EVALUATING THE EFFECTIVENESS OF THE TRAVEL ASSISTANCE DEVICE ON THE BUS RIDING BEHAVIOR OF INDIVIDUALS WITH DISABILITIES

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Abstract

Independence for individuals with disabilities can be facilitated through the use of devices that have been created and adapted for these individuals. Research regarding the use of technology to afford independence to those with disabilities is growing as new electronic devices are created. One such device is the Travel Assistance Device (TAD), a software application for mobile phones which provides real-time navigation guidance to public transportation riders. TAD has undergone technology proof-of-concept testing, which determined that TAD could provide timely prompts to transit riders at the programmed locations. The purpose of this research study was to determine whether the prompts given by TAD would exhibit stimulus control over the participant's behavior of pulling the cord to stop the bus at the appropriate time and exiting the bus at the appropriate stop. TAD was evaluated in an ABAB design with three adults with mental retardation. Results show favorable outcomes for the 3 participants who were able to pull the bus cord at the appropriate stops and exit the bus only when TAD delivered prompts.

1 INTRODUCTION

Many individuals who have disabilities are no strangers to having care providers as constant fixtures in their everyday lives. Care providers are necessary for individuals with disabilities due to an array of physical or cognitive impairments that they experience. These individuals may face a variety of potential dangers throughout their day due to a lack of knowledge or ability to stay home without supervision, leave a building if it were on fire, cross the street safely when traffic is present, or use public transportation without getting lost *(Sohlberg, Fickas, Hung, & Fortier, 2007)*. However, with the technological growth that has been seen in the last 20 years, a wide array of devices have been adapted, created, and utilized with the potential to create independence for individuals with disabilities. The majority of the research gathered for the purpose of this study specifically refers to individuals with an intellectual disability rather than individuals with mobility limitations. Virtual reality, pagers, hand held computer devices, and cellular phones have all been used to assist those who require assistance in their day to day lives *(Padgett, Stickland, & Coles, 2006) (Riffel, et al., 2005) (Self, Scudder, Weheba, & Crumrine, 2007) (Taylor, Hughes, Richard, Hoch & Coelo, 2004)*. These devices and others have been utilized across settings including in the home *(Cheslock, Barton-Hulsey, Romski, &Sevcik, 2008((Hersh & Treadgold, 1994; Lancioni, et al., 2008)*, in the work place *(Davies, Stock, & Wehmeyer, 2001) (Davies, Stock, & Wehmeyer, 2002a)*, and in the community *(Taylor, et al., 2004) (Zaruba, Kamangar, & Huber, 2003)* to facilitate such behaviors as, task initiation *(Wade & Troy, 2001)*, task completions *(Davies, Stock, & Wehmeyer 2002b)*, and indoor travel *(Lancioni, Gigante, O'Reilly, Oliva, & Montironi, 2000) (Lancioni, Mantini, O'Reilly, & Oliva, 1999) (Lancioni & Oliva, 1999) (Lancioni, Oliva, & Bracalente, 1995a) (Lancioni, Oliva, & Bracalente, 1995b) (Lancioni, Oliva, & Ten Hoppen, 1997) (Lancioni, O'Reilly, Oliva, & Bracalente, 1998).*

Assuring safety within the community is one of the most challenging aspects of providing individuals with intellectual disabilities the chance to be independent. This independence includes accessing the community, navigating safely when in the community, and returning safely to the original starting point. However the challenges faced by individuals with disabilities are great, especially when talking about accessing and using public transportation. Yet according to Rosenkvist, Risser, Iwasson, Wendel, and Stahl *(2009)*, training individuals with intellectual disabilities to use public transportation is one of the least researched areas. Individuals with intellectual disabilities may have a difficult time being able to find suitable transportation to complete their desired task and, once in the community, these individuals may forget why they have come out and how to get to their destination, and may get lost or disoriented *(Rosenkvist et al. 2009)*.

Although research in this area is scarce, some research on independence in the community is beginning to emerge in the literature. Understanding the navigational patterns and needs of individuals with intellectual disabilities has been the first step in developing tools to be utilized by individuals with intellectual disabilities. Sohlberg, Todis, Fickas, Hung, and Lemoncello *(2005)* conducted several focus groups with individuals with intellectual disabilities, care providers, and transit workers to determine the travel patterns of these individuals, how they access the community, with whom they access the community, how often they access the community, for what purposes, and what type of device could be designed to aid individuals to decrease barriers to independent travel.

The first part of the study focused on documenting the navigational patterns of 6 individuals and for what purposes the individuals went out into the community. After tracking these individuals for 4 months, researchers found that errands such as going to the mall, grocery shopping, and banking were the most frequent trips taken into the community. They also found that if trips into the community were taken independently, participants were more likely to walk or take the bus. Interestingly, researchers found that participants did not generalize the use of one mode of transportation across different tasks. For example if an individual habitually took the bus to go to the mall every Wednesday but walked to the store every Thursday the same individual would not take the bus to the store or walk to the mall.

In the second part of the study Sohlberg et al. *(2005)* conducted focus groups with individuals with disabilities, care providers, and transit workers to determine the challenges faced by individuals with disabilities, specifically traumatic brain injury, and how these challenges could be overcome. Some of the challenges faced by the individuals were fear of getting lost, getting separated from a travel companion, forgetting the destination, fear of asking strangers for help, expenses associated with taxis, concerns about safety, and following written directions. The groups also gave suggestions to researchers on what features they would find helpful in an assistive device. This study showed how the independence of individuals with disabilities is affected by their difficulties traveling and how their difficulties could be overcome through assistance from a travel device.

Further research by Sohlberg, Fickas, Hung, and Fortier *(2007)* used the findings from Sohlberg et al. *(2005)* to develop and test the effectiveness of using a PDA to deliver four different prompting methods and to see which prompting method was most effective while walking. The four prompting methods were an aerial map, a point-of-view map with arrows superimposed on the picture, text-based step-by-step instructions, and verbal step-by-step instructions. Participants of the study were given four different routes to follow on foot with the four different promoting methods. The researchers found that the best prompting method for these individuals was verbal step-by-step instructions.

According to Rosenkvist et al. *(2009)* some people with intellectual disabilities often do not even consider using public transportation or only consider using public transportation in the distant future due to factors such as the advice from other individuals around them not to use the bus because of potential dangers, the inability to handle performing complex series of tasks that are high paced, and forgetting how to use the bus. By investigating issues such as the navigational patterns of individuals with intellectual disabilities, modifications to the current transit system, and the development of prompting devices that can assist these individuals, researchers can afford independence to individuals with intellectual disabilities within the community that was not available before. Some research by Fischer and Sullivan *(2002)* focused on understanding the barriers experienced by people with intellectual disabilities, designing a user friendly model to reduce the cognitive load for these individuals within public transportation, and implementing their design in the real world.

Fischer and Sullivan *(2002)* found that:

a) Mistakes made by familiar and unfamiliar users fall into 2 categories:
    a. System errors (mislabeled buses, buses not running on time, detours from bus routes)
    b. User errors (falling asleep, failing to hear or understand announcements, forgetting to signal for the appropriate stop, and getting off at the wrong stop)

b) Even familiar users of public transportation made mistakes when using traditional navigational prompts such as maps, schedules, signs, landmarks, and clocks.

These findings led Fischer and Sullivan to propose two strategies for developing a user friendly model for individuals with disabilities. The first was to simplify the current navigational prompts used by the public transportation system and the second was to design and develop a technology-based device to deliver individualized prompts at the appropriate time. The authors decided that the second option would be better given that existing navigational prompts already use simplification measures such as the color coding of maps. The outline given for such a device included a schedule and activity management system, a system to share schedules with caregivers, and automated error detection with performance feedback, recovery, and care giver notification.

Although the study described above did not provide an actual device that could be tested, such a device would be the next step in providing independence to individuals with disabilities. The Travel Assistance Device (TAD) is a software application for GPS-enabled mobile phones that has been developed by the Center for Urban Transportation Research and the Department of Computer Science & Engineering at the University of South Florida under funding from the Florida Department of Transportation and the National Center for Transit Research. TAD is a navigation software program designed to prompt individuals via a cell phone to exit the bus at a pre-scheduled location. Once the software is downloaded to the cell phone, parents, travel trainers, or other authorized individuals can access the web management page to schedule trips to be transmitted to the cell phone. TAD offers phone alerts for the user on the bus, real time tracking of the cell phone via the web management page, an alarm that triggers when the user deviates from the pre-scheduled route, and estimated arrival times shown to the rider while they are waiting for the bus.

Two separate conceptual tests have been performed to assess whether each of the different components of the TAD system works consistently and adequately with the help of Hillsborough Area Regional Transit (HART) in the Tampa, Fl area *(Barbeau, et al. 2008; Barbeau, Georggi, Winters, 2010)*.These tests showed that when TAD was active each of the features of the device worked as it was intended.

Because these two conceptual tests were designed only to test whether TAD's features worked as intended, additional tests were needed to see if TAD had the ability to gain stimulus control over the transit rider's behavior. Stimulus control refers to the increased probability that a behavior will occur in the presence of a particular stimulus because that behavior was reinforced in the past when that environmental stimulus was present (Miltenberger, 2008). In other words, an important question remained: would TAD's features actually help a transit rider to pull the cord and exit the bus at the correct time and location?

The purpose of this research study was to determine whether the prompts given by TAD would exhibit stimulus control over the participant's behavior of pulling the cord to stop the bus at the appropriate time and exiting the bus at the appropriate stop.

2 METHOD

2.1 Participants and Setting

Participants in this study were three individuals with moderate mental retardation. Pseudonyms are used in this paper to refer to individual participants. The participants were ambulatory and had previous travel training on how to use public transportation but were unable to travel a novel route on the bus independently. Travel training for each of the participants was tailored to their individual need. The travel trainer establishes one to three locations that the trainee travels to or wishes to travel to and then provides the trainee with pictures of each location to act as a visual prompt when riding the bus. He then accompanies the participants to each of these locations, teaching the trainees how to deposit their money or show their bus pass, select a seat near the door, recognize the bus stop before the location in their picture, pull the bus cord when they pass the stop before their stop, and exit the bus.

Mark was a 22 year old male diagnosed with moderate mental retardation with an IQ of 50. Mark was travel trained in 2008 and used the bus approximately 5 times a week using the same bus and route each time. Mark traveled to a local university to attend a transitional training program for individuals with disabilities which was approximately 2 miles from his home. Mark independently completed personal hygiene tasks such as brushing his teeth and bathing. He managed his time and daily routines with minimal prompts from others. Mark required others to prepare his meals. Paige was a 20 year old female diagnosed with Down syndrome and moderate mental retardation with an IQ of 49. Paige was travel trained in 2004 and used the bus approximately 5 times a week using the same bus and route each time. Paige traveled approximately 20 miles to an adult day training program. Paige independently completed her personal hygiene tasks and some daily routines. She required assistance with meal preparation and time management. Clark was a 25 year old male diagnosed with Down syndrome and moderate mental retardation with an IQ of 45. Clark was travel trained in 2004 and did not use the bus to access the community at that time. Clark independently completed all personal hygiene tasks. He required assistance with preparing meals, managing time, and managing his daily routine. The observations for baseline and intervention phases were conducted on the city transportations system in a metropolitan area. Training for the Travel Assistant Device (TAD) took place by providing participants with behavioral skills training (BST) in a classroom setting.

2.2 Target Behaviors and Data Collection

The target behaviors marked for increase when utilizing TAD were pulling the bus cord to signal the desired bus stop within 5 seconds of passing the bus stop prior to the appropriate stop and exiting the bus at the appropriate stop. Participants received 1 point if they pulled the bus cord signaling their stop at the correct location and within the time limit. Participants received another point if they then exited the bus at the correct location. If participants failed to pull the cord at the appropriate location and time they automatically received a 0 for the assessment, even if they exited the bus. The score was assigned in this way because a rider first has to pull the cord to request the bus to stop before exiting.

Data were also collected on whether the participant looked at TAD when it vibrated, whether TAD provided the prompts at the appropriate locations, whether the participant asked people for directions to his or her location, and any observational data on what the participant was doing while on the bus. The bus routes chosen for assessment were different on every assessment. The routes were chosen based on the participants' current and past travel patterns. Bus routes that the participants traveled on more than once a week were excluded from assessments due to the possible confounding variable of practice effects. Also, any bus stop that provided a connection to another bus route was excluded because at these stops the bus driver is instructed to announce the names of streets for riders; however the bus did pass through these bus stops on the way to the participant's appropriate stop.

2.3 Interobserver Agreement

Interobserver agreement (IOA) was assessed for 33% of the trials in each phase of the study and was calculated by dividing the number of agreements by the response opportunities. A small hand held video camera was used to record the participant and was viewed separately by a research assistant. During the first baseline IOA was calculated to be 83%. During the first post-training phase IOA was calculated to be 100%. During the second baseline phase IOA was calculated to be 100%. For the final post-training phase the IOA was calculated at 100%. The overall IOA for all phases was calculated at 95.8%.

2.4 Social Validity

Social validity was assessed by giving parent social validity surveys before baseline and after the completion of the study. The surveys were intended to capture how parents felt about their child using public transportation with and without an assistive device, and to capture how the parents feeling changed from before to after their child was able to use TAD. The surveys asked questions focusing on how often each participant used the bus system, how confident the parents were in their child's ability to use the bus system to access familiar and novel locations, how confident would they be if their child had an assistive device, and how confident they were in their child's ability to access new locations when their child used TAD.

2.5 Travel Assistance Device

The Travel Assistance Device (TAD) is a mobile phone software application for cell phones that prompts a transit rider using audio, tactile (vibration), and visual prompts to pull the bus cord when the bus is approaching the appropriate bus stop (Figure 1). Users of the TAD system can access and download the TAD mobile phone software from a web site. Desired trip itineraries can be planned by parents, caretakers, travel trainers, or capable trainees via the TAD website and saved for future travel. A trip is planned by clicking on the bus stop that a user should board as well as the bus stop where the user should exit the vehicle for each segment of the trip. The TAD website also allows parents, travel trainers, and caretakers to view the real-time position of the transit rider on a map in case they become lost. Once the trip has been planned using the website, the transit rider can then access their pre-planned trips on their phone via the TAD mobile application. More information about the TAD website, including screenshots, is available in *(Barbeau, et al. 2008; Barbeau, Georggi, Winters, 2010).*

TAD delivers two sets of prompts to the participant during a given trip. The first prompt is delivered once the bus comes within 300 meters of the desired bus stop (Figure 1a). The prompts consist of TAD vibrating and providing an audio prompt, "Get ready." The second set of prompts occurs once the phone passes the bus stop prior to the desired bus stop (Figure 1b). The prompts consist of the phone vibrating and then providing the audio and visual prompt, "Pull the cord now." The phone continually vibrates and provides a visual and audio prompt to "Pull the cord now" until the participant responds to the prompts by pressing a button on the phone.

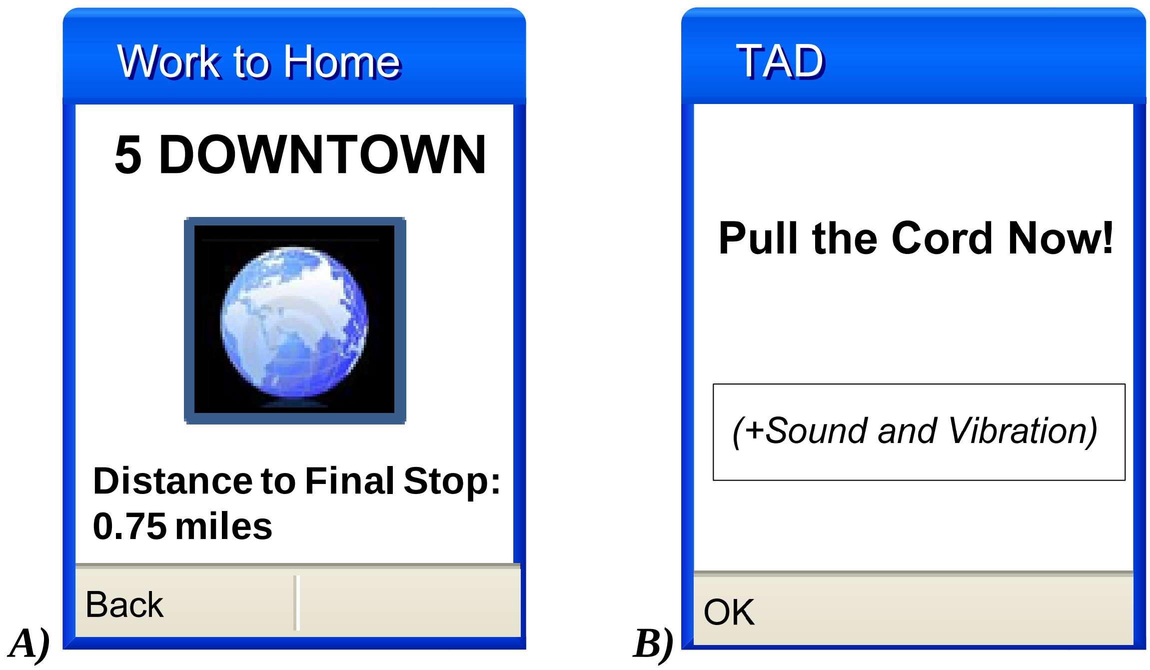

Figure 1 - The two TAD mobile phone application screens that the rider sees while riding the bus. A) The "Get Ready" prompt is repeated twice in an audible voice, while the phone vibrates. B) The TAD mobile phone application screen that is displayed when the rider passes the stop prior to the destination bus stop. The phone announces "Pull the Cord Now" in an audible voice and vibrates continuously until the rider presses the "Ok" button.

2.6 Procedure

The effects of TAD were evaluated in an ABAB research design (A = baseline and B = post-training). The ABAB design measures a baseline (the first A), a treatment measurement (the first B), the withdrawal of treatment (the second A), and the re-introduction of treatment (the second B). If TAD was not effective during the treatment phase, in-situ training would be provided and evaluated in a reversal design. As previously mentioned each participant had received travel training focused on using public transportation prior to this study. The travel training program for each of the individuals was custom designed to fit the ability and needs of the participant. All programs addressed how to use public transportation to access trips frequently taken by the participant at that time, such as to and from work and to and from home.

Baseline and post-training. For the purpose of this study there were two types of research assistants (RA): an RA who was familiar to the participant (familiar RA), and an RA who the participant did not know (inconspicuous observer or unfamiliar RA). During all phases participants were observed by inconspicuous observers on the bus to gather data and to ensure the safety of all participants. During assessments, participants met two familiar RAs at a local transit center. Transit center start locations for the first baseline assessments were chosen by each participant. Transit center start locations for further assessments were randomly assigned and were limited to 4 transit centers. The familiar research assistants introduced themselves to the participant when they arrived at the transit center. The primary researcher instructed the participant to follow him or her to "X" bus. The primary researcher then told the participant that he or she was going to take a short trip on "X" bus making sure to point to the appropriate bus. The primary researcher then told the participant that this bus trip would be new for him or her and the participant would exit the bus at a new location too. The primary researcher told the participant to try his or her best to get off the bus at the new bus stop. The primary researcher told the participant that even though the bus stop was new and might be difficult to find, the researchers will make sure the participant gets off the bus and he or she would be safe. The primary researcher then told the participant that he or she would take the bus to the bus stop at "X" location and asked the participant to repeat the bus stop location. If the participant repeated the correct location the primary researcher delivered verbal praise which again stated the bus stop location. For example: “Good job remembering you need to get off the bus at the corner of Fletcher and Nebraska.” If the participant did not state the correct location, the primary researcher restated the location of the bus stop and then asked the participant to state the location once again. The location was repeated to the participant until he or she stated the correct location. The primary researcher then told the participant that the bus would leave at “Y” time and he or she should get on the bus. The participant and the inconspicuous observer were observed boarding the bus by the primary researcher. The second familiar RA observed the primary researcher delivering the directions to the participant then left the transit center to go to the appropriate bus stop to wait for the participant’s bus. The inconspicuous observer boarded the bus after the participant in order to sit near enough to the participant to hear and directly observe the participant. The primary researcher observed the bus leaving the curb before going to her car to follow behind the bus.

Each trial began once the participant and the inconspicuous observer were both on the appropriate bus. The trial was ended once the participant and inconspicuous observer exited the bus. The bus rides were no more than 20 minutes in length for each trial as dictated by optimal scheduled travel time provided on the HART website. The duration of the average bus trip taken by participants was 11.8 minutes, with a range between 6 minutes and 20 minutes. Once on the bus, the inconspicuous observer offered no feedback or aid to the participant unless the participant was being given in-situ training. If the participant failed to pull the cord after the bus had passed the bus stop immediately before the appropriate stop, the inconspicuous observer pulled the cord to ensure that the bus stopped at the appropriate location. During baseline it was unnecessary for the inconspicuous observer to pull the cord because another familiar research assistant was visibly waiting at the stop. Having a second RA standing at the bus stop ensured the bus would stop at the appropriate stop. If the participant did not exit the bus once the bus stopped at the appropriate location, the familiar RA at the bus stop entered the bus and informed the participant that this was his or her stop and the participant needed to exit the bus. The primary researcher followed behind the bus during all phases of the study. Following the bus served two functions: it allowed the primary researcher to provide transportation back to the starting location for either the participant or the inconspicuous observer, and, in the event that the participant exited the bus at the wrong location, it allowed the primary researcher to pick up the participant without the inconspicuous observer having to reveal him or herself. Due to the limited numbers of RA’s for this study, the ability to avoid revealing the identity of the inconspicuous observer was a great benefit. Once the participant exited the bus the familiar research assistant who was waiting at the bus stop provided transportation back to the transit center. The primary researcher then provided transportation for the inconspicuous observer to the transit center. In the event that the participant pulled and exited the bus before the appropriate location was reached the inconspicuous observer exited the bus with the participant. The researcher who followed the bus then stopped and picked up the participant. The inconspicuous observer did not reveal him or herself to the participant but ensured that the participant was safe while not on the bus.

TAD training. Training for using TAD consisted of behavioral skills training (BST) which consisted of instructions, modeling, rehearsal, and feedback *(Himle, Miltenberger, Flessner, & Gatheridge, 2004)*. Each participant was trained individually as he or she moved from the first baseline phase to the first post training phase. Only one training session was conducted for each participant with no booster sessions (i.e., additional training) in between trips or phases. The verbal instructions described how TAD operates, what prompts would be given by TAD, and how to respond to the prompts. Verbal instructions were given once to Mark and Paige and twice to Carl. The modeling consisted of allowing the participant to hear the prompts, and showing the participant how to respond to the prompts. Rehearsal consisted of the participant hearing the prompts given by TAD and following the prompts given by TAD in a simulated setting. During the training session, participants were allowed to rehearse as many times as they wanted until they felt comfortable. Verbal praise was provided to the participant as well as corrective feedback as needed. The training for TAD was carried out in a classroom setting using a simple simulated bus set-up. A simulated bus setting was chosen primarily to ensure that participants could practice responding to TAD as many times as necessary in a short period of time (*Neef, Lensbower, Hockersmith, DePalma, & Gray; 1990*). Without using a simulated setting, the participants could have had to ride the bus several times in order to hear and respond appropriately to the prompts given by TAD. This would have increased the time participants spent on the bus and the cost of the study. This set up consisted of chairs lined up to simulate bus seats and a string attached to the wall that simulated the cord that needed to be pulled on the bus. Following training, participants participated in at least 3 assessments designed to evaluate their response to TAD. The length of training for each of the participants ranged from 3 minutes to 5 minutes.

In-situ training. In-situ training was never needed for this study; however it would have been conducted by the inconspicuous observer following three incorrect trials during the assessments. During the in-situ training the inconspicuous observer would board the bus after the participant and would sit behind him or her. Once the prompt to pull the cord had been issued to the participant, the inconspicuous observer would have allowed 3-5 seconds to pass with no response from the participant. The inconspicuous observer would then pull the bus cord, tell the participant he or she did not respond to the prompt given to by TAD, and then instruct the participant to pull the cord.

3 RESULTS

Figure 2 shows the results from each participant. Trials are presented on the x-axis and steps completed are presented on the y-axis. In baseline all participants scored a zero on all assessments, indicating that they did not pull the cord or exit the bus at the appropriate time when they did not carry TAD. After intervention, all participants scored a 2, indicating that they pulled the cord and exited the bus at the appropriate bus stop when they carried TAD. During the reversal to the second baseline (i.e., no TAD) all participants scored a zero, and during the second intervention phase (i.e., carrying TAD) all participants scored a 2 in all assessments. Further data taken during assessments found that TAD provided all prompts at the correct locations. In addition, while each of the participants responded to TAD when the phone vibrated and provided the audio prompt of “Get Ready,” none of the participants looked at the phone’s visual display when responding. Mark asked the bus driver where his bus stop was on the very first baseline trip. For further baseline and post training trips he did not ask anyone any questions. Paige called her mother on the very first baseline trip to ask her mother where her bus stop was but made no more calls after that first trip. Carl made no attempts to ask for directions from anyone while on the bus.

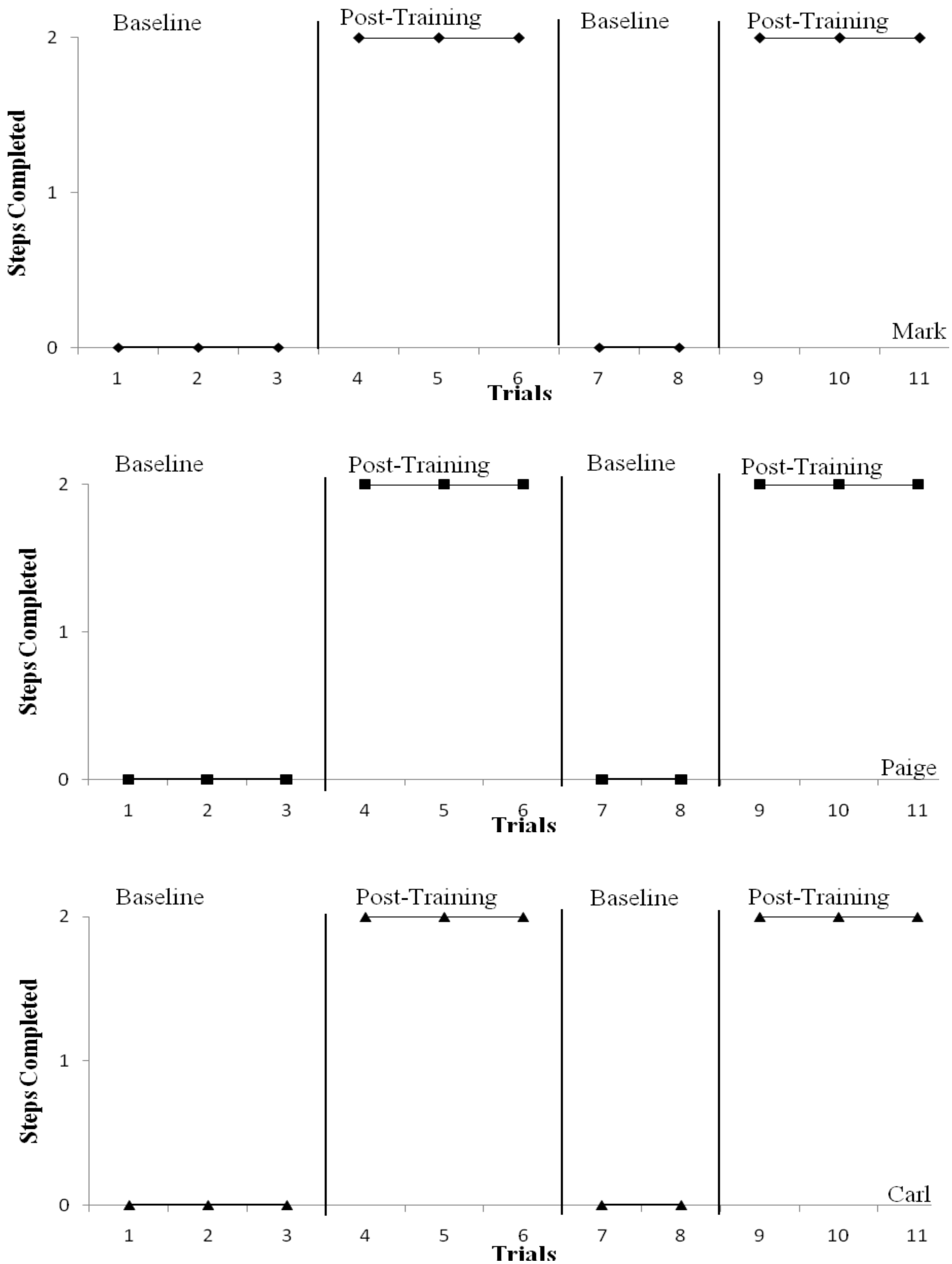

Figure 2 – Experiment Results, with trials on the x-axis and steps completed on the y-axis for each participant.

It should be noted that the time between the first post training assessments and the second post training assessments (i.e., when the participants carried TAD) differed for each individual. For Mark there were 23 days in between trial 2 and 3 of the first post training phase. From the end of the first post training phase and start of the second post training phase there were 6 days. For Paige there were 14 days in between the completion of the first post training phase and the beginning of the second post training phase. For Carl there were 8 days in between the completion of the first post training phase and the beginning of the second post training phase.

The social validity results showed the mean confidence level for parents pertaining to their child's ability to travel to new locations before using TAD equaled 1.3 (1 = not at all confident, 5 = very confident). The mean confidence level for parents pertaining to their child's ability to travel to new locations when using TAD equaled 4.3. Table 1 provides the full results from the social validity surveys for each participant before and after the study.

Table 1 - Results from the social validity surveys pertaining to the parent's attitudes and beliefs about their child's ability to access the community using public transportation.

	Mark	Paige	Carl		Mark	Paige	Carl
	Before	Before	Before		After	After	After
To what extent does your son/ daughter/ client want to travel independently?	5	5	4	To what extent does your son/ daughter/ client want to travel independently?	2	5	5
To what extent do you want your son/ daughter/ client to travel independently?	4	4	4	To what extent do you want your son/ daughter/ client to travel independently?	5	5	4
How confident are you in your son/ daughter/ client's ability to get off the bus at the correct bus stop?	2	5	3	How confident are you in your son/ daughter/ client's ability to use public transportation to reach new locations using the TAD?	4	5	5
How confident are you in your son/ daughter/ client's ability to use public transportation to reach new locations?	2	1	1	In general how confident are you in your son/ daughter/ client's ability to use public transportation when using the TAD?	4	5	5
How confident would you feel if your son/ daughter/ client had an assistive device when using public transportation?	4	5	4				

Note: 1 = no desire or not at all confident, 5 = very confident or strong desire

4. DISCUSSION

The current literature shows that with the advancement of technology, devices can be created to assist individuals with intellectual disabilities to increase their independence. The least researched and developed area is independent travel in the community. This study provides supporting evidence that, following one brief behavioral skills training session, TAD was an effective device for prompting individuals to pull the cord indicating their stop and exit the bus at the appropriate location. During both baseline phases without TAD, participants did not pull the cord indicating their stop at the appropriate times and without the safety measure put into place for this study, the bus would not have stopped. Failing to pull the cord at the correct time would increase the possibility that an individual would have missed his or her stop and ultimately could have gotten lost. With the prompts given by TAD the participants pulled the cord and exited the bus at the appropriate locations. During assessments it was observed that if the participant had the phone closed when the prompt to "pull the cord now" was delivered, they did not open the phone to look at the visual prompt (but still reacted to the audible and tactile prompts). All participants waited to deactivate the audible prompt until they had exited the bus.

To some, the use of TAD might seem unnecessary, as an individual riding the bus could just ask the bus driver for assistance as a way to ensure exiting at the correct stop. However, such a strategy is not always successful, and this practice is discouraged by some travel trainers since it can impede the rider's progression towards true independence. The risks of this strategy were illustrated by the experience of one participant in particular, Mark, during this study. On the very first trip during baseline Mark asked for assistance from the bus driver, which was permitted because in the natural environment it is highly likely that people ask for assistance while on the bus. When asked for assistance the bus driver told Mark the wrong bus stop. Due to this information Mark got off the bus at the wrong stop and had to be picked up early, therefore showing that asking for help, although a seemingly sensible travel assistance strategy, does not always lead to successful completion of a bus trip. It should be noted that the bus driver's primary responsibility is the safe and efficient operation of the transit vehicle, and therefore providing directions to riders is a secondary priority.

TAD has the potential to afford independence for individuals with intellectual disabilities who desire to travel independently by giving these individuals a tool that will assist them in finding the places they want to travel. It also provided the individuals in the study with security during their trips. During baseline assessments all of the participants expressed anxiety or concern when traveling without TAD to the unknown locations. One participant, Paige started every baseline trip by saying, "I don't know where that is at." However, once she was given e TAD she did not express any concern about the location she was asked to ride the bus to. Social validity surveys collected from the parents of the participants before and after the study show that before using TAD parents were not confident to somewhat confident in their child's ability to get off the bus at familiar and novel bus stops. Surveys given to the parents after the study showed that, when the participants used TAD, parents were confident to very confident in their child's ability to get off the bus at familiar and novel bus stops. Parents also stated that they would like their child to use TAD again when using public transportation. None of the participants for this study expressed their concern that TAD was in any way stigmatizing when they were using it; however the authors recognize that there is potential for this to occur. This potential is somewhat counter balanced with the volume control of the phone. Furthermore, if headphones can be used, then they might reduce any concern of being stigmatized while using TAD. Since these experiments were performed, the TAD development team has successfully tested TAD with common wired headphones, which will be an option for audible prompt delivery on compatible phones.

Although the parent of participants were more confident about their child reaching their destination when using TAD, the consistency of the TAD functioning reliably could be a concern in a more dense metropolitan area. TAD uses embedded Global Positioning System (GPS) hardware in the cell phone to determine the real-time location of the user, and cellular radio signals for data communication with cell towers and the TAD server. GPS technology calculates the device's position by receiving radio signals broadcast from satellites. Therefore, since the TAD mobile phone application is running on the cell phone and receiving real-time location information from the embedded GPS hardware, even if the cellular signal is interrupted TAD should still provide the prompts to guide the user to the correct bus stop. However, if the GPS signal from satellites is blocked by significant obstructions, such as a tunnel, parking garage, or extremely dense urban environment with high rise buildings, the accuracy of TAD could be degraded, or, if the view of the sky is completely blocked, TAD would not provide the prompt to the user to request the stop. Fortunately, TAD does have a safeguard that would protect individuals in case the above scenario did occur. The TAD system has the ability to notify a travel trainer, parent, or other third party that the individual using the device has significantly deviated from their planned route. This safeguard would lessen the probability that an individual would get lost while traveling in the community. Additionally, as long as the TAD application on the mobile phone is active, GPS and cellular signals are available, and the rider is still carrying the cell phone, the rider's real-time position can be seen on a map on the TAD website. Therefore, the rider could be quickly located if they do become lost. During this study, all prompts were delivered to the participants at the correct time and location during all trips. Future testing will need to take place to evaluate TAD's behavior is dense metropolitan environments.

For this study, the trips were not designed to test whether the buildings or topography of the area would interfere with the ability of TAD to receive the GPS signal. None of the trips taken by participants ended in a downtown portion of the city where a high concentration of tall buildings would be located. However, the starting and ending locations of trips were diverse in their attributes and included residential areas, business parks, and shopping malls. The trips also had buses passing large structures (e.g., tall buildings, professional sports stadium, and a large amusement park) that had the potential to affect the GPS signal but, given that all prompts were successfully delivered, these structures did not significantly affect the operation of TAD. During early TAD proof-of-concept testing, TAD delivered prompts to testers in ideal locations for 39 of 50 field tests in suburban environments. Most early or late prompts were due to incorrect bus stop locations in transit agency bus stop inventories, which can be corrected through a TAD website tool. Once corrected, the improved bus stop location is automatically used for all future TAD trips for all users. Since these early field tests (and prior to the human behavior analysis experiments described in this paper), additional improvements have been made to TAD to increase the reliability of prompts. More information about these tests and improvements to TAD are documented in *(Barbeau, et al. 2008; Barbeau, Georggi, Winters, 2010)*. Additional future improvements based on hybrid GPS technologies (e.g., accelerometers + GPS) could also be considered to help reduce the effect of GPS signal degradation on TAD. Considering that TAD is desired to be a widely-deployable mobile application, such technologies must be realistically implementable given commercially-available sensors in mobile phones and will likely always rely on GPS as the primary outdoor positioning technology due to the high-accuracy, global coverage, and relatively inexpensive nature of GPS. Future improvements in global navigation satellite systems, including the availability of new systems such as Russia's GLONASS and the European Union's Galileo and the GPS modernization program, should increase the number of satellites in view to GPS receivers and therefore improve the accuracy of mobile apps such as TAD.

As mentioned earlier in this paper, all participants had to be travel trained to be eligible for this study. The travel training for each participant was different and was designed based on the current skills of the individual and the remaining skills that needed to be taught. Each participant's skill level for independent traveling before travel training is unknown. However, after travel training (and prior to the study documented in this paper) all participants had the skills necessary to successfully use public transportation to access specifically trained locations. Interestingly, some skills from the travel training generalized from frequent trips to novel trips across all phases of the study while others did not. Specifically, the behaviors of entering the bus, paying, and sitting near an exit generalized through all phases while pulling the cord and exiting the bus did not generalize and required prompts (given by TAD) for the participants to complete. In speaking to Mark Sheppard, the local travel trainer for Hillsborough Area Regional Transit (HART), he stated that the hardest skill to learn for any individual participating in travel training is to know when to pull the cord and when to get off the bus at the appropriate stop. Since this skill must be learned for each destination, training is typically limited to 2-3 frequently visited locations for each trainee. This study did not intend to examine what skills taught in travel training would and would not generalize.

When using TAD for an extended period, TAD (or prompts given by TAD) could become unnecessary for frequently traveled trips. It is also unclear if skills taught to navigate to a destination after getting off the bus would generalize from frequently taken trips to novel trips. Further studies would need to be conducted in order to see if navigational skills would generalize to novel trips or if specific training would be needed. If these skills did not generalize, then additional studies and alterations to the TAD would be necessary to see if the TAD could assist with navigating outside of the current bus riding context.

TAD could also be integrated into a travel training program for each trainee. TAD may be able to reduce travel training time for trainees, which would allow travel trainers to train more individuals. However, it should be emphasized that TAD is a tool to aid travelers but is <u>not</u> a travel training replacement. Travel training teaches many important skills required to use public transportation that TAD alone cannot provide. However, since TAD does assist travelers with one of the most difficult skills, the process of integrating TAD into a travel training curriculum should be examined in future work.

Although this study shows good evidence supporting the use of an assistive device to gain independence in the community there are some limitations to this study related to generalization. First, all participants in this study were diagnosed with the same level of mental retardation. The results from the study show favorable outcomes for these three participants with moderate mental retardation; however more research needs to be conducted with a more diverse population to determine if TAD is a device that can be used by individuals other than those with moderate mental retardation, particularly individuals with more limited intellectual abilities. Other populations that could benefit from an assistive device when traveling is the general population who travel to new locations and do not know the area, elderly individuals, people with brain injuries, and those with visual impairments. Second, all participants had been previously travel trained to use the local bus system. One of the parameters for selecting participants for this study was that all participants had to have been trained to use the city bus by the transit agency's travel training program. Although the years between when each of the participants was trained to the beginning of this study varied from participant to participant and the frequency of using the bus varied, they were all previously taught a specific set of skills to be able to use the city bus to access frequently taken trips on the city bus *(Groce, 1996) (Wolf-Branigin & Wolf-Branigin, 2008)*. This study did not look at whether individuals who were not travel trained would be able to use TAD as successfully as those who had been travel trained.

Additional studies are needed to assess what level of independence individuals using this device will experience. The current study only assessed how the participants responded to TAD when the TAD application was already activated and the bus trip had been selected. In order for TAD to provide prompts, the phone must be programmed with the bus stop locations for a trip, the application on the phone must be turned on when using TAD and each trip must be selected once the TAD application on the phone has been turned on. Future research should focus on whether individuals with disabilities can use the internet to access the TAD website to input bus trips into the system, access the TAD application on a cell phone, and select the desired bus trip. These studies would help clarify who will be able to use TAD independently and how much assistance individuals might need to be able to use TAD. Studies that focus on practice effects should also be conducted to see how many times an individual must take a trip to a particular location before it is unnecessary to rely on the prompts given by TAD.

Another area for future research would be to assess the effectiveness of TAD for more complex bus trips, such as those that require a transfer. Because transfers from one bus to another to get to a location are common, research of this nature would be important. TAD currently supports transfers from one route to another as different "segments" within a trip, which can be planned via the TAD website. However, TAD does not currently provide walking directions to the user if they must walk to a different bus stop to begin the second segment of their trip. To conduct such research, researchers would need to establish the ability of TAD to exert stimulus control over the behavior of the rider to navigate the bus transfer. It is important to note that in this study, each participant did push the button to confirm the "Pull the Cord Now" prompt after they got off the bus. This button advances the state of TAD to begin monitoring the bus stop locations for the next segment of the trip. Therefore, in this research study the participants successfully completed the first step in navigating additional trip segments via transfers.

Further research on promoting independent travel in the community for individuals with disabilities might also focus on helping them navigate to a location once they exit the bus at the correct stop. Such research can be accomplished using GPS-enabled mobile, although the accuracy of GPS in an urban environment may need to be examined to determine if it is sufficient to provide continuous accurate directions to the user. Another consideration would be the availability of accurate pedestrian infrastructure data (e.g., sidewalks) that would be required to plan a pedestrian path, as well as the method of delivery of prompts to individuals with different types of disabilities (e.g. visual impairments, mobility impairments, cognitive impairments, auditory impairments). Currently, OpenStreetMap.org, a Wikipedia-like system for geographic data, appears to be the best repository for pedestrian infrastructure data.

This research would also require the evaluation of behavioral skills training procedures to teach individuals to use such a device successfully.

TAD supports the General Transit Feed Specification (GTFS) format in order to add and maintain transit agency data in the TAD system. There are currently over 110 agencies in the United States that have already placed their data into the GTFS format for use in the free online Google Transit trip planner, and therefore TAD has a large number of potential deployment locations available. Currently, TAD has been tested with five transit agencies in Florida. USF has partnered with Dajuta, a Florida-based company, to offer TAD as a commercial service, and therefore expanded deployment and testing of TAD to additional cities is expected in the near future. As more cities are added TAD service could be expanded to other above-ground public transportation systems such as commuter trains, and intercity coaches and trains. Additional research will be performed to ensure the GPS signal would be sufficient in more dense urban areas and on public transportation vehicles beyond buses.

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