Travel Behavior of Blind Individuals before and after Receiving Orientation and Mobility Training (Phase 2)

FINAL REPORT

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This study devised, tested, and refined a new method for assessing O&M training involving Global Positioning System (GPS) data loggers and accelerometers to collect objective, quantitative, and valid measures of blind individuals’ travel behavior, physical activity pre- and post-O&M training. A total of 12 visually impaired travelers were recruited from scheduled recipients of O&M training at the Bosma Enterprises and Leader Dogs for the Blind. Prior to receiving the training, participants’ travel and physical activities were recorded using a hip-worn GPS travel recorder and accelerometer devices, and subjectively via an audio-recorded travel diary. Altogether, over 4,000 hours of locational and physical activity data were recorded and analyzed over the 322 days evaluated. The Difficulty with Mobility Questionnaire (DMQ-23) was also administered to measure the participant’s perceived level of difficulty in getting around both before and after the training. The researchers found that the perceived difficulty with mobility among study participants, measured by the aggregate DMQ-23 score, was significantly lower after receiving O&M training indicating enhanced confidence in their mobility skills once they received the training. Small but statistically significant increases in trip distances and durations were found after the training, as measured via more objective measures gleaned from GPS and accelerometer data although no significant gains were observed among study participants in terms of more general physical activity.
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EXECUTIVE SUMMARY

This study devised, tested, and refined a new method for assessing O&M training involving Global Positioning System (GPS) data loggers and accelerometers to collect objective, quantitative, and valid measures of blind individuals’ travel behavior, physical activity pre- and post-O&M training. A total of 12 visually impaired travelers were recruited from scheduled recipients of O&M training at the Bosma Enterprises and Leader Dogs for the Blind. Prior to receiving the training, participants’ travel and physical activities were recorded using a hip-warn GPS travel recorder and accelerometer devices, and subjectively via an audio-recorded travel diary. Altogether, over 4,000 hours of locational and physical activity data were recorded and analyzed over the 322 days evaluated. The Difficulty with Mobility Questionnaire (DMQ-23) was also administered to measure the participant’s perceived level of difficulty in getting around both before and after the training. The researchers found that the perceived difficulty with mobility among study participants, measured by the aggregate DMQ-23 score, was significantly lower after receiving O&M training indicating enhanced confidence in their mobility skills once they received the training. Small but statistically significant increases in trip distances and durations were found after the training, as measured via more objective measures gleaned from GPS and accelerometer data although no significant gains were observed among study participants in terms of more general physical activity.
1. Introduction

A Cochrane Review (Virgili & Rubin, 2010) of research in the area of Orientation and Mobility (O&M) training for adults with low vision indicates 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-Kitchin & Brown, 2001). In a study of 70 individuals (60 and older) who received blind rehabilitation services including O&M training, 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. On the other hand, 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 as measured by the Difficulty with Mobility Questionnaire-23. Participants in this study reported significant improvement in all but 3 of the 23 skill areas.

Such conflicting results may have resulted, at least partly, from challenges of measuring functional effects of O&M training in an objective manner. Studies of the pedestrian travel of disabled and non-disabled individuals have found disparities between subjective and objective measures of pedestrian activity (e.g. 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 the relationship between O&M training and a person’s travel experiences suggests that both subjective perceptions and objective measures of activity are necessary to fully examine 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; Neven et al. 2013; Rodriguez, Brown, & Troped, 2005). Van der Spek, Schaick, Bois, and Hann (2009) provides evidence that the use of these new technologies, coupled with qualitative data from travel diaries and surveys aimed at capturing perceived confidence in the ability to get around safely, will allow researchers to obtain a more comprehensive and objective assessment of O&M training effectiveness. The
purpose of this study is to examine actual travel behaviors of blind individuals and determine the effectiveness of programs of O&M training measured in both objective and subjective methods.

2. Methods

Study Design and Participants

Upon approval from WMU’s Human Subjects Institutional Review Board (HSIRB), 14 visually impaired adults were recruited from scheduled recipients of the Leader Dogs for the Blind’s Accelerated Orientation and Mobility Program (AOMP) or Bosma Enterprises’ Orientation and Mobility program (see Research Procedure for details). Thirteen completed the study and the data from all but one participant were usable for analyses. Selection criteria included legal blindness, reasonably good stamina (i.e., stamina to walk for 30 minutes without resting), high motivation (i.e., keen interest 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 where there are stores, parks, or other points of interest in walking distance. Participants’ visual acuities ranged from no light perception to 20/40, and visual fields for some of the participants were constricted to 5-15 degrees. There were 8 female and 4 male participants, whose ages ranged from 35 to 57 (median age = 52).

Apparatus

The Qstarz 66-CH series: BT-Q1000XT Travel Recorder (see Figure 1) was used in the study given the following merits: 1) small device size and weight, 2) ease of use, 3) battery life, 4) geographic/positional accuracy, 5) storage capacity, and 6) durability. This compact (7.2 cm x 4.7 cm x 2cm) and lightweight (67g) device is also DGPS-enhanced (i.e., it makes use of ground-based reference stations thus improving locational accuracy (<2.5m) and velocity readings (0.05m/s)). Thanks to its integrated vibration sensor technology to detect movement status,
which reduces power consumption while not in motion, daily charging enabled the device to operate continuously during our data collection periods.

In addition, the Actigraph wGT3X-BT monitor (see Figure 1) was used in light of its merits in size (3.5 cm x 3.5 cm x 1 cm), weight (14 g), large storage capacity (4 GB), and its ability to support the GPS travel recorder with the simultaneous detection of transportation modes and logging of fine-scale trip characteristics. The device was capable of producing the information we aimed to obtain, including steps taken, participant position (standing, sitting, or lying) and overall physical activity intensity measured in terms of a number of energy expenditure algorithms including . For recording travel diaries, the Wilson digital voice recorder (Model 2309457MX) was used in light of its simplicity of operation and blind-user-friendly design, including large and easy-to-find buttons.

**Survey Instrument**

Difficulty with Mobility Questionnaire (DMQ-23), developed by LaGrow et al. (2014) to measure participants’ perceived ability to get around, was used in the study (see LaGrow et al., 2014, for the questionnaire). Concurrent validity of DMQ-23, assessed by examining the correlation between the 23-item DMQ score and the ability-to-get-around 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).

**Research Procedure**

The participants were asked to keep an activity log (travel diary) each time they change location by recording the time, starting location, destination, trip purpose, mode of travel (e.g., walk, private car, public transportation, etc.), and whether they were accompanied by someone.
Participants used the Wilson Digital Voice Recorder (see Apparatus for details) to record their travel activity.

Source: https://arkidecture.wordpress.com

Figure 1. Hip-Mounted Accelerometer and GPS Data Logger Devices as Worn by Research Subjects

One of the experimenters visited the participants prior to their scheduled O&M training. Upon signing the informed consent form approved by WMU’s HSIRB, each participant wore a portable GPS travel recorder and an accelerometer (see Apparatus for details). The participant was instructed to wear these devices at all times except during sleep, swimming, and taking a shower. These devices were initially set up by the experimenter and the participant was instructed to charge the devices regularly. The GPS travel recorder was configured to collect
locations every 20 seconds. Travel activity data from the GPS travel recorder and the accelerometer were downloaded at the end of each of the two-week-long pre-training and post-training data collection periods. Our pilot study indicated that two weeks of data collection in each period provides adequate amount of data to answer our research questions.

Considerable data processing was needed to make the information collected by the two sensors meaningful for analysis. Processing the GPS log data involved several steps including the filtering invalid values, trip detection and travel mode estimation. We established ten minutes as the maximum amount of time between GPS fixes allowed to occur before loss-of-signal (LOS) was declared. For durations less than this value, the previous good GPS fixed was assumed. GPS coordinates reported with horizontal dilution of precision (HDOP) values exceeding 20 were also determined to be invalid and removed from the analytical dataset in order to maintain locational accuracy. Further, records with maximum speeds between GPS points exceeding 130 kmh (or 80.8mph) were discarded as well as minimally significant distances in records that suggest rapid forwards and backwards movements often caused by GPS jitter.

Travel trips were identified using a combination of GPS and accelerometer data, with frequency, density and speed information algorithmically smoothed over a two-minute analytical window to control for sensor instability in data capture (Procter et al. 2018). For each window we calculated the mean, standard deviation, and 95th percentile of each accelerometer axis and speed, from the GPS device. Trips were initiated if the participant traveled a minimum distance of 34 meters in one minute (using 95th percentile averages of speed), with each trip having a minimal distance (100 meters), duration (3 minutes) and maximum pause time (5 minutes). GPS locations associated with a pause exceeding five minutes, then, would be labeled a trip end point.
In terms of mode estimation, we established 1kmh (or 0.62 mph) as the minimum velocity needed for a series of points to be identified as part of a walking or non-motorized pedestrian trip, while speeds exceeding 10 kmh (or 6.2 mph) were labeled as motorized vehicle trips. Note that bicycle trips were not estimated or otherwise considered in the objective analysis, in part because participants did not indicate this travel mode within their travel diaries. Public transit trips were also not considered in the analysis due to the inconsistent logging of such trips in the travel diaries and the lower detection rates achieved in past studies using the selected mode estimation methodology (Kang et al. 2018).

In addition to travel behavior, accelerometer data were utilized to measure the general physical activity of study participants, based on the premise that enhanced confidence in mobility skills has the potential to translate into greater physical activity via walking. Raw accelerometer measurements or counts of movements (recorded at 30Hz) derived from both the vertical axis (VT) and vector magnitude (VM) methods along three axes (x, y and z) were aggregated into 60 second epochs to arrive at counts per minute (CPM) values. Together with the inclinometer function, these activity count rates were used to estimate sedentary time and other categories of physical intensity (Sasaki, John, and Freedson 2011).

Table 1 summarizes the evaluation periods as well as the quantity and category of data collected using the GPS data logger, accelerometer and travel diary by participant. The data represent the hours and entries remaining after the aforementioned filtering and other quality control measures. Altogether, 786,626 GPS data points were analyzed together with 326,684 aggregated accelerometer readings. The incompleteness of the data is notable, with only four (or 33 percent of) study participants yielding a complete set of both objective and subjective data. Missing or incomplete data resulted from a variety of factors including the mishandling of
hardware devices, sensor limitations and variability in the consistency of study subject participation, more generally.

Table 1
Travel and Physical Behavior Data Collected by Study Participant, Category, Before and After O&M Training

<table>
<thead>
<tr>
<th>Participant</th>
<th>Evaluation Period (days)</th>
<th>GPS Data Log (hours)</th>
<th>Accelerometer Epochs (hours)</th>
<th>Travel Diary Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>P1</td>
<td>14</td>
<td>14</td>
<td>256</td>
<td>98</td>
</tr>
<tr>
<td>P2</td>
<td>14</td>
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<td>297</td>
<td>122</td>
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<td>14</td>
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<td>259</td>
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<td>256</td>
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<td>P6</td>
<td>14</td>
<td>14</td>
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<td>9</td>
<td>170</td>
<td>184</td>
</tr>
<tr>
<td>P8</td>
<td>12</td>
<td>12</td>
<td>N/A</td>
<td>285</td>
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<tr>
<td>P9</td>
<td>14</td>
<td>14</td>
<td>234</td>
<td>254</td>
</tr>
<tr>
<td>P10</td>
<td>14</td>
<td>14</td>
<td>271</td>
<td>295</td>
</tr>
<tr>
<td>P11</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>N/A</td>
</tr>
<tr>
<td>P12</td>
<td>14</td>
<td>14</td>
<td>210</td>
<td>N/A</td>
</tr>
</tbody>
</table>

At the completion of the pre-O&M-training data collection period, each participant’s level of difficulty with mobility was measured with DMQ-23 and WHOQOL ability-to-get-around question (see Survey Instrument for details). Upon completion of the post-O&M-training data collection period, each participant’s level of difficulty with mobility was measured again with the same instruments.

We used two O&M training programs for this study: Leader Dogs for the Blind’s (Rochester, MI) Accelerated O&M Program (AOMP) and Bosma Enterprises’ (Indianapolis, IN) O&M program. The AOMP is a seven-day intensive residential O&M training program that
provides blind individuals safe travel skills. Although the AOMP is shorter in timeframe than
many traditional O&M training 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, and rural settings. The Bosma Enterprises’
O&M program is a residential O&M training program that provides blind individuals the skills
needed to travel safely. This program is typically 3-4 months long (five days a week), but the
participants receive other rehabilitation training as well as an O&M training during this period.
This program also provides training in a variety of environments (indoor, residential, business,
etc.).

Variables and Analyses
Travel behavior of blind individuals were operationalized via the following variables: 1) trip
frequencies, 2) trip modes, 3) trip distances, 4) travel times, 5) trip purposes, 6) whether trip was
assisted/accompanied; and 7) perceived ability to get around. The first six measures were derived
from GPS travel recorder, accelerometer, and travel diary data of each participant, while the
perceived ability to get around measure was obtained from the DMQ-23 questionnaire and
WHOQOL ability-to-get-around question.

Following Freedson, et. al, four cut points were used to categorize different intensities
of movement namely, sedentary (99 CPM or less), light (100-1,951 CPM), moderate (1,952 to
5,724 CPM), vigorous (5,725 to 9,498 CPM) and very vigorous (9,499 CPM or more) (Freedson,
Melanson, and Sirard 1998).

We used a significance level of .05 for all statistical tests (two-tailed). The statistical
power for the t-tests was .71 when a large effect size (d = .8) was assumed (Cohen, 1988;
Erdfelder, Faul, & Buchner, 1996). All statistical analyses, except for power analyses (G*Power version 3.1), were conducted with SPSS version 25.

3. Results

Participants’ perceived difficulty with mobility, measured by the aggregate DMQ-23 score (1 = none at all, 2 = a little, 3 = a moderate amount, 4 = a great deal, 5 = an extreme amount), was significantly lower after receiving an O&M training (M = 2.06, SD = .60) than before receiving the training (M = 3.31, SD = .59), t = 7.28, p < .001, indicating more confidence in their mobility skills once they received the training (see Table 1). Perceived difficulty scores in most skill areas, including indoor travel, sidewalk travel, street crossing, and orientation skills, were significantly lower after the training than before the training (see Table 1). However, perceived difficulties in using public transportation before (M = 3.86, SD = 1.22) and after receiving an O&M training (M = 3.14, SD = 1.68) were not significantly different, t = 1.99, p = .094. For consistency with the DMQ-23 scale, the original scale of the WHOQOL question (‘How well are you able to get around?’) was reversed (1 = very well, 5 = very poorly) before the analyses. Perceived difficulty in mobility measured by the WHOQOL question was also significantly lower after the training (M = 1.92, SD = .19) than before the training (M = 3.00, SD = .30), t = 3.03, p = .012 (see Figure 2), also indicating more confidence in their ability to get around after receiving an O&M training. Some of the challenges in mobility expressed by the participants before they received an O&M training included irregular walking surfaces, debris on sidewalks, reduced depth perception, glare, and lack of public transportation service in their local communities. Some of the mobility challenges the participants expressed after they received an
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O&M training were unfamiliarity with surroundings, difficulty reading signs, glare, adverse weather conditions, and lack of public transportation services.

Table 2. DMQ-23 Difficulty with Mobility Questionnaire Mean Scores Before (Pre-) and After (Post-) Orientation and Mobility (O&M) Training

<table>
<thead>
<tr>
<th>Skill Area</th>
<th>Pre (SD)</th>
<th>Post (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Travel (N = 12)</td>
<td>3.30 (.73)</td>
<td>2.16 (.91)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sidewalk Travel (N = 12)</td>
<td>3.15 (.87)</td>
<td>1.61 (.50)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Street Crossing (N = 12)</td>
<td>3.76 (.76)</td>
<td>2.43 (1.09)</td>
<td>.003</td>
</tr>
<tr>
<td>Orientation (N = 12)</td>
<td>3.00 (1.15)</td>
<td>1.94 (.68)</td>
<td>.008</td>
</tr>
<tr>
<td>Use of Public Transportation (N = 7)</td>
<td>3.86 (1.22)</td>
<td>3.14 (1.68)</td>
<td>.094</td>
</tr>
<tr>
<td>Aggregate DMQ-23 Score (N = 12)</td>
<td>3.31 (.59)</td>
<td>2.06 (.60)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Figure 2. WHOQOL Ability-to-get-round Question Score (1 = very well, 5 = very poorly) (N = 12). Error bars Indicate Standard Errors.
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Figure 3
Box Plots of Selected Travel Behavior (i.e., Trip) and Physical Activity Scores Before (Pre-) and After (Post-) Orientation and Mobility (O&M) Training

Results from the travel behavior and physical activity data are presented in Table 3. A total number of 1,989 trips were identified across the nine participants reporting both pre- and post-training data. Maps comparing the GPS-recorded travel over these two periods are presented in Figure 3 by participant. The travel behavior data suggest that there was no statistically significant difference between the number of trips taken before (\( \bar{x} = 104.6, \text{sd} = 70.6 \)) and after (\( \bar{x} = 87.3, \text{sd} = 78.1 \)) training (t\(=\) -0.491, p\(=\) 0.630) nor were there significant gains in the percentage of walking trips pre- (\( \bar{x} = 53.7, \text{sd} = 49.9 \)) and post- (\( \bar{x} = 51.3, \text{sd} = 52.1 \)) training (t\(=\) -0.068, p\(=\) 0.293). Our analyses did find significant differences for both average trip distance (in kilometers) before (\( \bar{x} = 6.5, \text{sd} = 23.4 \)) and after (\( \bar{x} = 10.4, \text{sd} = 38.8 \)) training (t\(=\) 2.70, p\(=\) 0.007) and average trip durations (in minutes) before (\( \bar{x} = 29.9, \text{sd} = 37.0 \)) and after (\( \bar{x} = 34.5, \text{sd} = 42.9 \)) training.
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training \((t=2.58, p=0.010)\) across all trips taken \((N=1,989)\). However, no significant differences were observed between the pre- and post-periods for either trip distance nor duration when data were grouped by participant \((N=9)\). Further, the activity data suggest no statistically significant differences in physical intensity across the pooled hourly data \((N=5,154)\), save for a slight decrease in the rate of light movements detected before \((\bar{x}=7.6, sd=11.2)\) and after \((\bar{x}=7.0, sd=10.8)\) O&M instruction \((t=1.70, p=0.090)\). Similar two-group t-tests executed among participants \((N=9)\) also failed to show statistically significant differences.

Figure 4
Travel GPS Data Before (Pre-) and After (Post-) Orientation and Mobility (O&M) Training by Study Participant

4. Discussion

Interpretation of the findings

Participants’ perceived difficulty with mobility was significantly lower after receiving an O&M training than before receiving the training in multiple aspects, including indoor travel, sidewalk travel, street crossing, and orientation skills. This result indicates that they felt more confident in their mobility skills once they received the training. However, although there was an increase in trip distance and duration, an improvement in participants’ perceived ability to get around didn’t translate to actual increase in number of trips or level of physical activity of visually impaired individuals.

The results of this study are consistent with the findings of some of the previous studies (Chaudhury et al., 2010; Hagstromer et al., 2010; Robinson et al., 2011) in that subjective measures of physical activity, including walking in the community, and actual physical activity level do not tend to correlate closely with each other. It is possible that lack of readily available public transit system where the participants resided prevented them from attempting to travel to places that are meaningful to them (e.g., grocery stores, shopping malls, fitness centers, etc.) even after receiving an O&M training. In fact, most of the participants lived where there was no public transportation available within walking distance. The finding that the participants didn’t take more walking trips and their level of physical activity didn’t increase after the training may stem from the fact that lifestyle change is generally challenging and often requires strong incentives or life-changing events. Most of the participants had been leading a sedentary lifestyle
with limited physical activities and it appears that they didn’t change their lifestyles to incorporate more physical activities even after receiving the O&M training. Adverse weather conditions (e.g., cold weather, severe snow storms, etc.) might have also made it challenging for some participants to engage in more physical activities such as regular walks in the neighborhood.

One of the limitations of the study was that the vast majority of the participants in the study received an O&M training from one rehabilitation agency and the result of the study may not generalize to the participants receiving an O&M training that may differ in training duration or the training setting. Another limitation of the study is related to weather conditions. Due to challenges in recruitment, we did not limit participants to those who were scheduled to receive an O&M training during temperate seasons. As a result, adverse weather conditions, particularly extremely cold or severe snow storms, might have kept some of the participants home even after they received the training.

The findings of the study indicate that the recipients of an O&M training became more confident in their abilities to get around independently. Since even the perception of independence contributes significantly to life satisfaction (Good, LaGrow, & Alpass, 2008), such change in sense of independence will likely improve one’s sense of quality of life. However, in the absence of readily available public transit system and strong incentives to walk and exercise more, direct health benefits resulting from an O&M training may be limited because no improvements in level of physical activity were obtained.

Future studies conducted with a larger sample that includes participants who receive various types of O&M training (e.g., extensive residential training, short itinerant training, etc.) may be helpful to improve the generalizability of the findings. Inclusion of more participants
who live in a neighborhood with readily available public transit system would also be helpful to
determine whether the absence of available public transit system indeed plays a significant role
in an individual’s travel behavior.
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