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Transit Apps for People With Brain Injury and Other Cognitive Disabilities: The State of the Art

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Needs Identified by Research

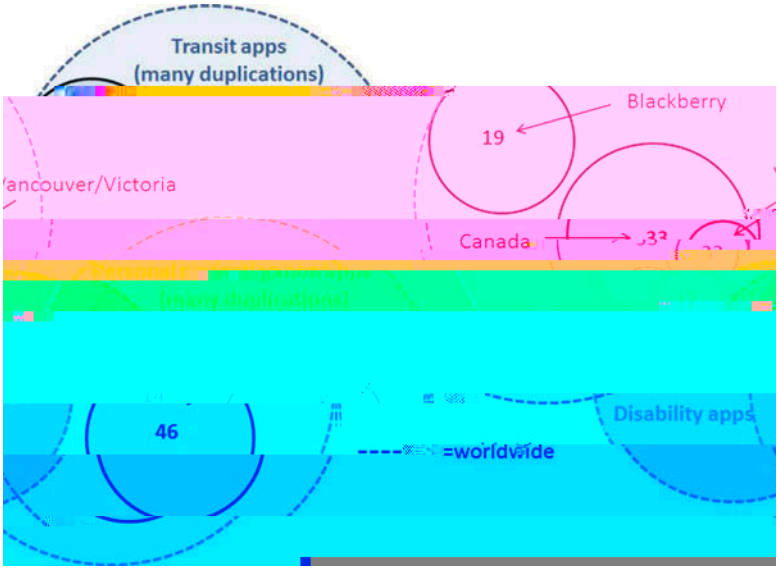
A small number of studies have investigated navigation issues for individuals with cognitive disabilities and made recommendations for the development of app or device features (Supplemental Material). For example, Lemoncello et al. (2010a) found that individuals with a brain injury were able to orient as well as healthy individuals as long as navigation instructions referred to landmarks (and not simple left/right turns or cardinal directions). Based on their own and other research in the field, these authors recommended that navigation aids: (1) Provide auditory feedback and only give left/right instructions based on which way the navigator is currently facing (Sohlberg, Fickas, Hung, & Fortier, 2007), (2) "prime" individuals concerning upcoming decision points, limit redundant information, and give route instructions from the perspective of the navigator (Lovelace, Hegarty & Montello, 1999) and, (3) pay special attention to instructions provided at initial orientation, choice points, and destination (Denis, Pazzaglia, Cornoldi, & Bertolo, 1999). Furthermore, Lemoncello, Sohlberg, and Fickas (2010b) found that, compared to healthy participants, participants with cognitive disabilities were more hesitant and anxious about finding their way in the world. These participants also gave vague or inaccurate solutions to navigational problems, indicating that their navigational abilities were impaired and that their anxiety might be well-founded. The authors also noted that a third of participants with cognitive disabilities had trouble hearing instructions (delivered by smartphone) due to background noise. They recommended: (1) Including the capacity to reassure (to reduce anxiety), (2) adding landmarks for reorientation when lost, and (3) asking individuals to be stationary (not wandering) while receiving reorientation instructions.

Some research has also directly addressed public transit issues for people with cognitive disabilities. A survey in Scotland (Stradling, Carreno, Rye, & Noble, 2007) concluded that three key barriers to transit use were anxiety (especially while waiting for the bus), lack of privacy, and mobility issues. Based on their survey of stroke survivors with cognitive disability, Risser, Iwarsson, and Ståhl (2012) reported problems related to fear (of getting lost, missing the bus, or being uncertain about the bus stop), physical demands (e.g., abrupt stops and braking), and cognitive problems (getting off at wrong stop, unable to read timetables, unable to understand changes in buses). Based on qualitative analysis of information from brain-injury survivors and focus groups comprised of caregivers and transit workers in both rural and urban settings, Sohlberg, Todis, Fickas, Hung, and Lemoncello (2005) identified previously unreported barriers to navigation. For example, even with easy access to public transit, people with cognitive disabilities tend to make few independent bus trips, in part because they have trouble initiating trips and remembering destinations. The authors provide a comprehensive list of problems, solutions, and device recommendations. They note particularly that user training is a necessary aspect of good app development and that ideally, devices and apps should be connected to the bus (for identification by the driver). More recently, Stock et al. (2011) emphasized the importance of independent bus travel and suggest that independence can be improved by: (1) Training (virtual and real-world), (2) devices combining GPS with audio or visual cues, and (3) personal trackers/locators to provide feedback (location information) to caregivers.

Objectives and Approach

The present study had two main objectives. The first was to investigate prior research concerning the difficulties people with cognitive disabilities encounter when using public transit; we were interested in the best ways to help this population use transit and what features were recommended for transit apps. The second objective was to investigate whether these recommended features are available in existing smartphone apps. The overall goal was to point out areas of unmet need, so that researchers and developers can better target their future efforts. We also hoped to identify specific features that would be useful to future developers of transit apps specifically for people with cognitive disabilities. Our primary focus was community-living adults with brain injury, but our findings should be applicable to people with cognitive disabilities of other origins. Although it would also have been desirable to identify apps to help people with dementia (e.g., Alzheimer's disease), there were too few applicable apps to report or consider here.

Our approach consisted of three stages: (1) Searching the academic literature concerning the transit needs of people with cognitive disabilities, (2) searching the app market to identify available apps and features with a focus on personal navigation and transit apps, and (3) comparing the identified needs to the available features to determine which transit needs have been



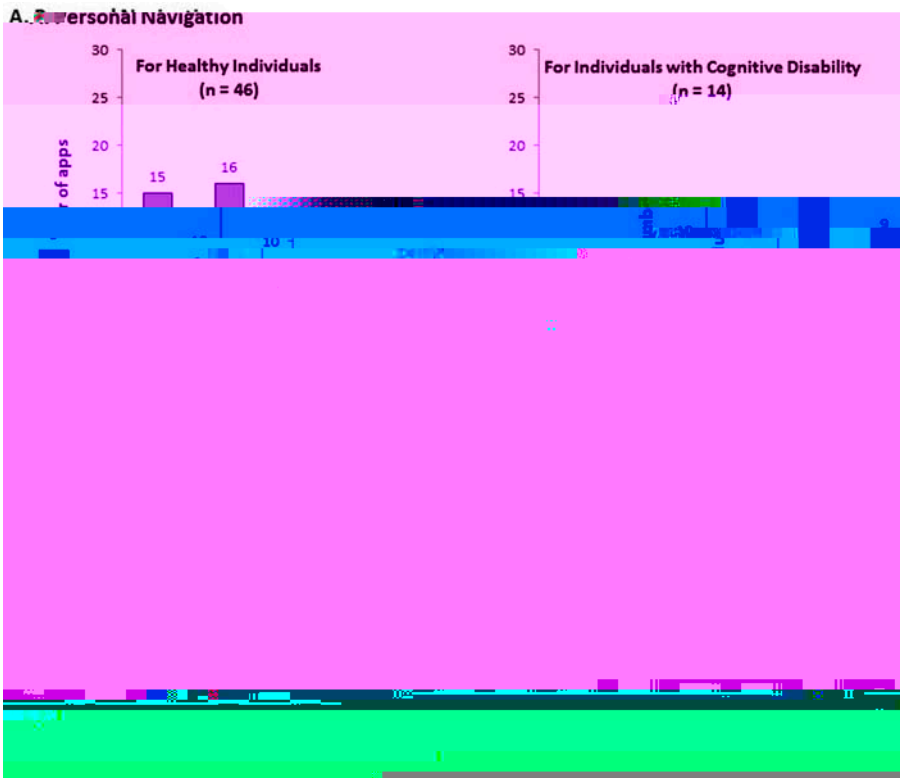
F . 1. Conceptual representation of search areas and targets showing how many apps were examined in each category of the total number reviewed (159). The search focused on three app types: Transit, disability, and personal navigation with a worldwide search but with an emphasis on apps usable in Canada and two geographic areas in particular (Victoria/Vancouver and Ottawa). The most important apps were those found at the intersection of transit and disability (n = 7). Because we are developing an app for Blackberry, our search and analysis kept these as a special interest. Note: The circles are conceptual and are not quantitative representations.

particularly good use of offline data. The apps of most interest were transit apps specifically designed to assist cognitive disability (Figure 1).

Several other inclusion and exclusion criteria were established. We mainly sought apps available in English and designed for North America. However, because our own app development is for Blackberry® devices, we included Blackberry apps as a special focus and report a sample of transit apps for Blackberry available in other jurisdictions worldwide, like Europe. We ended our search when it became apparent that apps were repeating the same features and do not report apps that appeared poorly developed or had no features of interest. Thus, the present search is a "snapshot" of app availability but is not a comprehensive review. A spreadsheet of complete search results can be provided on request.

App Sources

The search method varied according to app source. Worldwide, the majority of transit apps have been developed for one of four platforms: The Web (internet websites), and Blackberry, Apple®, and Android™ devices. Main sources of information were transit websites (in select Canadian cities), Google™



F . 2. Number of apps found for various devices/platforms for (A) personal navigation and (B) transit. We found very few apps specially designed for individuals with cognitive disability. The search included useful North American apps with a focus on Canada (mainly Ottawa and Vancouver/Victoria regions) and a focus on Blackberry apps. The search for transit apps for cognitive disability was worldwide. Apps developed to run on multiple platforms are shown in the "> one type" category.

Using these search parameters, we examined and categorized 159 apps according to features that would be useful to people with cognitive disability or to app developers for this population. We found seven transit apps specifically designed for cognitive disability, 14 personal navigation apps for individuals with cognitive and other disabilities, and 92 transit apps for healthy individuals. We examined 46 personal navigation apps for healthy individuals, though there were far more available (see

features (according to the app developer's own description) and information concerning features/apps in development. Where possible, we link available apps and features to research on what features are needed by people with cognitive disability. We conclude by examining how well currently available apps and features meet the assistive needs of people with cognitive disability taking public transit.

Transit Apps for Individuals With Cognitive Disability

There appear to be very few transit apps developed specifically for individuals with cognitive disability, even when we expanded our search to all available apps in English worldwide. We found seven apps, the majority of which were developed in the United States and conceived and tested in university environments.

Features (Transit for Cognitive Disability)

Figure 3 shows the diverse set of 18 features available with the seven apps designed for transit and cognitive disability. The four most commonly appearing research-aligned features were: (1) A trip planner, (2) caregiver programming, (3) voice instructions, and (4) walking instructions. A glossary of terms used to describe app features is available on request.

Best Apps

In this category, all apps were of particular interest, but we recommend three that have especially interesting features or development approaches. "OnTheBus" (for Android) has many features (i.e., 14 of the 18 features shown in Figure 3) that would be of interest to individuals with cognitive disabilities and to app developers. Development was based on "guiding principles" drawn from research at the Center for Universal Design at NCSU (1997). A second app of interest is "Tiramisu," designed to be useful for both healthy individuals and those with disabilities. This app may be more noteworthy for the way it is being developed than for its feature set. It is "crowd sourced," and in its present testing phase, users must participate in a study in order to sign in to the app. Thus, the developers are recruiting healthy users as research participants, even though the ultimate goal is to develop an app for those with cognitive disability. A third app, TAD, has many useful features and is at the stage of implementation by a commercial partner that is hoping to expand distribution

social media links) were deemed less important because individuals with cognitive disabilities would have difficulty using them. However, some, such as offline schedules and system alerts (from transit authority), may be useful for caregivers who program routes into the smartphone.

Personal Navigation for Healthy Individuals

There were four research-aligned features that were available in more than half of the apps examined: (1) A walking route planner, (2) street view maps of important locations and landmarks, (3) voice instructions, and (4) a phone locator (for finding a person on a shared network).

Linking Research With Availability

Transit Apps for Cognitive Disability

In this category, most apps and features align well with fundamental principles and recommendations identified by empirical studies (Supplemental Material); virtually all of the reported features would be of interest to people with cognitive disability and to app developers. For example, features like "signal a stop" and "not your stop" correspond to specific research recommendations (Risser et al., 2012; Sohlberg et al., 2005). However, not all desirable features appear in all apps, and some features appear less frequently than others. For example, notifications by caregivers and a "not your stop" feature are needs identified by research (e.g., Mechling & O'Brien, 2010; Sohlberg et al., 2005) but are rarely available (see Figure 3). Indeed, most apps do not adopt the recommendation (Lemoncello et al., 2010b; Sohlberg et al., 2005) that devices/apps should reduce anxiety for the user (by allowing communication for assistance). However, voice instructions and emergency buttons (available on some apps) may partially address this issue.

There are some noteworthy features found in two smartphone apps being developed (i.e., not publically available) in close conjunction with research on the needs of this population. Liu, Chen, Chang, and Chen (2009) reported success when testing an app (using Wi-Fi in train stations) to help people with cognitive disabilities use city trains in Taiwan. Research-aligned features included reminders (by sound or vibration) of when to get off the bus, when the next stop was coming, when users were going the wrong way, and when they had missed a stop. Caregivers were automatically informed of the person's location. These detailed features were well received by participants and align with research by providing important information at choice points and reducing anxiety (by allowing for contact with the caregiver). More recently, Riehle, Anderson, Lichter, Brown, and Hedin (2011) identified a small set of potentially useful app features during development of a transit app for Android. Research-aligned features included: (1) Advance trip planning, (2) remote caregiver programming, and (3) caregiver notifications ("off-route" or "successful trip"). Other technical "behind-the-scenes" features included: (1) Automatic run at boot time, (2) resumption of tracking with reboot, and (3) storage of relevant information. The first of these may help with trip initiation and the second with anxiety reduction, for example by assuring that the app does not leave users stranded by having to be re-programmed if the phone is turned off. The authors report the successful development of these features and provide some methods and algorithms. They also report information that may be useful for developers: 98% accuracy of GPS data and 100% accuracy (during 41 trips) of their "proximity to stop" alert using a distance threshold of 100 m.

Taking a different approach to determining and satisfying the needs of those with cognitive disability, Davies, Stock, Holloway, and Wehmeyer (2010) developed and studied WayFinder, a type of personal digital assistant software. These researchers chose to design detailed and customizable software that can be used on computers (including pocket personal computers). Unlike a typical app, this software package is not available in app stores but rather must be purchased (at much greater cost) from the development company. However, the developers suggest that the software may also be loaded into smartphones. Notable and research-aligned features include: (1) Recorded voice instructions, (2) walking routes, (3) initial prompt to start trip, (4) programming of landmarks, (5) notification of "not your stop," (6) notification to "get off the bus now," and, (7) customized reminders. The software also allows caregivers to program more than one route. The authors report that 73% of participants were successful (exited the bus correctly) on a novel bus trip. Unfortunately, the WayFinder software is not available as an app, but many of its features may be useful for app developers, especially given that these features have been proven to be effective with the population of interest.

It should be noted that three of the features currently available have not been specifically recommended by research (Figure 3): (1) Offline schedules, (2) search by bus-stop number, and (3) social alerts in real time. While these features may not be helpful (due to their complexity) for the user with cognitive disabilities, at least the first two may be useful for caregiver programming.

Navigation Apps for Cognitive Disability

In this category, several reported features would be useful in a transit app and align with empirical research. For example, caregiver notifications and programming would allow the caregiver to monitor (and intervene) in a trip to correct a route. Importantly, such features might have the added benefit of reducing anxiety for the user by giving them reliable personal assistance en route (Lemoncello et al., 2010b). Furthermore, features like showing pictures of landmarks may help users if they are lost and need to reorient (Lemoncello et al., 2010b).

A number of useful and research-aligned features were also found within technologies designed to assist people with cognitive disabilities in various everyday tasks (sometimes including navigation or use of transit). For example, Mechling and O'Brien (2010) used videos and photos to pre-train individuals with intellectual disability to press a "request to stop bus" signal in response to the appearance of a learned landmark. Results at post-test (on a real bus trip) were mixed, perhaps because participants had to rely on memory. However, such training might be useful if combined with a transit assistant to aid in the task of exiting the bus. Other researchers have tested user-interface features and training methods to assist people with cognitive

disabilities to use smartphones. For example, Verstock et al. (2009) report features of their Personal Social Assistant (for smartphones) including an interactive agenda (using symbols and voice instructions), photo-based GPS (with large arrows), and "games" to help people practice the phone features. These approaches may be useful for developers of transit apps because they provide users with simple instructions and the opportunity to practice, both features identified as important by research.

Features From Apps for Healthy Users

Some research with healthy users has identified app features that would be useful in transit apps for people with cognitive disability. For example, Fukuta, Ito, Kawamura, and Sugahara (2012) demonstrated the importance of context for healthy users of transit. They identified three important and well-received features: (1) Walking directions to bus stops and ticket booths, (2) an explanation of acceptable forms of payment, and (3) an animated bus rather than a simple moving pin on the smartphone screen. Further, Watkins, Ferris, Borning, Rutherford, and Layton (2011) found that providing detailed bus-arrival information reduced frustration (and potentially anxiety) in healthy users, a feature that may also assist users with cognitive disabilities.

Rare but Potentially Useful App Features

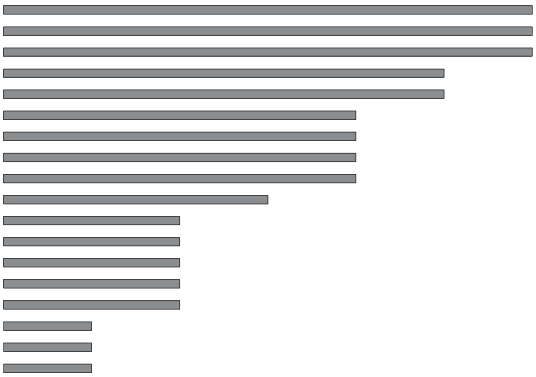
We found a number of research-aligned but "rare" features that might be useful to people with cognitive disability (Supplemental Material). The most notable were found in "Walk with me Bus Travel" developed for users with autism. This app has a screen that can be used to indicate to the bus driver either that the individual has a cognitive disability or that they are experiencing an emergency and comes with built-in reminders about what social situations to expect during bus travel. The emergency screen feature aligns well with the recommendation that the app be linked to the bus and driver; both features may contribute to reducing anxiety for users.

Meeting the Transit App Needs of Individuals With Cognitive Disability: How Are We Doing?

We found only seven transit apps specifically designed for people with cognitive disability, suggesting that there is an overall shortage of such apps on the market. Figure 3 shows how many of these apps meet current requirements as identified by navigation research for individuals with cognitive disabilities. As noted previously, there was a surprisingly good match between the general principles identified by an accumulation of research in the field of disability (Supplemental Material) and the few apps targeted to this population. For example, most are flexible, simple, intuitive, and perceptible (Center for Universal Design, NCSU, 1997) and the majority of available features align with current research recommendations. However, some specific issues have not been fully addressed.

Further examination of available features with respect to recommendations shows that there are significant unmet needs with respect to transit use and cognitive disability. Table 1 shows a list of desirable app features (summarized from available research) and how many of the seven best apps offer them. To highlight important unmet needs, we also present the availability of recommended features ordered by frequency of availability within the seven found apps (Figure 4

1. Feature comparison of available transit apps based on identified needs of people with cognitive disabilities.



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