity patterns has been a subject of interest among transportation, sports science, public health and other professionals since the mid-1990s (Hakobyan et al. 2013; Houston et al. 2011; Shoval 2008). The chief benefit of GPS devices for social-behavioral research is their ability to provide a nearly continuous logging of participants' locations across activity spaces over a given study period. Further, portable and user-friendly GPS devices with large data storage capacities reduce both respondent and researcher burden by automating the process of spatio-temporal data capture. Beyond logging locations, recent research has demonstrated that aligning GPS data with information gathered from other sensor technologies such as accelerometers can help define, via numerous algorithms, the beginning and end points of trips, calculate trip speeds, estimate trip distances and durations, and classify trips based on the mode of transportation (i.e., vehicle, bicycle, pedestrian, or stationary) (Feng & Timmermans, 2013; Kang et al. 2013; Neven et al. 2013; Rodriguez, Brown, & Troped, 2005).

However, equipping research participants with GPS and associated sensors alone is not an adequate strategy for creating a reliable travel activity database (Carlson & Theodore, 1997). For example, technical limitations can compromise the integrity of GPS-generated data. Satellite signals can be disrupted or lost when travelers move underground, within urban canyons, and near and inside buildings. Moreover, GPS locational traces do not independently identify trip purpose (e.g., spontaneous versus planned, daily or recreational shopping, etc.) and the aforementioned algorithms used to impute trip mode are not perfect. As a result, transportation

scholars have increasingly used some combination of travel diary, GPS, and accelerometer data to effectively and efficiently log, categorize, and validate spatial behavior (Houston et al. 2011).

The use of GPS and accelerometer technology in this proposed study will add valuable objective quantitative measures to the subjective measures we also plan to use (*Difficulty with Mobility Questionnaire* and travel diary) in examining the behaviors of blind travelers. To our knowledge, no previous study has combined both subjective and objective measures to examine the behaviors of blind travelers as they relate to the effectiveness of Orientation and Mobility (O&M) training. The primary objective of the present study is to produce preliminary data about the actual travel behaviors of blind individuals and the effectiveness of an O&M training measured in both objective and subjective manners.

2. Methods

Participants

Upon approval from WMU's Human Subjects Institutional Review Board (HSIRB), using the recruitment procedure successfully employed in our previous work (Kim et al., 2009; Kim et al., 2010), six visually impaired adults were recruited from scheduled recipients of Leader Dogs for the Blind's Accelerated Mobility Program. Selection criteria included legal blindness, reasonably good stamina (i.e., stamina to walk for 30 minutes without resting), high motivation (i.e., interested in expanding the scope of one's travel with the skills obtained from the O&M training), and residence in an urban or suburban area. We limited our recruitment to 6 participants given the labor intensive and explorative nature of the study (i.e., pilot study).

Apparatus

Several factors were considered when choosing the appropriate locational and physical activity sensors for this research. Specifically, candidate devices were evaluated—via manufacturers' documentation and independent studies (Gastin & Williams, 2010; Schipperijn et al., 2014; McMinn, Rowe, & Čuk, 2012; Wu et al., 2010)—in terms of their hardware and software, including: 1) device size and weight, 2) ease of use, 3) battery life, 4) geographic/positional accuracy, 5) logging frequency, 6) storage capacity, 7) accelerometer sensitivity, 8) start-up (and/or "fix") times, and 9) durability. For GPS logging, we selected the Qstarz 66-CH series: BT-Q1000XT Travel Recorder. This is a compact (7.2 cm x 4.7 cm x 2cm) and lightweight (67g) device with considerable storage capability—up to three weeks of travel information collected at sub-second intervals (maximum sampling frequency of 5Hz (0.2 sec) and 400,000 total records. The unit is also DGPS-enhanced, making use of ground-based reference stations thus improving locational accuracy (<2.5m) and velocity readings (0.05m/s). In addition, the BT-Q1000XT integrates vibration sensor technology to detect movement status thus reducing power consumption, enabling up to 42 hours of continuous operation.

In addition, the Actigraph wGT3X-BT monitor was used to collect detailed physical activity, which, when combined with GPS data, will support the simultaneous detection of transportation modes and logging of fine-scale trip characteristics. Specifically, the dynamic acceleration data captured by the ActiGraph wGT3X-BT was used to estimate energy expenditure, steps taken, and physical activity intensity. Similar to the GPS logger, the Actigraph accelerometer is compact (3.5 cm x 3.5 cm x 1 cm), lightweight (14 grams) and has enough storage capacity (4 GB) to capture 240 days' worth of continuous data. Further, the device has considerable battery life (14 days), is water resistant, and can easily be worn on the wrist or waist.

Survey Instrument

Difficulty with Mobility Questionnaire (DMQ-23) developed by LaGrow et al. (2014) was used to measure participants' perceived ability to get around. DMQ-23 was reported to have yielded a high internal consistency reliability (Cronbach's alpha = 0.962), which is well above the acceptable value of 0.7 that is needed to establish reliability. Concurrent validity of the questionnaire, assessed by examining the correlation between the 23-item DMQ score and the "ability to get around" (AGA) score drawn from the World Health Organization Qualify of Life BREF (WHOQOL) (WHO, 1996), was reported to be strong ($r = 0.735$) (La Grow et al., 2014).

Orientation and Mobility Training (Accelerated Mobility Program: AMP)

The AMP is a seven-day intensive residential orientation and mobility training that provides blind individuals the skills needed to travel safely using a white cane. Although AMP is shorter in timeframe than many traditional O&M programs, the intensive nature of the program allows it to provide training in many of the same skill areas covered in traditional O&M training in a variety of environments, including residential, business, city, and country settings.

Experimental Procedure

The study was conducted in the participants' home communities. Prior to receiving a one-week Accelerated Mobility Program training by Leader Dogs for the Blind, participants were visited by a member of the research team. Upon signing the informed consent form approved by WMU's HSIRB, each participant wore a portable GPS travel recorder (BT-Q1000XT Travel Recorder) and an accelerometer (Actigraph wGT3X-BT). The participant was instructed to wear these devices at all times except during sleep and taking a shower. These devices were initially set up and initiated by the research team and the participants were instructed to charge the devices regularly. Travel activity data from the GPS travel recorder and

the accelerometer were downloaded at the end of each of the 3-week-long pre-training and post-training data collection periods.

Concurrently, the participants were asked to record in an activity log each time they change location by recording the time, checking whether they were indoors (home, work, school, other), outdoors (walking, biking, other), or in-vehicle (auto, van, or truck, transit, or other), and noting other location details. Participants used a compact voice recorder (Olympus VN-7200 Digital Voice Recorder) to record their travel activity, which is commonly used by blind individuals to record travel route information.

At the completion of the 3-week-long GPS data logging period prior to the O&M training, each participant's level of difficulty with mobility was measured using DMQ-23. Upon completion of the 3-week-long post-training data logging period, each participant's level of difficulty with mobility was measured again using the same instrument.

Variables

Travel behavior of blind individuals was operationalized via the following variables: 1) trip routing (i.e., route choices including crossings), 2) trip distances, 3) trip frequencies, 4) trip origins and/or destinations, 5) trip modes, 6) travel times, 7) trip purposes, 8) whether assisted/accompanied, and 9) perceived ability to get around. As described in the next section, the first seven measures were extracted from the GPS logger, accelerometer, and travel diary data of each participant, while the last measure was obtained from the DMQ-23 survey data. The proposed method utilized GPS and accelerometer technologies together with conventional personal travel diaries to arrive at a nuanced, comprehensive, and reliable understanding of participant activity and travel behavior.

Data from this study were analyzed descriptively without the use of inferential statistical procedures given the small size of the sample and explorative nature of the study. Pre-training DMQ-23 score as well as the "ability to get around" (AGA) score were compared with those collected after the training. As for data from the GPS loggers and accelerometers, once they were extracted from the sensing devices, they were processed in four phases. In phase one, GPS and accelerometer data were aligned using the Physical Activity Location Measurement System (PALMS) in order to estimate the number of trips, trip speeds, trip distances, trip duration, and trip mode (Boruff, Nathan, & Nijënstein, 2012). PALMS was also be used to detect whether a GPS point was collected indoors or outdoors based on the number and signal quality of satellites. Trips were classified as vehicle, bicycle, or pedestrian based on speed cutoff values, with speeds less than 7 km/h flagged as walking trips. In the second phase of the process, trips were visually assessed by first overlaying the GPS points over high-resolution and geo-rectified Digital Ortho Quarter Quads (DOQQ) aerial photography in Q(uantum)GIS. In phase three, participant logs were examined relative to the summarized and detailed geographic and physical activity data, noting any irregularities, inconsistencies, specification loss and/or unreported activities.

3. Results

Data from only three of the participants were analyzed in the preliminary analyses.
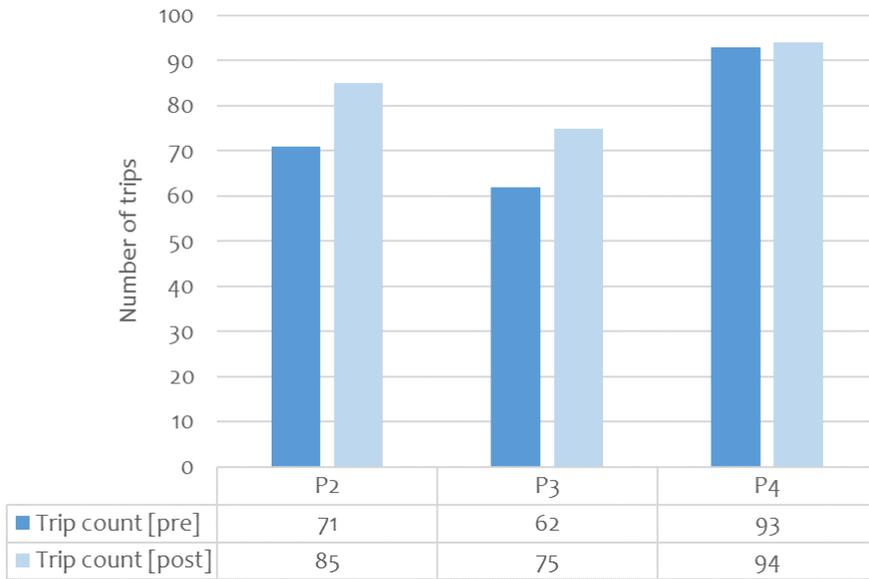
**Trip Counts**

Figure 1

Trip counts before and after receiving orientation and mobility training
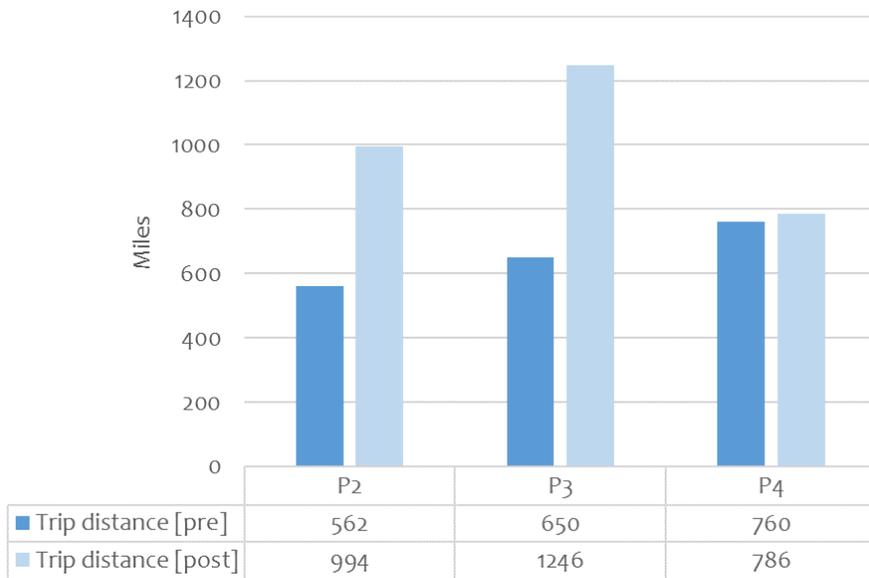
Trip Distance

Figure 2

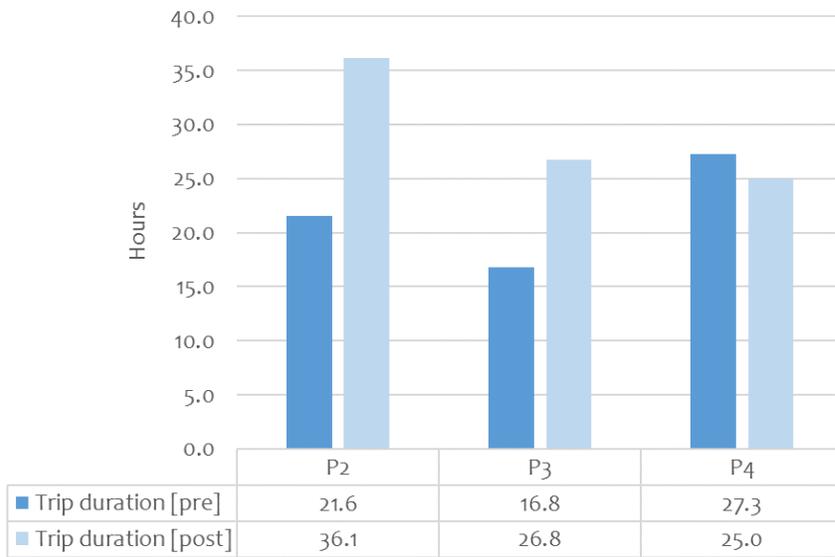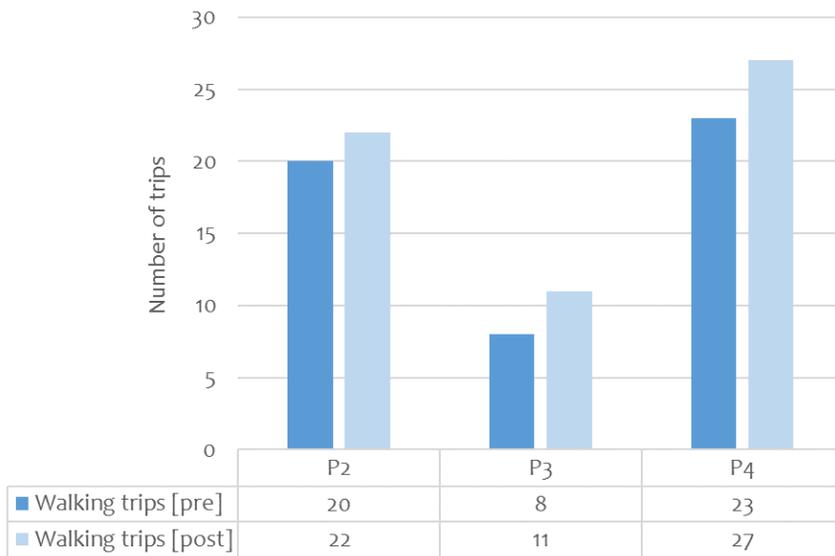Trip distance before and after receiving orientation and mobility training

Trip Duration

	P2	P3	P4
■ Trip duration [pre]	21.6	16.8	27.3
■ Trip duration [post]	36.1	26.8	25.0

Figure 3

Trip duration before and after receiving orientation and mobility training

Walking Trips

	P2	P3	P4
■ Walking trips [pre]	20	8	23
■ Walking trips [post]	22	11	27

Figure 4

Number of walking trips before and after receiving orientation and mobility training

__Vehicular Trips__

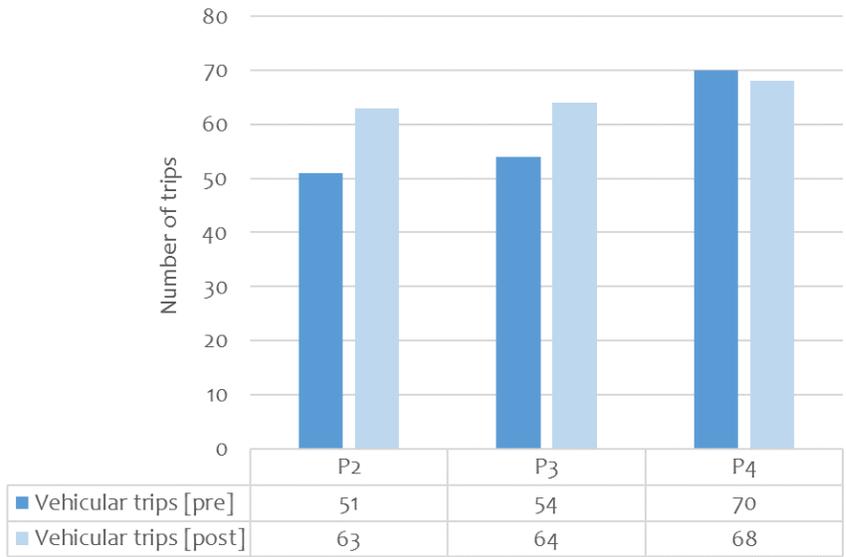|	P2	P3	P4
■ Vehicular trips [pre]	51	54	70
■ Vehicular trips [post]	63	64	68

Figure 5

Number of vehicular trips before and after receiving orientation and mobility training

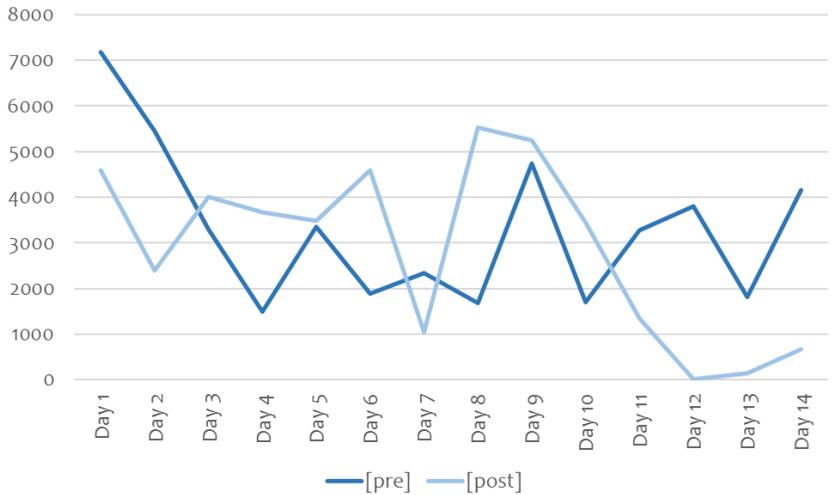*__Physical Activity Level__*

Figure 6

Physical activity level measured in vector magnitude before and after receiving orientation and

mobility training

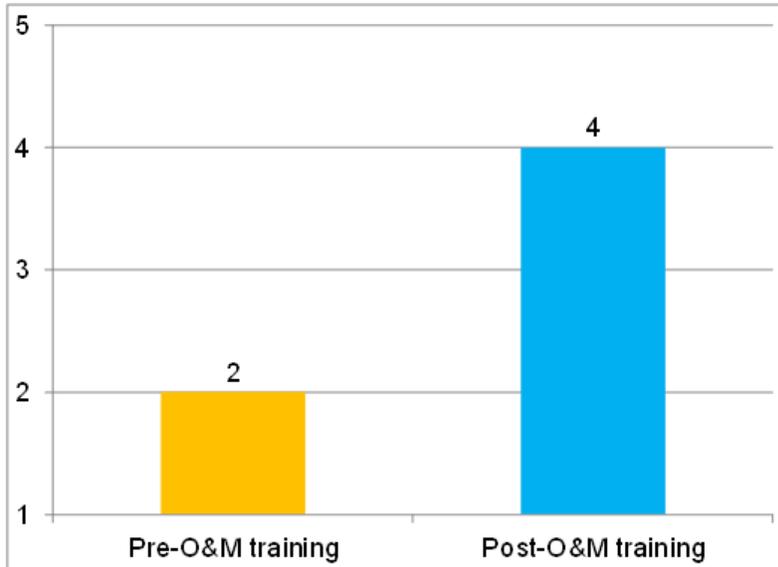### *World Health Organization Quality of Life Question*

Figure 7

WHO QOL Question (How well are you able to get around (1: very poorly – 5: very well)?

Difficulty with Mobility Questionnaire 23 (DMQ-23)
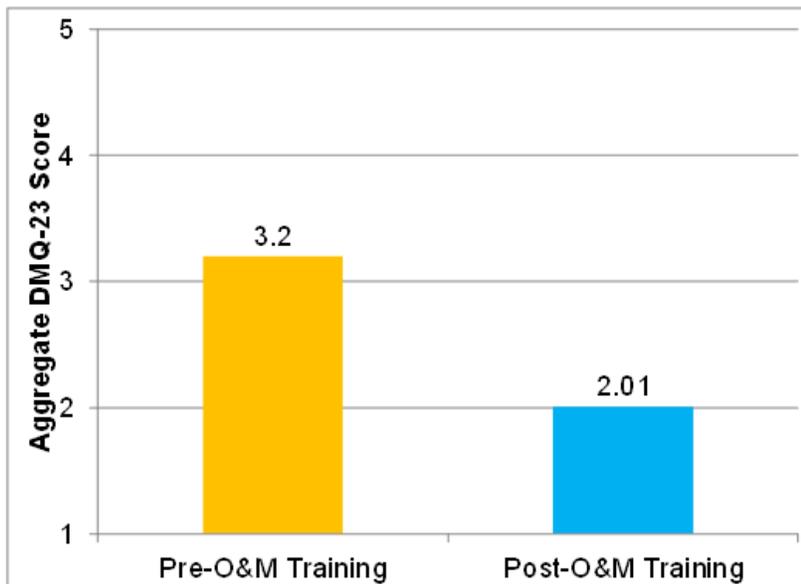

Figure 8

Aggregate DMQ-23 Score (1: not at all, 3: a moderate amount, 5: an extreme amount)

4. Discussion

The present study was a pilot study and the analyses we did are simple descriptions of the behaviors of just three participants. In other words, there was no attempt to generalize the findings to a corresponding population. Having said that, although there was some improvement in actual trip frequency and distance, a substantial improvement in participants' perceived ability to get around didn't fully translate to actual increase in trips and activities of visually impaired individuals

Given that the present study was a pilot study leading to a full-scale study, the most meaningful and important result of the study was that the devices and the research protocol we used successfully captured the information we aimed to obtain for the travel behavior analyses of the blind individuals. A logical progression for this study would be a larger-scale study that incorporates different types of O&M training programs and larger number of participants. Such a study may suggest some alterations in O&M training that may involve changes in the focus or approach of the training. Through such study, we also expect to discover some of the characteristics of the physical environment that inhibit access by blind pedestrians and are more amenable to mitigation through better geometric design of the facilities.

References

Barlow, J. M., Bentzen, B. L., Sauerburger, D., & Franck, L. (2010). Teaching travel at complex intersections. *Foundations of orientation and mobility*, *2*, 352-419.

Bentzen, B., & Barlow, J. (1995). Impact of curb ramps on the safety of persons who are blind. *Journal of Visual Impairment & Blindness, 89*, 319-328.

Blades, M., Lippa, Y., Golledge, R., Jacobson, R.D., & Kitchin, R. (2002). The effect of spatial tasks on visually impaired peoples' wayfinding abilities. *Journal of Visual Impairment & Blindness, 96,* 407 – 420.

Boruff, B.., Nathan, A., & Nijënstein, S. (2012). Using GPS technology to (re)-examine operational definitions of 'neighbourhood' in place-based health research. *International Journal of Health Geographics 11* (1): 22. doi:10.1186/1476-072X-11-22

Carlson, V. L., & Theodore, N. (1997). Employment availability for entry-level workers: An examination of the spatial-mismatch hypothesis in Chicago. *Urban-Geography, 18(3)*, 228-242.

Chaudhury, M., Stamatakis, E., Roth, M., & Mindell, J. (2010). Objective and subjective method of physical activity measurement in a cross-section of English adults: Health survey for England 2008. *Journal of Epidemiology and Community Health*, *64*(Suppl 1), A47-A47.

Engel, R. J., Welsh, R. L., & Lewis, L. J. (2000). Improving the well-being of vision-impaired older adults through orientation and mobility training and rehabilitation: An evaluation. *RE: view*, *32*(2), 67-76.

Erickson, W., Lee, C., & von Schrader, S. (2014). *Disability statistics from the 2012 American Community Survey (ACS).* Ithaca, NY: Cornell University Employment and Disability Institute (EDI). Retrieved Jan 10, 2015 from www.disabilitystatistics.org

Feng, T., Timmermans, H. (2013). Transportation mode recognition using GPS and accelerometer data. *Transportation Research Part C: Emerging Technologies 37 (December)*, 118–130. doi:10.1016/j.trc.2013.09.014.

Gastin, P., & Williams, K. (2010). Accuracy of 1 Hz versus 5 Hz GPS devices to measure movement patterns in team sport activities. *Journal of Science and Medicine in Sport, 2010 Asics Conference of Science and Medicine in Sport Hot topics in the tropics'', 3-6 November 2010, 13*, Supplement 1 (December): e32. doi:10.1016/j.jsams.2010.10.529

Good, G., LaGrow, S., & Alpass, F. (2008). An age-cohort study of older adults with and without visual impairments: Activity, independence, and life satisfaction. *Journal of Visual Impairment & Blindness, 102*, 517-527.

Griffin-Shirley, N., Kelley, P., Matlock, D., & Page, A. (2006). Consumers' perspectives on effective orientation and mobility services for diabetic adults who are visually impaired. *RE:View, 38*(2), 86-95. Retrieved from http://search.proquest.com/docview/222957672?accountid=15099

Hagstromer, M., Ainsworth, B. E., Oja, P., & Sjostrom, M. (2010). Comparison of a subjective and an objective measure of physical activity in a population sample. *Journal of physical activity & health, 7(4),* 541.

Hakobyan, L. Lumsden, J. O'Sullivan, D., & Bartlett, H. (2013). Mobile assistive technologies for the visually impaired. *Survey of Ophthalmology 58* (6): 513–28. doi:10.1016/j.survophthal.2012.10.004

Hill, E., & Ponder, P. (1976). *Orientation and mobility techniques: A guide for the practitioner*. New York: American Foundation for the Blind.

Houston, D., Ong, P., Guillermo, J. & Winer, A. (2011). Traffic exposure near the Los Angeles–Long Beach Port Complex: Using GPS-enhanced tracking to assess the implications of unreported travel and locations. *Journal of Transport Geography, Special section on Alternative Travel futures, 19* (6): 1399–1409. doi:10.1016/j.jtrangeo.2011.07.018

Jacobson, W. H. (1993). *The art and science of teaching orientation and mobility to persons with visual impairments*. New York: American Foundation for the Blind Press.

Jacobson, W. H. (2013). *The art and science of teaching orientation and mobility to persons with visual impairments (2nd ed.)*. New York: American Foundation for the Blind Press.

Kim, D.S., Wall Emerson, R., & Curtis, A. (2009). Drop-off detection with the long cane: Effects of different cane techniques on performance. *Journal of Visual Impairment & Blindness, 103*, 519-530.

Kim, D.S., Wall Emerson, R., & Curtis, A. (2010). Interaction effects of the amount of practice, preferred cane technique, and type of cane technique used on drop-off detection performance. *Journal of Visual Impairment & Blindness, 104,* 453-463.

Kuyk, T., Elliott, J. L., Wesley, J., Scilley, K., McIntosh, E., Mitchell, S., & Owsley, C. (2004). Mobility function in older veterans improves after blind rehabilitation. *Journal of rehabilitation research and development*, *41*(3), 337-346.

LaGrow, S., & Blasch, B. (1992). Orientation and mobility services for older persons, in A.L. Orr (Ed), *Vision and aging: Crossroads for service delivery*, (pp. 255-287). New York:

American Foundation for the Blind.

LaGrow, S., Ebrahim, B., & Towers, A. (2014). Development of the Difficulty with Mobility Questionnaire: A pilot study. *International Journal of Orientation & Mobility, 6*, 59-69.

LaGrow, S. J., & Long, R. (2011). *Orientation and mobility: Techniques for independence*. New York: Association for Education and Rehabilitation of the Blind and Visually Impaired.

McMinn, D., Rowe, D., &, Čuk, I. (2012). Evaluation of the TrackstickTM Super GPS Tracker for use in walking research. *Research Quarterly for Exercise and Sport 83* (1): 108–13. doi:10.1080/02701367.2012.10599831

Neven, A., Janssens, D., Alders, G., Wets, G., Van Wijmeersch, B., & Feys, P. (2013). Documenting outdoor activity and travel behaviour in persons with neurological conditions using travel diaries and GPS tracking technology: A pilot study in multiple sclerosis. *Disability and Rehabilitation 35* (20): 1718–25. doi:10.3109/09638288.2012.751137

Robinson, C. A., Shumway-Cook, A., Ciol, M. A., & Kartin, D. (2011). Participation in community walking following stroke: subjective versus objective measures and the impact of personal factors. *Physical therapy*, *91*(12), 1865-1876.

Rodriguez, D., Brown, A., & Troped, P. (2005). Portable Global Positioning Units to complement accelerometry-based physical activity monitors. *Medicine & Science in Sports & Exercise 37* (Supplement): S572–S581. doi:10.1249/01.mss.0000185297.72328.ce

Rovner, B., & Casten, R. (2002). Activity loss and depression in age-related macular degeneration. *The American Journal of Geriatric Psychiatry, 10*, 305-310.

Shoval, N., & Isaacson, M. (2006). Application of tracking technologies to the study of pedestrian spatial behavior. *The Professional Geographer*, *58*(2), 172-183.

Shoval, N. (2008). Tracking technologies and urban analysis. *Cities 25* (1): 21–28. doi:10.1016/j.cities.2007.07.005

Soong, G. P., Lovie-Kitchin, J. E., & Brown, B. (2001). Does mobility performance of visually impaired adults improve immediately after orientation and mobility training? *Optometry & Vision Science*, *78*(9), 657-666.

Virgili, G., & Rubin, G. (2010). Orientation and mobility training for adults with low vision. *Cochrane Database of Systematic Reviews* Issue 5. Art. No.: CD003925. DOI: 10.1002/14651858.CD003925.pub3

Whiteneck, G.G.(1994). Measuring what matters: Key rehabilitation outcomes. *Archives of Physical Medical Rehabilitation, 75,* 1073-1076.

van der Spek, S. (2009). Mapping pedestrian movement: Using tracking technologies in Koblenz.
In *Location Based Services and TeleCartography II* (pp. 95-118). Springer Berlin Heidelberg.

van der Spek, S., Van Schaick, J., De Bois, P., & De Haan, R. (2009). Sensing human activity: GPS tracking. *Sensors*, *9*(4), 3033-3055.

World Health Organization. (1996). WHOQOL-BREF: Introduction, administration, scoring and generic version of the assessment: field trial version, December 1996.

Wu, J., Chengsheng, J., Zhen, L., Houston, D., Guillermo, J., & McConnell, R. (2010). Performances of different global positioning system devices for time-location tracking in air pollution epidemiological studies. *Environmental Health Insights 4* (November): 93–108. doi:10.4137/EHI.S6246