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

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

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Individuals with cognitive disability have difficulty using public transit, but little research is directed toward this issue. Recent studies suggest that smartphones may be useful assistive devices in this context. Current objectives were to (1) survey research into difficulties people with cognitive disabilities experience when using public transit, (2) survey the current state of the art of transit and personal navigation applications (apps) and features, (3) recommend best existing transit apps for people with cognitive disability, and (4) recommend the best designs and features of these apps to developers of future transit apps. Potentially useful features were found in four categories: Transit apps for (1) individuals with cognitive disabilities and (2) healthy individuals, and personal navigation apps for (3) individuals with cognitive disabilities and (4) healthy individuals. A total of 159 apps were examined, but only seven were found specific to public transit for cognitive disability. By comparing research recommendations and currently available features, we identified several unmet needs. We note that there appears to be a shortage of apps for this population-function but that there is good research in the area and it is well suited to inform app development.

Keywords: assistive technology, caregiver support, cognitive disability, public transit, smartphones, transit apps

Introduction

The use of public transit is a problem for people with cognitive disabilities, since they may have difficulty understanding bus numbers, schedules, or other transit information. Social problems may result, because this restricts mobility and access to family, friends, and support programs. Improving access to transit for people with cognitive disabilities should improve their independence and confidence in their ability to navigate in everyday life.

Research on assistive technology for the visually impaired to help them take transit has made progress in identifying issues and solutions that may also be applicable for people with cognitive disabilities. Researchers have studied barriers to navigation (e.g., Arditi & Tian, 2013; Golledge, Marston, Loomis, & Klatzky, 2004; Roentgen, Gelderblom, & de Witte, 2011) and developed assistive personal navigation devices (e.g., Arditi & Tian, 2013; Golledge et al., 2004; Katz et al., 2012), including some applications (apps) for smartphones (e.g., Harrington, Antuna, & Coady, 2012). People with visual impairments have difficulty taking shortcuts and making decisions at choice points (Golledge et al., 2004), problems that may also be experienced by individuals with cognitive disabilities (Lemoncello, Sohlberg, & Fickas, 2010a).

Golledge et al. (2004) recommended that navigation devices contain information about landmarks, routes, and, importantly, how to use public transit. Others have noted that people with visual impairment prefer the opportunity to explore the environment in advance (Katz et al., 2012; Roentgen et al., 2011). They also prefer unobtrusive assistive devices (Arditi & Tian, 2013) as do people with cognitive disabilities (Verstock, Decoo, Van Nieuwenhuyse, De Pauw, & Van de Walle, 2009).

Because smartphones are unobtrusive, programmable, and use accessible global positioning systems (GPS), specially designed transit apps could provide on-going instructions and feedback to the user and inform caregivers as to trip progress or problems. Availability of GPS is now commonplace, and existing public transit apps may provide useful information for app developers. In addition, smartphone use is on the rise, and in the future, most individuals with cognitive disabilities will have prior experience with such devices. This may be especially true for recent disability from adult onset, such as traumatic brain injury or stroke.

Current State of App/Feature Research

There is little information related to the availability of transit apps/features for individuals with cognitive disabilities even when compared to other forms of disability, like visual impairment (Stock, Davies, Wehmeyer, & Lachapelle, 2011). Systematic searches of the academic literature revealed few studies and no comprehensive review of personal navigation or transit apps for individuals with cognitive disability. Nevertheless, what we did find (reported below) should be relevant to people with cognitive disabilities and for app developers.

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 met (or not) by existing transit apps for people with cognitive disability.

Methods

Procedure

App Search Criteria

An internet search assessed availability of smartphone transit apps (and useful features) for individuals with cognitive disability. The search took place between June and December of 2013 and focused on transit apps, personal navigation devices/apps (using GPS), and apps for assisting those with disabilities. A "transit app" was considered to be any phone-based app designed to assist taking public transit. Personal navigation apps were included because they might contain features useful to developers of assistive transit apps. The search was not exhaustive, mostly because there are very many apps for both transit and personal navigation and because they duplicate one another's features. A total of 159 apps were examined for potentially useful features: 99 for transit and 60 for personal navigation (Figure 1).

A key emergent criterion was that, for those with cognitive disability, transit apps would be more useful if they utilized "real-time" data rather than static offline schedules. This would allow the app to more reliably indicate bus arrival time and accommodate service interruptions. Unfortunately, such data is not available in all cities. The majority (66%) of the transit apps reported here employ real-time data, but others have been included because they contain additional useful features or make
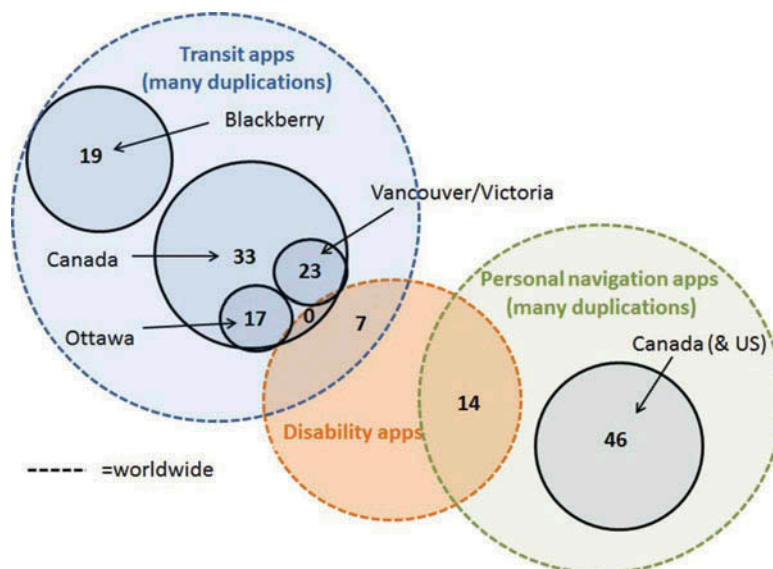
Fig. 1. Conceptual representation of search areas and targets showing how many apps were examined in each category of the total number reviewed (159). The search focused on three app types: Transit, disability, and personal navigation with a worldwide search but with an emphasis on apps usable in Canada 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™ search, brain-injury resource websites, and app stores (e.g., Google Play™, Apple, and Blackberry). Web applications were found through internet search and through links from websites recommending apps useful for individuals with brain injury and/or cognitive deficits. Smartphone apps were found using internet search and by direct app store search. Importantly, online versions of the Apple and Blackberry stores categorize apps and do not allow for keyword search within categories; thus the search for Apple and Blackberry relied on pre-defined store "navigation" categories containing transit, personal navigation and other apps. Also, search features on smartphones differ from those used in online

app stores. For example, on the Apple iPhone™, the search for transit apps results in only locally useful apps. Therefore, some apps found on smartphones may not be found using internet search and vice versa.

Search Methods

The initial search was focused on the Blackberry store and on a local Canadian transit system (Ottawa Transpo). The search was then expanded worldwide and to Apple, Google Play, and the internet during the period from June to December 2013. During the preparation of the manuscript (in the latter half of December 2013) the search terms were run again to check for any new apps that might have been developed. A list of search terms is provided in the supplemental materials.

App Categorization

Transit apps were the primary focus. However, details of another app type (i.e., personal navigation) were included, and notable features are highlighted below. Also, transit and personal navigation apps were found to fall into several categories, ordered below from the most useful (in terms of cognitive disability) to the most basic. Some category names (e.g., navigation and transit) are in general use, but others (e.g., disability and personal navigation) we constructed for present purposes. Figure 2 summarizes types and number of apps found, and the platforms utilized. For Blackberry developers, note that in the North American marketplace there appear to be fewer transit apps designed for Blackberry than for either Apple or Android devices. There also appear to be fewer personal navigation apps designed specifically for Android than for Apple or Blackberry devices. There was also some duplication of apps—that is, some were available on two platforms; the most common pairing was Apple with Android.
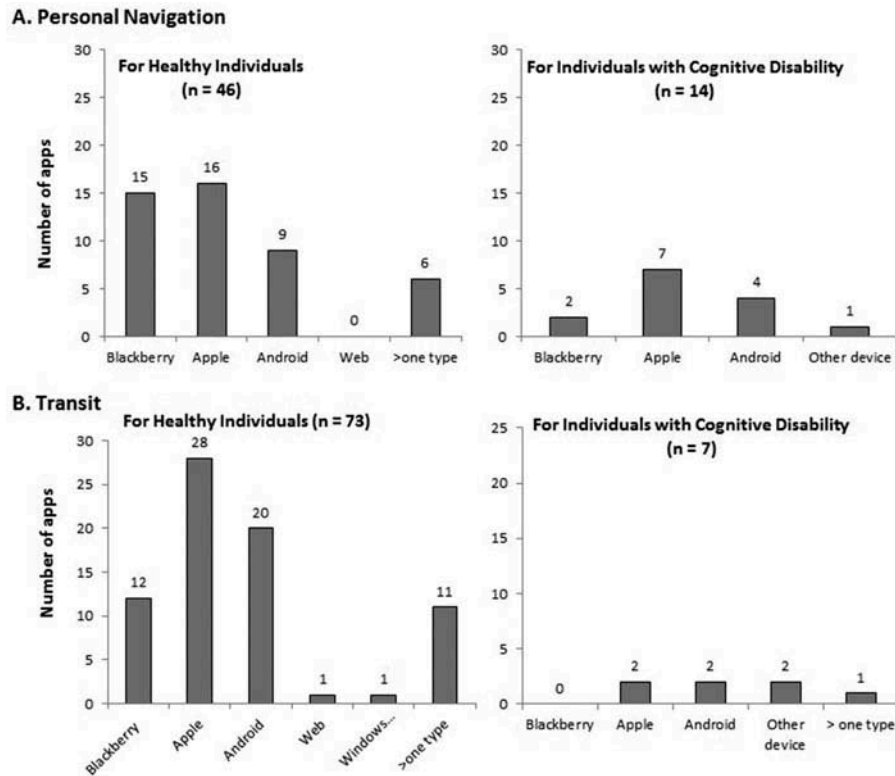
A. Personal Navigation

B. Transit

Fig. 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 Figure 1).

App Ratings

Apps were rated by how many desirable features they had, as suggested either by individual studies or by principles identified through cumulative research in the field of cognitive disability (e.g., Center for Universal Design, NCSU, 1997). Customer ratings were not reported because they were found to be: (1) Too sparse (especially in the newest apps), (2) from a healthy population rather than the population of individuals with disabilities, or (3) too unreliable.

Caveats

There are several important caveats to the present search. First, this is not a comprehensive review and thus does not include all possible apps. In addition, the smartphone app market is rapidly changing such that apps may be introduced, re-developed, or

deleted within relatively short time periods. Consequently, additional apps and features are likely to have been developed after this search was completed (December 2013). Second, the report on features is limited according to the descriptions provided by individual app developers. That is, developers may choose to advertise particular features and not others, or conversely, they may describe features that are not fully implemented.

Trademarks/Copyright

Proprietary names are noted as ®, ©, or TM at first appearance but not thereafter. Many apps are not marked as "copyright" or "trademark" by the developers or in the store/marketplace. Therefore, in text, app names have been placed in quotation marks at first appearance but not thereafter. No quotation marks or copyright marks are used in tables.

Results and Discussion

Overview

Results are organized according to the four categories described in the methods, with the most relevant first: (1) Transit apps for individuals with cognitive disabilities, (2) personal navigation apps for individuals with disabilities, (3) transit apps for healthy individuals, and (4) personal navigation apps for healthy individuals. For all categories, we provide a summary of useful

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 of the app from Florida, where it was developed. Some parts of the TAD technology are subject to patents, and the app has been described by Barbeau, Winters, Georggi, Labrador, and Perez (2010).

Notable App Features From Other App Types

Personal Navigation for Cognitive Disability

Although few apps were found, there were several features of note. The four most frequently occurring were (1) phone locator, (2) voice instructions, (3) caregiver programming, and (4) caregiver notifications. Other less-frequently occurring but notable features were touch screen, writing in symbols, walking route planner, street views, text-to-speech, and showing pictures of important behaviours or landmarks.

Transit for Healthy Individuals

In this category, we report only features that appear to be aligned with current research recommendations. Two such features were available in more than half of examined apps: (1) Real-time tracking of buses (bus locators), and (2) trip planners. Others appeared less frequently (in less than a quarter of reviewed apps): (1) Voice instructions, (2) customized reminders, (3) bus arrival prediction, and (4) walking instructions. A large proportion of transit apps contain "offline" schedules, but this and some other features (e.g.,
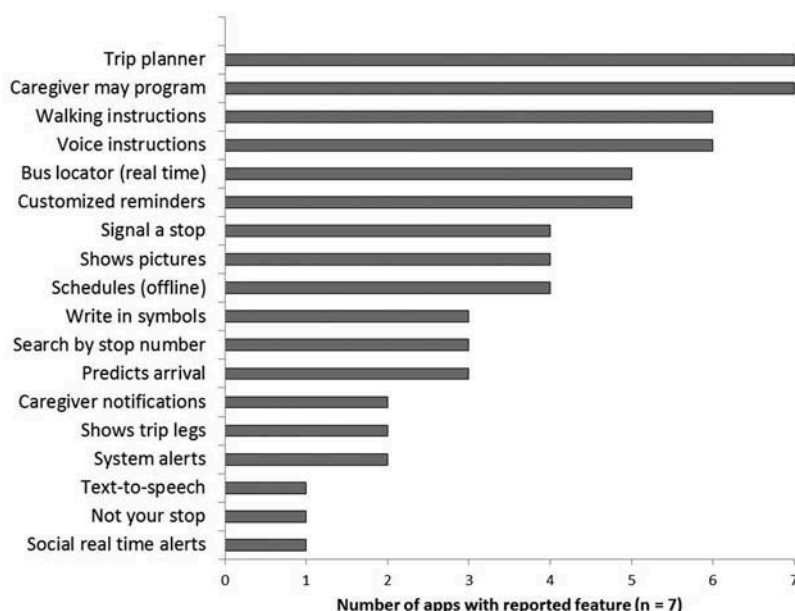

Fig. 3. Feature availability within the seven transit apps specifically developed for individuals with cognitive disabilities. Only three of these features (identified by an asterisk) have not been identified as important by research.

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). Clearly, not all apps contain all desirable features, but more importantly, a significant number of recommended features have not yet been implemented or appear infrequently (e.g., knowing the direction the user is facing, phone loss prevention, exploration, training, emergency bus driver notification, and a "when *not* to get off the bus" feature). Most especially, the issue of anxiety has not been well addressed for users of these apps. As previously noted, the problem of anxiety could be partially addressed by improving features like distant caregiver programming; anxiety might also be reduced by several other features including emergency buttons (for caregiver and bus driver notification) and the opportunity for training and exploration (either real-world or virtual). Indeed, it will be important to measure the effect of improvement in features on aspects of the transit use experience such as degree of anxiety and degree of confidence people have when taking an unsupervised trip. It may be the case that addressing some key unmet needs will improve these aspects of transit use for people with cognitive disability and could perhaps encourage more frequent use of public transit.

We believe our lists of apps (available) and app features (available and needed) are relevant primarily to app developers and rehabilitation therapists who deal with adults with brain injury. They should help these professionals select the best app and/or feature set for their particular interest. The findings may also be relevant to educators and transition specialists dealing with other populations (e.g., youth) and other forms of cognitive disability (e.g., developmental delay), helping them choose the one best adapted for their own populations. In general, we believe that usability testing should be an integral part of any app development or adoption. After all, what is the value of an app that users can't use or don't want to use? In our own preliminary evaluation research of the app we were developing, we discovered several aspects that needed to be changed once they were tested by individuals with brain injury.

Conclusions

There is a shortage of transit apps designed for individuals with cognitive disability. There are also a substantial number of unmet needs regarding availability of transit app features. Unfortunately, there is little research conducted on the transit/navigation needs of those with cognitive disabilities (from brain injury, dementia, or developmental disorder). However, the few studies that have been published are very good and provide clear guidance for those wishing to develop apps in this area. We found numerous existing transit and personal navigation apps designed for healthy individuals, some with pertinent features that developers of apps for people with cognitive disability could incorporate into their designs. Furthermore, now that smartphones are being used by the majority of the population, development of apps targeted to survivors of brain injury will become more viable, as these individuals will likely be familiar with this technology before acquiring their injury. We therefore suggest that for individuals with cognitive disability, new

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

	WayFinder (N/A)	Tiramisu	TAD* (N/A)	OnTheBus	ITWP**	WalkWithMe	TravAlarm Denmark
Requirements (as Recommended by Research)							
Personal Navigation							
Auditory feedback (voice or sound)	✓	✓	✓	✓	✓	✓	✓
Capacity to reassure (reduce anxiety with personal contact)		✗	✓			✓	✗
Keeping person stationary while they receive instructions		✗		✗			✗
Know direction person is facing (before instructions given)		✗		✗			✗
Limit redundant screen information	✓	✓	✓	✓	✓	✓	
Make sure device/feature doesn't make the person stand out	✓	✓	✓	✓	✓	✓	✓
Opportunity for exploration (practice)	✓	✗	✗	✗	✓	✓	✗
Priming about upcoming decision points (incl. bus stops)	✓	✓	✓	✓	✓	✓	✓
Instructions from perspective of navigator	✓	✓	✓	✓	✓	✓	✗
Shows landmarks for re-orientation	✓	✗	✓				✗
Special instructions at start, choice points, and goal	✓	✗		✓	✓	✓	✗
Transit							
Ability to add personalized landmarks and/or notes	✓	✓	✓	✓	✓	✓	✓
Ability to backtrack or review route	✓	✓					
Audio/visual (e.g. text to speech, symbols, voice recognition)	✓	✓	✓	✓	✗		✗
Beeper to locate companions				✗	✗	✗	✗
Caregiver programming	✓						
Connect device to bus driver (provide medical information)	✗	✗	✗	✗	✗	✓	✗
Link to support person (help button)	✓	✓	✓	✗	✓		✗
Link with bus GPS	✓	✓	✓	✓	✗	✗	
Make route corrections, mid-route		✓					
Options for low vision		✓		✓			
Protection from loss of smartphone		✗		✗			✗
Provide location updates (of bus)	✓	✓	✓	✓	✗	✗	✓
Save options (to save route)	✓	✓	✓	✓		✓	✓
Short, written directions	✓	✓	✓	✓	✓	✓	
Tell person not to get off bus yet	✓		✗	✗	✗		
Tell person when to get off bus	✓		✓	✓	✓	✓	✓
Track riders who are in the system	✓	✓	✓	✗	✗	✗	✗
Training	✓	✗		✗	✓		✗
Walking Instructions	✓	✓	✓	✓	✓	✓	✗
Total	22	18	18	17	16	14	10

Note: *Travel Assistance Device, **ITravelWithMyPhone, Blank cells indicate that presence/absence of a feature is unknown.

✓   Has feature

✗   Does not have feature

transit apps and features would be useful, and that app development should be guided by fundamental principles identified by research. Understanding cognitive and navigational deficits that follow brain injury and other cognitively disabling conditions may provide the best possible foundation for developing the best apps for this population.
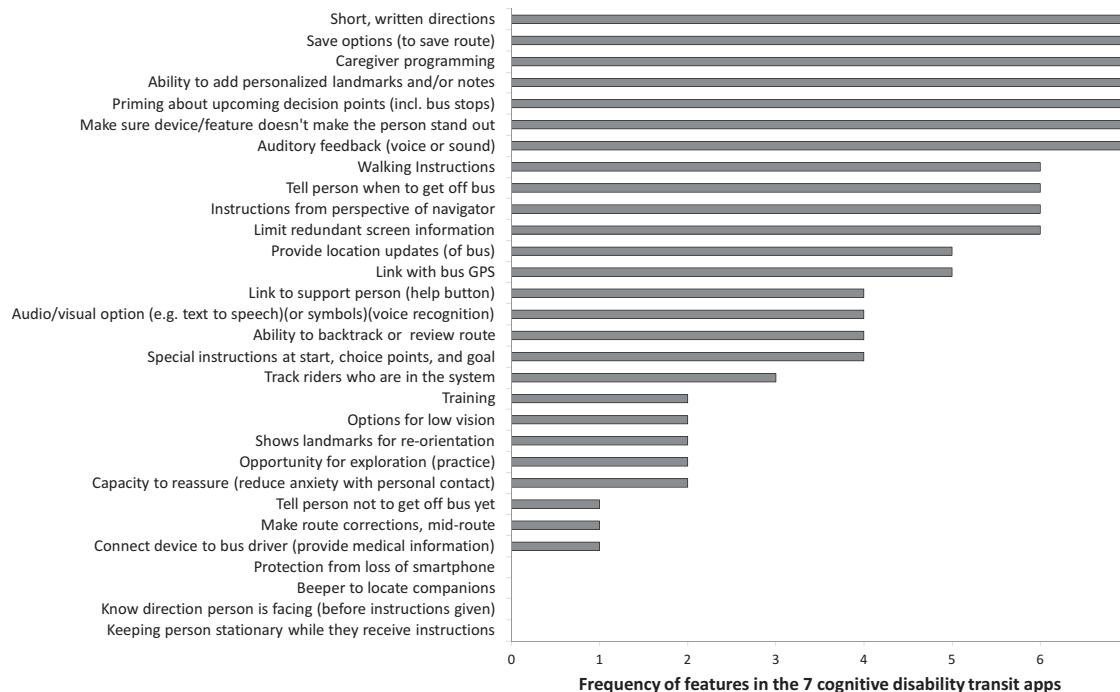
Acknowledgments

Fig. 4. Availability of features recommended by research within the seven transit apps developed for individuals with cognitive disability, according to app developer's descriptions of their app features. Thus, some features may be available but just not described in the online app descriptions. Note that the bottom-most features indicate research-identified needs that are rarely or not met and might be good target features for app developers.

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Supplemental Material

Supplemental data for this article can be accessed on the publisher's website.

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