When Directions Fail - - Investigation of Getting Lost Behaviour in Adults with Acquired Brain Injury

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Structured Abstract

Primary Objective: Investigate and describe getting lost behaviour and wayfinding strategies among acquired brain injury (ABI) survivors and matched controls.
Research Design: Matched control group comparison design
Methods & Procedures: We compared wayfinding performance of 18 adults with acquired brain injury to controls matched for gender, age, and education. Participants followed written directions along an eight-step route in an unfamiliar neighborhood, with three intentionally challenging choice-points. They used a cellular phone to request assistance if they became lost. Dependent measures included accuracy, directness, and wayfinding strategy. Statistical and qualitative analyses explored group themes and differences.
Main Results: Participants with ABI demonstrated significantly greater on-route wayfinding errors and hesitancy than matched controls. The ABI group requested assistance over the cell phone more frequently than controls and required more attempts at re-orientation with concrete, salient directions in order to re-orient in the field. Participants in the control group anticipated errors with greater frequency than those with ABI.
Conclusions: ABI survivors demonstrated greater challenges with wayfinding than matched controls. Re-orientation required concrete, explicit redirection with reference to salient landmarks. Implications for clinical practice and assistive technology are discussed.

Keywords: navigation, wayfinding, brain injury

Introduction

The ability to navigate one's community is a critical component of successful community reintegration following brain injury [1,2]. Cognitive, physical, and sensory impairments often limit a person's ability to drive [3,4,5], use public transportation [6], or travel on foot [7]. Navigation can be conceptualized as a spatial problem solving process that requires awareness, decision making, planning, and ongoing monitoring for error detection and correction [8,9]. These processes represent common areas of impairment for survivors of traumatic brain injury, and disrupt community navigation, or wayfinding.

Wayfinding & Cognitive Impairments

Navigation among individuals with cognitive impairments has been the subject of many investigations in the past decade. A growing body of neuropsychological literature has investigated the relation between specific navigational sub-skills and lesion site [10,11]. More specifically, researchers have attempted to describe spatial representation and navigation impairments associated with neglect syndrome [12,13]. Wayfinding difficulties have also been investigated in people with cognitive impairments due to progressive illnesses such as Alzheimer's disease in an attempt to identify the types of wayfinding problems and the associated cognitive correlates [9,14,15]. It has been suggested that spatial disorientation and wayfinding problems may be a sensitive indicator of the onset of Alzheimer's disease [16].

A less robust literature exists exploring wayfinding difficulties in brain injury survivors. Skelton and colleagues have employed virtual reality technologies to investigate navigational challenges in this population. Skelton, Bukach, Laurance, Thomas, and Jacobs (2000) [17] used a virtual reality water maze task to confirm spatial learning impairments among twelve moderate-severe TBI survivors compared to age and gender matched controls. In a similar water maze virtual reality experiment, Livingstone and Skelton (2007) [18] further demonstrated that eleven TBI survivors demonstrated difficulty forming cognitive spatial maps. Two additional single case studies detailed navigational behaviour in real-world environments and provided information about possible supports in this domain. Antonakos (2004) [19] reported on one traumatic brain injury survivor who was unable to travel independently to non-familiar destinations due to inability to memorize the sequence of steps along a novel route. Davis and Coltheart (1999) [8] reported on a second case, in which an ABI survivor used mnemonic devices to memorize the basic layout of a downtown district and used this knowledge to 'reason her way back to a familiar territory if she deviated inadvertently from a known route' (p. 27). Development of assistive compensations will require understanding of real-world navigational challenges in this population.

An emerging body of research has evaluated the effects of various treatment strategies to mitigate wayfinding challenges among adults with acquired cognitive impairments. Rehabilitation strategies have included modification of the physical environment [20], behavioural intervention [21], and use of landmarks and maps to teach specific routes [22]. Additional evaluations have explored the potential benefits of errorless learning to teach specific routes to brain injury survivors [23]. The field of Assistive Technology for Cognition (ATC) [24] has provided further guidance for development of compensatory wayfinding tools, such as step-by-step text or pictorial route prompting using personal digital assistants [25] or Global Positioning System (GPS) devices [26].

Rationale for the Current Study

The current study is part of a series of investigations evaluating navigational behaviours in people with ABI in order to identify effective supports. Early studies added to the nascent literature showing that people with ABI engage in limited community travel as a direct result of their cognitive impairments [6]. Findings from qualitative interviews and observations suggested that impulsivity, lack of planning, memory lapses, and anxiety significantly restricted community travel. This work led to the identification of navigational profiles that included ‘wish lists’ containing desired destinations that were not currently accessed. Subsequent work began to investigate navigational behaviours and potential assistive technology tools for when people did venture into the community.

In one study, we compared the effects of different modes of prompting during pedestrian route finding [27]. We delivered four types of instructions to participants with ABI using a handheld personal digital assistant. Results revealed that participants performed with greatest accuracy and least hesitation when presented with step-by-step auditory instructions, compared to printed text instructions, pictorial instructions, or map instructions. This important finding suggested that navigational prompting in the auditory modality reduces cognitive competition while completing a visual search task, such as navigation. However, a major limitation of this study was that a researcher had to physically orient the person at the beginning of each route. The investigation of prompting effectiveness led to questions about how best to orient people, and a study was conducted comparing orientation behaviour in response to different types of navigational directions (see Lemoncello, Sohlberg, Fickas & Prideaux, this issue).

In addition to identifying effective navigation prompting and orientation modes, wayfinding support must include mechanisms for troubleshooting. Even with well-designed supports or interventions, occasions will arise when a tool or system breaks down or a person does not implement the supports. We could find no studies specifically evaluating getting lost behaviours and in-the-field trouble-shooting in the ABI population. The purpose of the present exploratory study was to investigate and describe potential differences in navigational abilities and problem-solving strategies among ABI survivors and matched controls. We designed the experimental task to induce getting lost behaviour. We provided participants with a cellular phone to request assistance in order to gather information about troubleshooting behaviour and problem-solving strategies. The experiment sought to answer the following research questions:

1. Are there differences in navigational abilities (i.e. accuracy, directness) among individuals with ABI and matched control participants when following written route directions?
2. Are there differences in problem-solving strategies, including responsivity to navigational assistance provided via cell phone, among individuals with ABI and matched control participants when they are lost during community navigation?

We hypothesized that individuals with ABI would demonstrate greater difficulty (i.e. more errors and greater hesitancy) than matched controls on the overall task, as well as at the specific pre-planned challenging choice points along the route (i.e. initial orientation, missing step, hidden street sign, and wrong destination). We further hypothesized that participants with ABI would offer fewer effective solutions to navigational challenges, but that we would be able to re-orient all participants in the field by providing assistance over the cellular phone.

Methods

Participants

Two groups of participants completed this study: 18 adults with ABI and 18 matched control participants. The university Institutional Review Board approved all procedures. Each participant received monetary compensation for completing this study. The same participants completed both the orientation study (see Lemoncello et al., this issue) and the present wayfinding study. Characteristics of each participant are presented in the companion Orientation study.

Design

We employed a matched case-control design to describe and compare pedestrian wayfinding skills and strategies of individuals with and without ABI. Each participant followed the same written directions for a navigational route with eight choice-points.

Materials & Equipment

Figure 1 provides an overview of the route and the eight-step written directions provided to participants. The four steps highlighted in grey represent specific points along the route where challenges were anticipated: initial orientation (Step 1), a missing step (Step 4), a step with a hidden street sign (Step 7), and the incorrect destination (Step 8). A series of pilot evaluations with uninjured adults ensured clear wording of instructions, especially for steps not designed to present navigational challenges (i.e. steps 2, 3, 5, and 6).

The researcher asked each participant to wear a pair of sunglasses, which contained an imbedded video camera and attached to a portable digital recorder (available from www.theimportsworld.com/sunglspycawi.html). The captured audio and video were used for reliability assessment. In addition, the researcher provided each participant with a cell phone (Cingular 2125 smart phone) and paired Bluetooth headset (Motorola HS850). The phone remained connected (i.e. had an open voice call) to a second researcher ('phone helper'), who was at a distant office and unable to see the participant. The phone helper followed a script to provide assistance and gather information from participants who requested assistance. Each telephone conversation was recorded on a digital audio recorder (Olympus WS-100) using a mini recorder control (available from www.radioshack.com/product/index.jsp?productId=2104040) and transcribed for analysis. Participants carried a small over-the-shoulder tote bag with the video recorder and cell phone.

Procedures

To begin the wayfinding experiment, the researcher led each participant to a designated starting location. The researcher followed a script to provide standardized instructions to each participant, including: 'follow this set of written directions to the best of your ability', 'you may carry the instructions; you do not need to memorize them', and ‘do not take any short-cuts or deviate from the path’. The researcher asked questions to ensure comprehension.

Participants were instructed to use the cell phone headset to ask for assistance at any point along the route. Participants were instructed not to press any buttons, but simply to speak into the headset to request assistance. A researcher checked each recorded phone transcription to ensure that the phone helper did not deviate from the script when attempting to gather data and re-orient the participant. Fidelity was calculated for 21/36 (58%) trials by marking on a checklist if each instruction was delivered correctly and at the correct time, across three different phone helpers and for both groups. Overall, the phone helpers (three different helpers) followed the script with 95.56% fidelity (Range: 88-100%).

The researcher positioned the participant in a standardized location, facing the opposite direction as the first instruction. The researcher did not accompany the participant during this experiment, but remained in the field (‘field researcher’). To ensure participant safety, a trained research assistant served as a ‘shadow observer’. This observer was unfamiliar to the participant and attempted to blend into the environment, while writing field notes about the participant’s behaviour. The observer stayed within about one block of the participant. If the observer questioned the participant’s safety at any point (e.g. unsafe street crossing), she intervened to prevent immediate danger.

If a participant ever veered more than two blocks from the expected route, the observer would call the field researcher, and the researcher would intervene. In addition, if a participant requested assistance over the phone that required personal intervention or requested to stop the experiment, the phone helper would inform the field researcher. When the field researcher intervened, he followed a script to first ask participants to describe any navigational problems. Next, he instructed participants to use the cell phone headset to ask for assistance. If the phone helper was unable to orient the person by telephone, the field researcher re-oriented the participant in the correct direction, and asked the participant to continue to follow the remaining steps. Following any intervention, the field researcher reminded participants to use the headset to ask for any further assistance, and reassured participants that he would meet them at the end of the route.

The phone helper informed the field researcher when the participant reached the end of the route. The field researcher and shadow observer met the participant at this location and disclosed the nature of the shadow observations. The field researcher also conducted a structured interview to obtain participants’ opinions and perceptions about the navigational task. Participants in both groups followed the same procedures.

Dependent Measures

Participant performance was captured with three quantitative measures and additional qualitative data. A researcher watched the video -- captured by the sunglasses camera -- to score Accuracy, Wayfinding Strategy, and Directness at each of the eight choice points. Accuracy was scored on a 6-point scale (0 = unable; 1 = required intervention; 2 = asked for assistance; 3 = asked for verification; 4 = self-corrected; and 5 = correct & independent). This scale was also used categorically to represent Wayfinding Strategy. Directness was scored as hesitation (0) or direct (1).

Hesitations were defined as: participant pauses for more than three seconds for a reason other than traffic; participant looks at street signs or written directions more than two times sequentially; or participant verbalizes confusion. A second researcher watched the video recording for 18/36 (50%) participants across groups and time, and scored each for Accuracy and Directness. Percent Agreement was calculated for each score, and inter-rater agreement was found to be high, 87.94% agreement (Range: 77-100%). All disagreements were easily resolved by reviewing the video, and data were updated before running the analyses. The same researchers also reached consensus for Strategy categories based on the data.

Additional qualitative data were gathered from five sources: field observer field notes; field researcher field notes; video narrative notes; phone transcription recordings, and the post-trial interview. These data allowed the researchers to describe and investigate possible group differences in how participants described their current location, generated potential navigational solutions, and opinions about use of a cell phone for pedestrian navigational assistance.

Data Analysis

Quantitative data were entered into SPSS 16.0 (2007). Mixed Model analyses were employed, due to repeated measures for each participant (i.e. 8 choice points per participant). The Mixed Models analysis controls for repeated measures within-participant when investigating between-group differences [28]. To investigate the effects of group and type of direction on wayfinding ability, we ran a Mixed Model analysis for Accuracy and Directness. Chi-Square analyses investigated group differences in Wayfinding Strategies [29]. Significance tests explored relations between all quantitative variables. Effect size measures estimated the practical significance of any statistically significant finding using Cohen's *d* [30]. Two researchers analysed qualitative data for themes [31]. The researchers independently analysed the data, extracted themes as categories, compared results, and reached consensus.

Results

Assumptions

Descriptive statistics for the two dependent variables included in the Mixed Model analyses revealed non-normal distributions, especially for control group performance (see table 1). However, we conducted no transformations because these non-normal distributions represent hypothesized, naturally occurring phenomena (i.e. the control group performed near ceiling levels with less variance). The overall mixed model was significant, (Wald $Z = 11.66$, $p = .000$).

Wayfinding Accuracy

The interaction of group and choice point was not significant for accuracy, $F(7,272) = 1.11$, $p = .360$. Therefore, results are analysed for main effects of group and choice point. The effect of group on accuracy was significant, $F(1,272) = 26.37$, $p = .000$ (see table 2). Participants with ABI completed the on-route navigation trials with greater errors ($M = 3.72$) than matched control participants ($M = 4.35$); this was a medium effect ($d = 0.44$). The effect of choice point on accuracy was significant, $F(1,272) = 63.71$, $p = .000$ (see table 3). Follow-up pairwise comparisons revealed significantly greater challenges at choice point 4 (missing step; *M* = 3.00) and choice point 8 (wrong destination, *M* = 1.83) compared to other choice points, for both groups.

Despite the lack of interaction between group and choice point for accuracy scores, we analysed differences by group for specific choice points according to our a priori research questions. Participants with ABI completed Step 7 (hidden street sign) with greater errors than matched control participants, $F(1,34) = 6.79$, $p = .014$ (see table 4); this was a large effect ($d = 0.87$). Group differences were not significant at other choice points; both groups performed with decreased accuracy at choice point 4 (missing direction) and 8 (wrong destination).

Directness

The interaction of group and choice point was not significant for directness, $F(7,272) = 1.45$, $p = .184$. Therefore, results are analysed for main effects of group and choice point. The effect of group on directness was significant, $F(1,272) = 63.71$, $p = .000$ (see table 2). Participants with ABI demonstrated greater hesitancy ($M = 0.39$) than matched control participants ($M = 0.78$); this was a large effect ($d = 0.86$). The effect of choice point on directness was significant, $F(7,272) = 6.92$, $p = .000$ (see table 3). Follow-up pairwise comparisons revealed significantly greater hesitation at choice point 4 (missing step; $M = 0.22$) and choice point 7 (hidden street sign, $M = 0.42$) compared to other choice points, for both groups.

Despite the lack of interaction between group and choice point for hesitation scores, we analysed differences by group for specific choice points according to our *a prior* research questions. Participants with ABI completed Step 1 (initial orientation) with greater hesitation than matched control participants, $F(1,34) = 5.46$, $p = .025$ (see table 4); this was a large effect ($d = 0.78$). Participants with ABI also demonstrated greater hesitancy than matched controls at Step 7 (hidden street sign), $F(1,34) = 6.26$, $p = .017$; this was a large effect ($d = 0.84$). Although not significant with a Bonferroni correction applied, there was a trend toward greater hesitation among participants with ABI at Step 8 (wrong destination). Both groups hesitated similarly at Step 4 (missing direction; *n.s.*).

Wayfinding Strategy

We investigated relations potential differences in wayfinding strategies between groups using Chi-Square analyses. Table 5 shows the frequency of each strategy used across groups both overall (first column) and for each of the eight choice points. Overall, participants with ABI required significantly greater assistance with on-route problem-solving (38%, 55/144) compared to matched controls (22%, 32/144), $\chi^2(5) = 17.41$, $p = .004$; a small effect $\eta^2 = .06$. Differences between groups were not significant at each individual choice point -- possibly due to reduced power ($n = 18$ per comparison) -- yet, there are a few general trends worth mentioning. Two participants with ABI were unable to complete the route; all control participants completed the route. The researcher had to intervene (when a participant was >2 blocks off-track) one time for a control participant, but had to intervene five times for participants with ABI.

Qualitative Wayfinding Results

Narrative data from field notes, video analyses, phone conversation transcriptions, and the post-trial interview were analysed for themes.

Description of current location. When participants asked for assistance over the cell phone (or when the field researcher intervened), the phone helper asked them to describe their current location. Group differences emerged; participants with ABI tended to provide more vague or inaccurate descriptions than matched controls. An overwhelming majority of control participants (97%, 31/32) provided clear descriptions of their location, which included a list of the two streets of an intersection at minimum, often including additional modifiers, such as: 'I'm on Main Street, in front of Alpine Service Imports that services Volvos… I just passed 11th Street, now I'm at 12th Street', or 'I'm right in front of the Sutton Hotel, on Main Street, about half-way between 11th and 12th Streets'. Only one control participant provided a vague description ('I'm on Main Street'), requiring the phone helper to request additional information. In contrast, participants with ABI provided clear descriptions 69% (33/48) of the time, including: 'I'm at 8th and B, behind the post office', or 'I'm at 8th and Main, by a Legit Misfit place and a Subway'. However, 23% (11/48) of descriptions were vague (e.g. 'I'm on Main Street', or 'I'm in front of a bowling alley, I guess'), and 8% (4/48) were inaccurate.

Potential navigation solutions. The phone helper also asked participants to provide potential solutions to navigational challenges before providing participants with the correct solution. Group differences emerged; participants with ABI provided potential solutions that were more vague, inaccurate, or non-solutions than matched controls. For example, at Step 4 (missing direction), 100% (15/15) of potential solutions generated by control participants were judged by researchers to be 'reasonable,' including: 'I guess I'd have to turn Right onto 9th, go South, to get back up to A Street', or 'I'd walk a little further on B Street to see if it did run into A Street'. In contrast, 44% (7/16) of potential solutions generated by participants with ABI were judged as vague, inaccurate, or non-solutions by the researchers. These included, 'I would look for a landmark' (unclear which landmark they should search for), 'I don't know where Main Street is… I don't know my West from North', or 'Look for a bus stop and go home'. A similar pattern emerged for potential solutions at Step 8 (wrong destination). All potential solutions provided by control participants were judged as reasonable (29/29), while 32% (6/19) solutions provided by participants with ABI were judged as concrete (i.e. 'I've got to find the house with a blue roof') or non-solutions (i.e. 'I don't know').

Use of cell phone for navigational assistance. Participants were provided with a cell phone and wireless headset to communicate with the phone helper when they had any question during the trial. In the post-trial interview, the field researcher asked participants about use and helpfulness of the cell phone. Table 7 provides a summary of quantitative related to cell phone use. Control participants unanimously endorsed the cell phone as easy to use and helpful for accessing navigational assistance. All control participants also indicated they would like to use a similar system in the future if they required navigational assistance. One participant with ABI reported difficulty using the cell phone because the headset fell off his ear and he was unable to replace it. This participant carried the headset next to his ear for half of the route until he decided to stop the trial to due frustration in part with carrying the headset. Other participants with ABI endorsed the cell phone as easy to use, although five reported difficulty hearing due to nearby traffic noise. All participants with ABI reported that the assistance they received via the cell phone was helpful to reduce anxiety and re-orient them. Only one participant reported he would not use the cell phone for assistance in the future; this was the same participant who had difficulty replacing the headset.

Discussion

Results of this study confirmed the prevalence of navigational challenges faced by ABI survivors [8,17,18,19], even on a short pedestrian route. The current study compared navigational behaviour and problem solving abilities in adults with ABI to age, education and gender-matched control participants. As hypothesized, participants with ABI demonstrated significantly greater on-route navigational challenges -- more frequent errors and hesitations -- than matched controls. Also as hypothesized, participants with and without ABI exhibited different types of problem solving. The ABI group requested assistance over the cell phone more frequently than controls and required more attempts at re-orientation with concrete, salient directions in order to re-orient in the field. Participants in the control group anticipated errors with greater frequency than those with ABI.

These findings underscore the potential of providing on-route navigational assistance. Research in the area of Assistive Technology for Cognition has demonstrated initial success for route guidance [25,26]. We also know that in-car systems are now routinely available to provide route corrections. However, no in-car systems work with landmarks, and they have questionable problem-solving value when applied to a walking route or when using public transportation. In this study, we were particularly interested in the unique challenges faced in pedestrian travel. We chose to provide participants with a cellular phone for two reasons: (1) we wanted to capture real-time participant insights relevant to getting lost, and (2) we wanted a flexible means to provide route re-orientation to explore effective strategies. All participants highly endorsed the cell phone as a useful tool for both reorientation and reassurance. The anxiety that accompanied getting lost replicates a finding from our previous qualitative work [6], suggesting that for the ABI population, assistive navigational tools must not only provide redirection, but should also have the capacity to reassure travelers.

Analysis of the phone helper transcripts revealed several important implications for providing on-route assistance to travelers with ABI. Participants reported they might have quit the route without assistance and support. We also discovered that it was important to explicitly ask the participant to stop walking and remain at a given location while the phone helper attempted to provide assistance. When participants continued to move (e.g. cross a street or face a different direction), left/right directional assistance became irrelevant. It was also important to verify the participant’s current location. In one instance, the phone helper was unable to re-orient a participant who reported inaccurate information about his current location. In addition, it was critical to provide specific instructions that utilized landmarks for re-orientation. In several instances during this study, the person with ABI required multiple re-orientations over the telephone when the phone helper <u>assumed</u> to know the participant’s location and orientation to provide left/right street directions. We discovered that the only way to successfully re-orient these participants in the field was to provide explicit landmark re-orientation. For example, one participant with ABI required five attempts at re-orientation before the phone helper successfully described salient landmarks (i.e. face the blue house) to get her back on track. It should be noted that the phone helper in this study had access to photographs at each intersection along and near the route. For care providers who do not know the neighborhood or do not have access to such pre-planned information, global information systems (GIS) technology paired with GPS information may provide a useful supplement, such as the Street View images now available in many metropolitan areas provided by Google maps (maps.google.com).

The novel methodology employed in this study allowed the researchers a useful procedure to explore wayfinding behaviour. The video sunglasses allowed us to capture images of where participants looked while navigating, and enabled high inter-rater reliability for measuring navigational performance. Safety was a paramount concern for participants with ABI navigating independently in an unfamiliar neighborhood. The shadow observer played a critical role in maintaining participant safety; in one instance, the shadow observer intervened to prevent one participant, who was trying to reorient over the telephone, from stepping into the street with oncoming traffic. This also reiterates the importance of asking the participant to stop walking while attempting to reorient him/her; the increased cognitive load likely prevented the participant from the routine task of checking for traffic before crossing the street.

Study challenges arose due to the complexity of measuring real world navigational behavior. The equipment and safety precautions necessary to obtain authentic measures of wayfinding ability are intensive. Physical demands of the pedestrian study made it difficult to identify participants with ABI. Another limitation involves generalizability of findings. Most notably, participants never had to use any buttons to request cell phone assistance; they simply spoke into the Bluetooth headset through the already connected line. We wanted to minimize the potential of any participant forgetting how to use the cell phone and confounding the results of the study. Only one participant reported that he did not remember he could ask for assistance when the researcher intervened to re-orient him. However, it is not known if participants would have stopped the route earlier or how they might have tried to problem-solve on their own if not provided with the connected cell phone.

The current study results demonstrated that individuals with ABI perform pedestrian navigational tasks with greater errors and hesitancy than matched controls. Although there was insufficient power to investigate the relation between severity of cognitive impairment and getting lost behaviour (due to the small overall and skewed sample that included only two participants in the severe range), the trend suggested that individuals with more severe cognitive impairments demonstrated greater difficulty. Additional qualitative research, especially in-depth case studies of individuals who are either successful or unsuccessful navigators, may reveal important cognitive predictors of navigational performance. Future research must also continue to evaluate the potential effectiveness of various assistive technologies to improve navigational performance. One problem is accuracy: a GPS system carried by the traveler may not be able to provide location or orientation data accurate enough to place a pedestrian at the correct corner of an intersection and a specific heading [32]. However, even if a GPS device provided accurate enough data, there remains the issue of two-way interaction. We are dubious that an in-car style of assistant, programmed to provide directions without feedback from the user, will be effective with either (a) pedestrian situations, in general, or (b) travelers with ABI, in particular. We conjecture from this study that assistive devices for navigational assistance among this population must also provide reassurance and emotional support for those survivors who face increased anxiety associated with becoming lost. The interesting question from our view is whether we can replace the human in the loop (i.e. the phone helpers in our study) with a computer-based helper. How limiting would the two-way interaction be? Would it be enough to both help with problem-solving and provide reassurance? Our research group is currently working with public transportation administrators on how to incorporate the information gained in this study to their prompting and help systems.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

[1] Fraas M, Balz M, Degrauw W. Meeting the long-term needs of adults with acquired brain injury through community-based programming. Brain Inj 2007;21:1267-81.
[2] McColl M, Davies D, Carlson P, Johnston J, Harrick L, Minnes P, et al. Transitions to independent living after ABI. Brain Inj 1999;13:311-30.
[3] Brenner LA, Homaifar BY, Schulthesis MT. Driving, aging and traumatic brain injury: Integrating findings from the literature. Rehabil Psychol 2008;53:18-27.
[4] Legh-Smith J, Wade DT, Langton-Hewer R. Driving after a stroke. J R Soc Med 1986;79:200-3.
[5] Rapport LJ, Hanks RA, Coleman-Bryer R. Barriers to driving and community integration after traumatic brain injury. J Head Trauma Rehabil 2006;21:34-44.
[6] Sohlberg MM, Todis B, Fickas S, Hung P, Lemoncello R. A profile of community navigation in adults with chronic cognitive impairments. Brain Inj 2005;12:1249-59.
[7] Sohlberg MM, Fickas S, Lemoncello R, Hung P. Validation of the activities of community transportation (ACTs) model for individuals with cognitive impairments. Disabil Rehabil. Forthcoming.
[8] Davis SJC, Coltheart M. Rehabilitation of topographical disorientation: An experimental single case design. Neuropsychol Rehabil 1999;9:1-30.
[9] Rainville C, Passini R, Marchand N. A multiple case study of wayfinding in dementia of the Alzheimer type: Decision making. Aging Neuropsychol Cogn 2001;1:54-71.
[10] Aguirre GK, D'Esposito M. Topographical disorientation: A synthesis and taxonomy. Brain 1999;122:1613-28.
[11] Barrash J, Damasio H, Adolphs R, Tranel D. The neuroanatomical correlates of route learning impairment. Neuropsychologia 2000;38:820-36.
[12] Nico D, Piccardi L, Iaria G, Bianchini F, Zompanti L, Guariglia C. Landmark based navigation in brain-damaged patients with neglect. Neuropsychologia 2008;46: 1898-1907.
[13] Passini R, Rainville C, Habib M. Spatial-cognitive deficits in right parietal lesion and its impact on wayfinding: A case study. Neurocase 2000;6:245-57.
[14] Algase D. Wandering: A dementia-compromised behavior. J Gerontol Nurs 1999; 25(9):10-7.
[15] McShane R, Gedling K, Keene J, Fairburn C, Jacoby R, Hope T. Getting lost in dementia: A longitudinal study of a behavioral symptom. Int Psychogeriatr 1998; 10(3):253-60.
[16] Uc EY, Rizzo M, Anderson SW, Shi Q, Dawson JD. Driver route-following and safety errors in early Alzheimer disease. Neurol 2004;63:832-7.
[17] Skelton RW, Bukach CM, Laurence HE, Thomas KGF, Jacobs WJ. Humans with traumatic brain injuries show place-learning deficits in computer-generated virtual space. J Clin Exp Neuropsychol 2000;22:157-75.
[18] Livingstone SA, Skelton RW. Virtual environment navigation tasks and the assessment of cognitive deficits in individuals with brain injury. Behav Brain Res 2007;185:21-31.
[19] Antonakos CL. Compensatory wayfinding behavior in topographic disorientation from brain injury. J Exp Psychol 2004;24:495-502.

[20] McGilton K, Rivera T, Dawson P. Can we help persons with dementia find their way in a new environment? Aging Ment Health 2003;7(5):363-71.
[21] McEvoy C, Patterson R. Behavioral treatment of deficit skills in dementia patients. Gerontologist 1986;26(5):475-8.
[22] Day K, Carreon D, Stump C. The therapeutic design of environments for people with dementia: A review of the empirical research. Gerontologist 2000;40(4):397.
[23] Lloyd J, Riley GA, Powell TE. Errorless learning of novel routes through a virtual town in people with acquired brain injury. Neuropsychol Rehabil 2009;19:98-109.
[24] Scherer MJ, Hart T, Kirsch N, Schulthesis M. Assistive technologies for cognitive disabilities. Crit Rev Phys Med Rehabil 2005;17:195-215.
[25] Kirsch N, Shenton M, Spril E, Rowan J, Simpson R, Schreckenghost D, LoPresti EF. Web-based assistive technology interventions for cognitive impairments after traumatic brain injury: A selective review and two case studies. Rehabil Psychol 2004:49:200-12.
[26] Carmien S, Dawe M, Fischer G, Gorman A, Knitsch A, Sullivan JFJ. Socio-technical environments supporting people with cognitive disabilities using public transportation. ACM Trans Comp-Hum Interact 2005;12:233-62.
[27] Sohlberg MM, Fickas S, Hung P, Fortier A. A comparison of four prompt modes for route finding for community travelers with severe cognitive impairments. Brain Inj 2007;21:531-8.
[28] Bryk AS, Raudenbush SW. Hierarchical linear models: Applications and data analysis methods. Thousand Oaks, CA: Sage; 1992.
[29] Glass GV, Hopkins KD. Statistical methods in education and psychology. 3rd ed. Boston: Allyn & Bacon; 1996.
[30] Cohen J. Statistical power analysis for the behavioral sciences. 3rd ed. New York: Academic Press; 1988.
[31] Bogdan RC, Knopp-Biklen S. Qualitative research for education: An introduction to theories & methods. Boston: Allyn & Bacon; 2003.
[32] Ladetto Q. On foot navigation: Continuous step calibration using both complementary recursive prediction and adaptive Kalman filtering. Proceedings of the 13th International Technical Meeting of the Satellite Division of the Institute of Navigation; 2000 Sep 19-22; Salt Lake City, UT. p 1735-40.

Table 1. Non-Normal Distributions of Data for Mixed Model Analysis

	Accuracy		Directness	
	ABI	Control	ABI	Control
Skewness (SEM)	-0.77* (0.20)	-1.41* (0.20)	0.46* (0.20)	-1.40* (0.20)
Kurtosis (SEM)	-0.86* (0.40)	0.16 (0.40)	-1.81* (0.40)	-0.04 (0.40)

*Significance determined as > 2 standard errors from mean

Table 2. Wayfinding accuracy and directness by group

Group	**Overall Accuracy**	**Overall Directness**
ABI Group Mean (SD)	3.72 (1.63)	0.39 (0.49)
Control Group Mean (SD)	4.35 (1.20)	0.78 (0.41)
F test of significance	$F(1,272) = 26.37$ $p = .000$	$F(1,272) = 63.71$ $p = .000$
Effect size	$d = 0.44$	$d = 0.86$

n = 144 data points per group

Table 3. Wayfinding accuracy and directness by choice point

Choice Point	Overall Accuracy	Overall Directness
1 (Initial Orientation)	4.78 (0.73)	0.72 (0.45)
2	4.72 (0.82)	0.78 (0.42)
3	4.67 (0.89)	0.64 (0.49)
4 (Missing Step)	3.00* (1.33)	0.22* (0.42)
5	4.47 (1.34)	0.67 (0.48)
6	4.58 (1.27)	0.69 (0.47)
7 (Main Street sign)	4.19 (1.45)	0.42† (0.50)
8 (Wrong Destination)	1.83* (0.51)	0.56 (0.50)
F significance test	$F(7,272) = 37.06$ $p = .000$	$F(7,272) = 6.92$ $p = .000$

n = 36 participants per choice point
*Significantly different from other choice points in pair-wise comparisons ($p = .000$).
†Directness at choice point 7 was significantly different from steps 1, 2, and 6 in pair-wise comparisons ($p = .005$).

Table 4. Wayfinding accuracy and directness by group and challenging choice point

	Step 1		Step 4		Step 7		Step 8	
Group	**Accuracy**	**Directness**	**Accuracy**	**Directness**	**Accuracy**	**Directness**	**Accuracy**	**Directness**
ABI Mean (SD)	4.67 (0.97)	0.56 (0.51)	2.89 (1.37)	0.17 (0.38)	3.61 (1.75)	0.22 (0.43)	1.67 (0.69)	0.39 (0.50)
Control Mean (SD)	4.89 (0.32)	0.89 (0.32)	3.11 (1.32)	0.28 (0.46)	4.78 (0.73)	0.61 (0.50)	2.00 (0.00)	0.72 (0.46)
F test	$F(1,34) =$ 0.85 $p = .363$	$F(1,34) =$ 5.46 $p = .025$	$F(1,34) =$ 0.24 $p = .623$	$F(1,34) =$ 0.62 $p = .437$	$F(1,34) =$ 6.79 $p = .014$	$F(1,34) =$ 6.26 $p = .017$	$F(1,34) =$ 4.25 $p = .047$	$F(1,34) =$ 4.31 $p = .046$
Effect size		$d = 0.78$			$d = 0.87$	$d = 0.84$		

n = 18 participants per group

Table 5. Wayfinding strategies used by choice point and group

Strategy	**Overall**†		**Step 1**‡		**Step 2**‡		**Step 3**‡		**Step 4**‡		**Step 5**‡		**Step 6**‡		**Step 7**‡		**Step 8**‡	
	ABI	Con	ABI	Con	ABI	Con	ABI	Con	ABI	Con	ABI	Con	ABI	Con	ABI	Con	ABI	Con
Independent	82	109	15	16	14	18	13	18	4	5	12	18	14	18	10	16	0	0
Self-Corrected	7	3	2	2	0	0	1	0	2	0	1	0	0	0	1	1	0	0
Verifies Information	6	6	0	0	2	0	1	0	1	6	1	0	1	0	0	0	0	0
Asks for help	37	25	0	0	2	0	3	0	10	6	2	0	1	0	5	1	14	18
Researcher intervenes	5	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	2	0
Unable/Quit	7	0	0	0	0	0	0	0	0	0	2	0	2	0	1	0	2	0
χ^2 test	$\chi^2(5) = 17.41$		$\chi^2(2) = 1.03$		$\chi^2(2) = 4.50$		$\chi^2(3) = 5.81$		$\chi^2(4) = 6.68$		$\chi^2(4) = 7.20$		$\chi^2(3) = 4.50$		$\chi^2(4) = 6.05$		$\chi^2(2) = 4.50$	
p signif	$p = .004$		$p = .597$		$p = .105$		$p = .121$		$p = .154$		$p = .126$		$p = .212$		$p = .195$		$p = .105$	
Effect size	$\eta^2 = .061$																	

† *n* = 144 trials per group (18 participants x 8 choice points = 144)
‡ *n* = 18 trials per group (18 participants at each choice point)

Table 6. Anticipation of need for assistance at challenging choice points by group

Group	**Anticipation Score**
ABI Group Mean (SD) *n* = 11	0.82 (0.61)
Control Group Mean (SD) *n* = 12	1.83 (0.39)
F test of significance	$F(1,21) = 23.42$, $p = .000$
Effect size	$d = 1.99$

Table 7. Satisfaction data with cellular phone use by group

Group	**Ease of Phone Use**	**Helpfulness of Phone**	**Would you use a phone again?**
ABI Group Mean (SD)	3.56 (0.62) *n* = 18	3.72 (0.46) *n* = 18	0.94 (0.24) *n* = 18
Control Group Mean (SD)	4.00 (0.00) *n* = 17	3.94 (0.24) *n* = 17	1.00 (0.00) *n* = 17
F test of significance	$F(1,33) = 8.84$ $p = .005$	$F(1,33) = 3.04$ $p = .091$	$F(1,33) = 0.94$ $p = .339$
Effect size	$d = 0.99$		

Figure 1. Route map and instructions for wayfinding study

- - insert Figure 1 (map image) here - -

Real Route Directions
1. Start out toward 8th ST 2. Turn Left onto 8th ST 3. Turn Right onto B ST 4. Turn Right onto 9th ST 5. Turn Right onto A ST 6. Turn Left onto 8th ST 7. Turn Left onto Main ST 8. End at the entrance to a bowling alley with a blue overhang, about 2 blocks

Directions Given to Participants
1. Start out toward 8th ST (*orientation) 2. Turn Left onto 8th ST 3. Turn Right onto B ST (*missing step) 4. Turn Right onto A ST 5. Turn Left onto 8th ST 6. Turn Left onto Main ST (*hidden sign) 7. End at the entrance to a bookstore, about 2 blocks; a house with a blue roof. (*wrong destination)