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ASSISTED COGNITION IN COMMUNITY, EMPLOYMENT, AND SUPPORT SETTINGS (PROJECT ACCESS)

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GOALS OF THE PROJECT

The goal of Project ACCESS is to create novel technologies that will enhance the quality of life of people with cognitive disabilities. Specifically, we investigate the use of assisted cognition as a tool for providing situational awareness to support individuals with cognitive disabilities in living, working and fully participating in community activities. Being part of a community involves many aspects. In our project, we continue to focus on problems associated with navigating physical surroundings. These can often be confusing as traveling from one end of a city to another for employment or even navigating a complex medical building can be quit challenging. More broadly, we want to consider several other aspects of community integration including reminders for errands, assisting in social gathering, and improving performance on the job. We have two primary objectives: (a) developing technologies to support individuals with cognitive disabilities and their caregivers that will allow for greater independence; and (b) refining and implementing participatory processes for gathering and utilizing data from consumers and caregivers that guide the development process.

BACKGROUND

Individuals with cognitive disabilities rely upon support systems to accommodate their functional deficits. Providing appropriate supports can make a substantial difference in their lives. As Litvak and Enders (2001) note, "Supports influence the degree of disability that an individual experiences," (p. 711). In others words, with supports an individual is often able to engage in life roles with more independence. Without supports, an individual may be more dependent on caregivers and less able to pursue life goals. When adequate supports are in place, the experience of disability is mediated.

Support systems consist of three components: personal assistance services (PAS), assistive technology, and adaptive strategies (Litvak & Enders, 2001). All three are necessary and no single component can provide an individual with adequate support alone. In any given situation or environment, an individual may rely more heavily on one type of support than another. Cook and Hussey (2001) describe these decisions about which supports to use as "functional allocation" and Litvak and Enders describe "dynamic support systems," but the basic idea is that sometimes it makes sense to use personal assistance to accomplish tasks; other times it makes more sense to use assistive technology, and other times to learn and use adaptive strategies. For example, someone who uses augmented communication devices may choose to use assistive technology when out in public places because it allows more flexibility and accuracy, but may choose to rely upon personal assistance when in a private setting.

Unfortunately, not all components of a support system are readily available for all who need support. 3.2 million adults with disabilities have at least one assistance deficit, usually involving activities of daily living like housework (Kennedy, 2001). Few personal care providers are compensated for their efforts. In a large sample (N=8,471 adults) of individual with disability in community, LaPlante, Harrington and Kang (2002) report that of the 21.5

billion hours of help provided each year, only 16% of that total involved paid employment. Most people with disability receive informal or unpaid help. Nosek (1993) points out, however, that reliance on family alone for assistance is often considered inadequate due to challenges with burnout of family members, role conflicts and economic strains. Family caregivers are often overwhelmed with the burden of caring for a person with cognitive disabilities. Schultz and Beach (1999) showed that caregivers experiencing strain report poorer health status and have increased mortality.

People with cognitive disabilities prefer to live and function as independently as possible. Technology which promotes full participation not only serves individuals with disabilities, but also reduces the demands for support on the family or caregivers. Significant differences are seen between reliance based on personal care assistance versus functions that are augmented through assistive technology. The latter appears to augment self-efficacy in disability management. Among older adults who have a substantially greater likelihood of experiencing disability, uses of assistive technology is known to be associated with fewer hours of personal assistance used or required (Hoenig, Taylor, & Sloan, 2003). Agree (1999) and Verbrugge, Rennert and Jadans (1997) have shown that persons relying on assistive technology reported less residual disability than did those who were relying on personal assistance. Kim, et al. (2000) contend that the use of assistive technology may result in higher levels of independence, increases in self-esteem, increases in confidence and life estimation, reductions in anxiety, improvements in role performance, decreases in burden on caregivers, and increases in adherence to social and work schedules.

Assistive technology systems comprise a complex interaction between the **human** user, the **activities** in which she or he wants to engage, the **context** in which the activity occurs and the **assistive technology** available to support the activity (Cook & Hussey, 2001). Planning for the development, selection, implementation, continued use and evaluation of assistive technology solutions requires an understanding of each variable.

In our project, we have focused primarily on the needs of 'human users' with intellectual disabilities and traumatic brain injury. We have also focused primarily on the 'activity' of community navigation or wayfinding. However, we believe that our work is broadly applicable to individuals with other cognitive disabilities, including people with developmental disabilities (e.g., autism), degenerative conditions (i.e., Alzheimer's disease, multiple sclerosis), and conditions that result from internal trauma to the brain (e.g., cerebrovascular accident/stroke). We also believe that much of what we have learned as we develop approaches to support individuals in navigation will be applicable to other functional areas.

The functional limitations associated with cognitive disabilities can make it difficult for a person to maintain employment and have a successful social and home life. For example, a person may use an inappropriately loud voice in talking to a co-worker, lose track of time while taking a coffee break, or fail to recognize errors in work completed. These deficits in executive function can also result in significant difficulties navigating independently in the community, for example, when an individual needs to complete a multi-step navigation plan, such as taking public transportation to and from work. Certain kinds of cognitive disabilities also impair a person's ability to stay oriented in space. The individual may become lost even in a familiar neighborhood. An additional complication is that impaired self-initiation may prevent an individual from taking action if he becomes lost; instead of asking for help, he may "freeze help." Navigation may become even more difficult when individuals must deal with competing cognitive demands or stressful conditions.

When individuals cannot navigate safely and/or independently, the burden on caregivers and community services (such as "paratransit") increases and opportunities to act independently and participate fully decrease. These restrictions may have a significant impact on the degree to which individuals with cognitive disabilities can live independently or work in paid employment.

Support systems for people with cognitive disabilities should support the fullest participation possible in employment, education, community, and family. It is important that the goals of technology designed to be used by people with cognitive disabilities parallel these goals rather than addressing specific functional limitations in isolation. In our work, we have focused primarily on cognitive support and wayfinding, but are interested in technologies that broadly provide cognitive support. In the following sections, we describe our current work in navigation/wayfinding and conclude by describing future research.

DEVELOPING AND FIELD TESTING NEW TECHNOLOGIES

Over the past four years researchers in the University of Washington (UW) ACCESS project have developed machine learning and ubiquitous computing algorithms that support new kinds of intelligent wayfinding systems. This work includes methods for (a) inferring a user's mode of transportation (such as walking, bicycling, or riding on a bus) in order to provide mode-appropriate information; (b) learning multi-step transportation plans by demonstration, rather than by manually entering a complex route; (c) learning significant places in a user's life (such as the user's home, workplace, and friends homes) without requiring explicit user input; (d) predicting the user's most likely destination based on the user's current location and the time of day, so that the user can simply confirm a destination rather than manually typing it in; and (e) detecting unusual variations from a user's typical daily movements, that may indicate the user is lost and needs help. Figure 1 demonstrates these concepts. After a few weeks of use, an individual's travel patterns provide enough information for our algorithms to infer important locations and points at which travel modes change such as bus stops and parking areas (left side of Figure 1). Well-trodden routes (as shown on the right in Figure 1) provide important information for deciding when the user may be heading in a wrong direction for their explicit or even implicit destination.

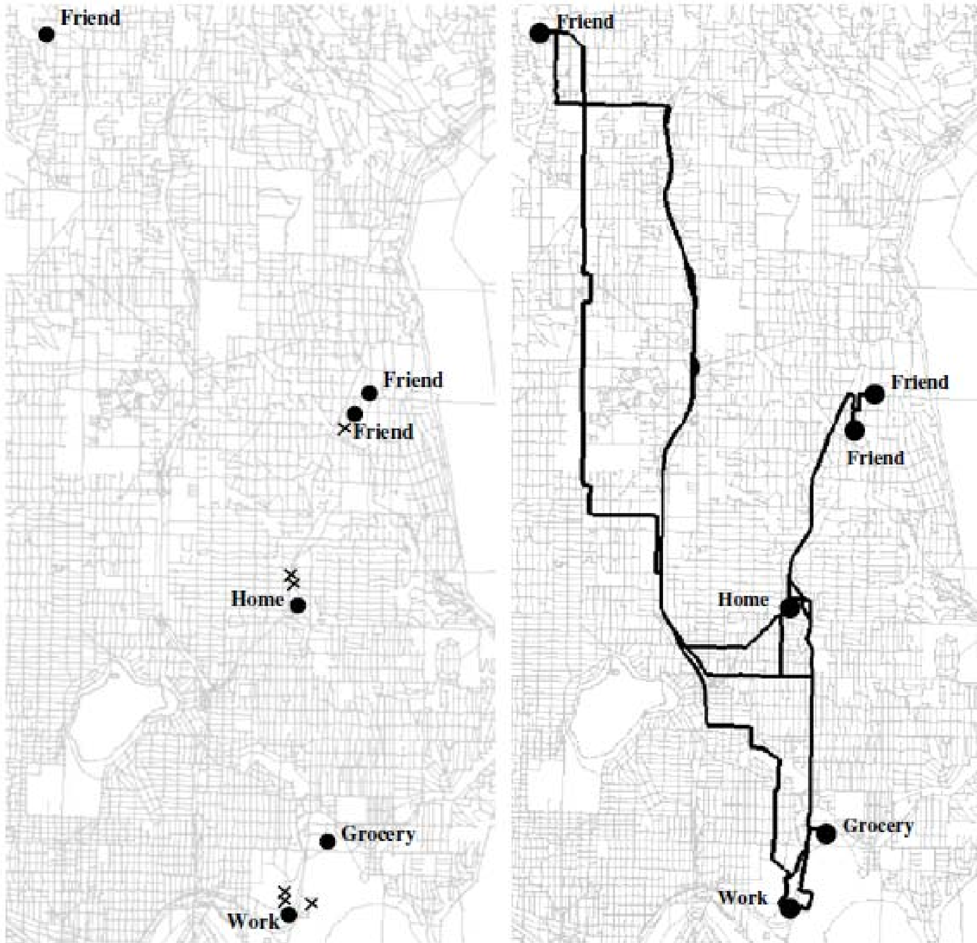

Figure 1: Examples of user's significant places and common routes between them. What is not shown in the figure is auxiliary information about the mode of transportation typically used between the points.

While the work so far has laid the foundations for intelligent wayfinding, the methods were tested on relatively small numbers of users, and demonstrated on prototype systems that were only able to run for fairly brief periods of time. In particular, the most advanced prototype system created at UW, called Opportunity Knocks (OK), used a cell phone that had to maintain an uninterrupted broadband connection to a remote computer system, where all reasoning about the user's current and future state was actually performed. When the connection was lost, the device carried by the user lost all functionality. This architectural weakness made it impractical to deploy OK to users, who would be endangered by such a catastrophic failure mode. Part of our future work is refining these algorithms so that they can work on autonomous handheld devices such as cell phones.

More recently, we developed a Wizard-of-Oz infrastructure so that potential users could walk through a realistic experience of using a wayfinding system without all parts of the system being fully implemented. This prototyping approach is particularly important in collaborative, iterative design with individuals with cognitive impairments, because simply 'thinking through' designs on paper is rarely effective (Lepisto & Ovaska, 2004).

We designed an interface suitable for use on a handheld device, a PDA initially and more recently a cell phone, to send directions and prompts to the user. These directions and prompts consisted of a subset of images, audio, and text messages. The design was a result of several rounds of pilot testing involving members of our research group and job coaches from a community based rehabilitation program. Job coaches were able to consider the needs of their clients when evaluating the system. Based on the pilot tests, we refined the types of images presented and the wording of the audio and text messages.

- *Images:* We used four types of images: photos, arrows and other generic symbols, photos with overlaid arrows, and photos with an outlined area (See Figure 2). Photos were of landmarks and other interesting features. Arrows and other generic symbols were used to tell a user to turn or stop and were used at times when appropriate photos were not available or distinctive enough. Overlaid arrows on photos were intended to disambiguate where to go as well as provide additional indication of where a user should go next. Some photos contained a highlighted area (e.g. a room number or elevator button).
- *Audio and Text Messages:* Text messages were brief messages displayed in large font. The text and audio messages had the same wording, in order to minimize the complexity of directions with both text and audio. See Figure 3 for an example direction.
- *New message Alert:* An alert chime preceded new messages and prompts to get the user's attention, alerting the user that a next step was being indicated.
- *Acknowledgement Message:* Besides directions and prompts, the interface also had a simple message 'Good', which was intended to tell the user when a prior direction was completed successfully and had been cleared from the screen.

Figure 2: Sample images used in the interface. Clockwise from top-left: plain photographs, directional symbols, photographs with highlighted areas (e.g., room number), and photographs with overlaid arrows.

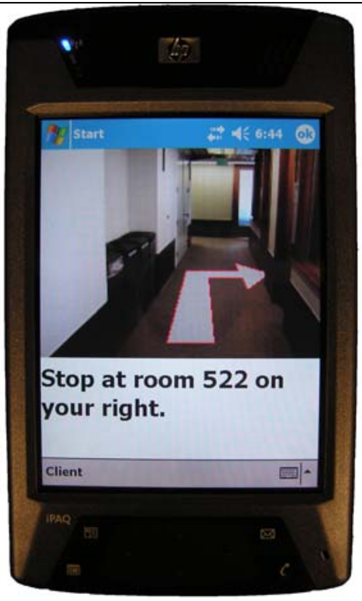

Figure 3: Sample iPAQ display. Participants get a combination of image, text, and audio directions to follow when navigating a route.

Figure 4: Sample mobile phone display on our most recent prototype.

Example screen images from our user devices are shown in Figure 3 and Figure 4. Figure 3 is our initial prototype using an iPAQ, while Figure 4 is our more recent implementation of the same functionality on a cell phone.

Our initial prototype was implemented in Java and SWT and ran under Windows Pocket PC 2003 on a HP iPAQ handheld with a 802.11 (WiFi) adaptor. The software supports display of images up to 240x320 resolution. We used images with 240x180 resolution in order to leave room for text to be displayed as well. Users can choose to use headphones or the built-in speaker to hear the audio. Figure 3 and Figure 4 show the device displaying a sample direction with image and text. Arrows and highlighted regions are overlaid on the photos manually. One could imagine automating this process but we wanted to first understand which modalities would work best for directions before tackling this complex image processing problem. The device acts as a client to a remote server controlled by the navigation wizard, a person who sends instructions to the client on what to display and play based on the participant's location and heading. To gather location and orientation information, we use a location wizard, a person who follows study participants and transmits their location and orientation to the navigation wizard in real- time using a simple map-based GUI that runs on a Tablet PC. Figure 5 shows the system diagram. Current WiFi-based localization systems are close to providing the resolution that we need (Hightower J. & Borriello, 2001)], but we also require orientation, which would necessitate a separate sensor. Therefore, we chose to use a location wizard as a substitute for now. Figure 6 shows the server control program and Figure 7 shows the map GUI. We divide study responsibilities between two wizards (in addition to other observers) in order to more effectively operate our multi-modal simulations (Salber & Coutaz ,1993). We preloaded all images and audio on the client device to maximize responsiveness of our initial prototype. With the high bandwidth of WiFi connectivity, these objects could be easily transferred in real-time from a locally-deployed server with negligible latency. However, we also wanted to support caching on the client for those situations where WiFi is not available. Audio messages were pre-recorded to match text directions although, in the future, audio could be automatically generated using text-to-speech converters.

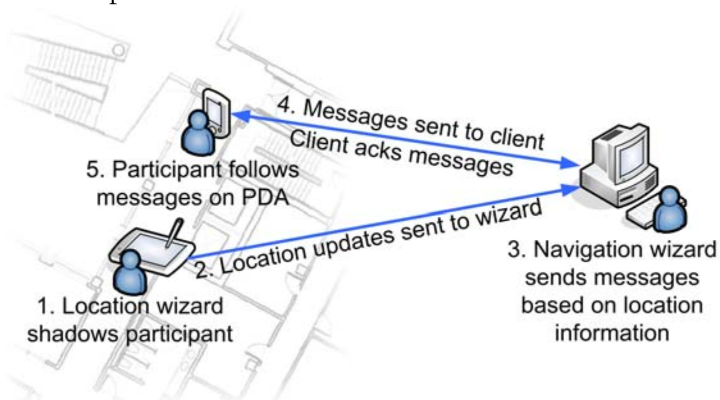

Figure 5: System interaction diagram. Location wizard provides location information on the participant (x, y, floor, and orientation) (1) sent over WiFi (2), while the navigation wizard uses that location information to decide which messages to send (3). Messages (to display images, text, and play audio) are sent to the client device over WiFi and acknowledged for robustness (4). Participant then follows the direction or prompt displayed on device (5).

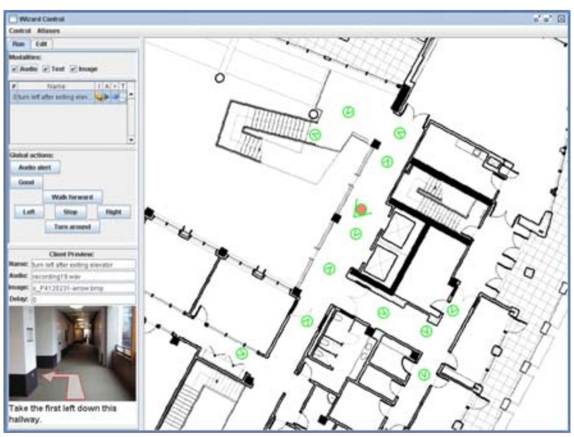

Figure 6: Server control program. Green marks on the map show where pictures were taken from, and are used to send prompts to client. Solid red mark shows information from location wizard.

Figure 7: Map GUI running on a tablet PC. Red mark shows participant location and orientation.

FUTURE WORK

Our focus today is on making the user devices autonomous, better connected to situational information, more responsive to the user, and with more streamlined interfaces.

Autonomy is critical for robustness. It is not appropriate for deployed systems to rely on any form of communication from the device to a server on the Internet. Instead we want to be able to run all of our inference and navigation algorithms directly on the device. This is now possible with increasing memory and computational capacity – to the point that a modern cell phone (e.g., an iPhone) is more capable than a PC of just a few years ago. The principal challenge will me managing the database requirements for photographs and directions – possibly by exploiting a user's common paths.

Situational information is important for applications to consider as they provide instructions to the user. Examples of this include time/space distance of caregivers, family, and friends as well as real-time positions of busses to be used to get to a destination. Having this information provides an opportunity for detailed instructions that can include appropriate auxiliary data that can relieve stress. For example, by informing a user that there is plenty of time to walk the two blocks to the bus stop as the bus is on its way but not likely to be missed.

Our systems should not be designed to only provide instructions to an individual, but also take that individual's reactions and wishes into account. We want to investigate ways to allow the user and caregivers to give the system positive and negative reinforcements that will be used to better use prompts and notification. In addition, we want to provide the user with a way to request information when they feel they require it. For example, to provide an alternate or finer-grain instruction for a more complex navigation step or even just to remind the user of the errands they need to complete on this trip or over the course of the day.

Finally, we want to streamline our interfaces so that user's have a more positive experience searching for information. Utilizing situational awareness, we want to overlay information directly on the camera screen that is now standard with every cell phone. We already have made some positive steps in the direction (Hile & Borriello, 2007) and Figure 8 provides an example of information overlay. One could imagine this getting further customized based on the user's abilities and goals.

Figure 8: A cell phone screen showing information overlays automatically placed directly on the screen.

Participation of users with cognitive impairments is critical when developing assistive technologies for their use. Sohlberg et al. (2003) found that participants with different levels of cognitive impairments had difficulties with skills that most interface designers take for granted. LoPresti et al. (2004) contend that the field needs to address the issues of usability over time (i.e., the human-technology-interface—customization, adaptability) and generalizability of device use across home and community settings.

EXPERIMENTS

Our Wizard-of-Oz design was the result of several rounds of pilot testing involving members of our research group and job coaches from a community based rehabilitation program. Job coaches were able to consider the needs of their clients when evaluating the system. Based on the pilot tests, we refined the types of images presented and the wording of the audio and text messages.

In the indoor experiments, the interface guided every participant through three routes of differing complexity using three different subsets of modalities. Combination 1 used all three modalities for messages. Combination 2 used only text and audio. Combination 3 used text and images. We varied the order of both routes and modalities presented to each participant in order to minimize ordering effects. The study was conducted in our Computer Science and Engineering building, which was unfamiliar to all participants. Two of our researchers from the Department of Rehabilitation Medicine followed each participant in order to take notes, get feedback from the participant, and provide assistance in case the participant became confused or uncomfortable. All participants gave permission to audio record their session. At the end of each study, we asked participants what they thought of the interface and how they navigate when in unfamiliar locations. We also asked them to look at alternative interfaces that displayed traditional maps with overlaid path arrows, identify where they would be, according to the map, (e.g. in a room or a hallway), and explain what the map was telling them to do (e.g. move forward and turn right).

In the outdoor experiments, every participant walked through three routes of differing complexity. Each participant's first route was a baseline (no interface) case where participants had a choice of written directions, a map, or verbal directions from a researcher. The other two routes were presented through the interface, using the full set of modalities. We varied the order of routes presented to each participant. The study was conducted around the central part of our university campus. Two of our researchers from the Department of Rehabilitation Medicine followed each participant.

The results from these studies begin to address the question of what kinds of modalities and direction-giving strategies are effective for individuals with cognitive impairments (Look, Kottahachchi, Laddaga, & Shrobe, 2005; Tversky, & Lee, 1999). Study participants were recruited from a pool of adults with cognitive impairments who were receiving employment services from a community-based rehabilitation provider. From this set of interested participants, we selected individuals with a primary disability of traumatic brain injury (TBI intellectual disability (Downs Syndrome), Pervasive Developmental Disorder (PDD), Asperger's Syndrome, cerebral encephalopathy or cerebral palsy (CP) with cognitive impact, ranging in age from 26 to 46. Such a diverse set was purposively selected in order to gain insight from a wide range of perspectives on the usability of the interface design..

STUDY RESULTS

Despite the challenge of navigating through unfamiliar environments, the results from both studies were positive. All participants were able to follow the interface's directions to their destinations. We found that although users were able to use all types of modalities to find their way indoors, they varied significantly in their preferred modalities. Our studies have demonstrated that there is no 'one size fits all' solution, and that arguably the most important aspect of a guidance system for persons with cognitive impairments is that it be widely customizable and adaptive. More specifically, our results indicate that an effective user interface should support multiple modalities (text, audio, graphics, and photographs), because no one modality or set of modalities was best for all users; that timeliness of prompts is crucial, as well as providing appropriate confirmations to the user; and that the way a user carries a wayfinding system has a significant effect on how such a system is used.

Participants gave different reasons for their modality rankings. Text was highly rated because it let participants process messages at their own pace, and refer back to them as necessary. Some participants said audio was useful in combination with other modalities, but audio by itself was not preferred (probably due to its fleeting nature), although all participants said the audio was of good quality and clear. Images were reviewed positively because they also gave the participants more time to consider the message and make the visual associations.

Participants liked directions that communicated a sense of responsiveness by the system. The system needed accurate location information in order to send directions at appropriate times. Those directions also needed to convey a sense of how long they were applicable, otherwise participants could get confused.

In the outdoor studies, we implemented a baseline condition. All but one participant struggled to navigate without the interface through their first route, needing extensive guidance from our researchers throughout the route. With the interface, all participants were able to reach their route destinations with only a few incidences that required external help and clarification from researchers. Participants did not have difficulty viewing the screen in bright sunlight, hearing the audio when the environment was noisy, or get distracted or confused by other pedestrians along the routes. However, participants varied in their level of caution when approaching one location that required crossing a campus path that accommodates both pedestrians and automobile traffic, despite the direction including a warning to watch for cars on the road. The brisk pace at which most participants walked when using the interface suggested confidence in its ability to guide them, and the lack of caution may be an indication of overconfidence, which may come from the novelty of the system.

FUTURE WORK

Our future work will pursue four main directions: (a) user interface improvements, (b) further user studies, (c) better corrections, and (d) technology implementation issues.

User Interface Improvements

We will investigate a greater use of visually distinct landmarks for giving directions, particularly for outdoor navigation. Psychological evidence suggests that landmarks play a crucial role in spatial understanding (Lynch, 1960). We will study the effectiveness of maps for conveying complex routes to more spatially-aware individuals. While all but one participant in the outdoor study chose to use written directions rather than a map, when asked to interpret a map shown on the iPAQ screen, four of the seven indoor study participants were able to successfully complete the task. Our next user interface will support greater interactivity. This will include methods for the user or caregivers to input destinations in a simple manner as, for example, using the method proposed in Patterson, Liao, Gajos, Collier, Livic, Olson, Wang, Fox, & Kautz (2004), where the system displays photographs of the most likely destinations based on a learned model of the user's day-to-day movements, and asks the user to confirm the correct choice. The user interface will also include methods for user-initiated feedback to the system, including explicitly asking for the instruction, indicating that the user does not understand the system, or requires more time.

Further User Studies

We will expand our user studies in several ways. First, we believe it is important to more accurately measure 'baseline' performance, that is, non-assisted wayfinding. Baseline information is useful both for evaluating the impact of the system and for determining the kinds of individuals who could potentially benefit from automated wayfinding technology. Second, we will study a wider variety of more realistic, purposeful tasks. For example, a task may be to enter a building, find a particular office, and deliver a package. By implementing more naturalistic routes, we expect participants to be more active and intentional in route-finding, and expect to learn more about how individuals might use the system in their daily lives. Third, we will use a reimplementation of our system on a mobile phone (see Figure 4), which will allow us to study the usability of the interface on a more widespread and accepted platform.

Better Correction Strategies

We will investigate improved ways of determining when the user should be corrected, as well as how the corrective prompts should be delivered. It is not always easy to determine when the user actually needs help; for example, the user may stop moving because she is confused, or because she is carefully looking around to orient herself. In the latter case, a premature prompt may actually create confusion. This suggests that the system be designed to adapt to the user. Our earlier work (Patterson, et al., 2004) argued that confusion is often signaled when the user's behavior does not fit with her 'normal' pattern. Such methods for automatically inferring the need for help can be combined with explicit user feedback about the need for help (and whether the system's prompts are understandable) as described above. We will also systematically examine a range of correction strategies. For example, the wizard in our study most commonly prompted users to retrace their steps when they missed a turn. Retracing, however, can be slow; in some cases it was much more effective to send directions that were specific to the user's new location. Lastly, we will explore the ability for the interface to connect the user with another person when human intervention may be necessary.

Technology Implementation Issues

Today's mobile phones have enough computational power and bandwidth (including WiFi) to implement all of our functions. In addition, they can be easily connected (over Bluetooth) to wireless headsets and external sensors carried by the person (e.g. barometer). We also plan to integrate a WiFi-based location system on that platform and augment it with a digital compass to provide approximate location and orientation (we will need 3-4m resolution with 30-45° angle accuracy) (Brunette, Lester, Rea, & Borriello, 2005; Hightower & Borriello, 2001)

Expanded Functions

To round out our support for community integration, we are also in the process of planning the development of a "sass" – a situational assistant. The concept is quite simple. An individual should be able to activate their phone and get a quick summary of their activities in the form of reminders, prompts, and basic feedback on what they've done so far. For example, when a user opens their phone in the morning, it could provide an animated character that could present a personalized "news show" that describes the activities they need to complete for the day and the likely steps/challenges they may face. Later on in the day, on their way to work, the information presented is more specific to the task at hand, namely, making sure that an appropriate bus transfer is made at the right place and time. Finally, in the evening, the phone can focus on social activities such as things to get for helping to make dinner, preparing for a friend's visit, or remembering to attend an event at the community center. Data for these presentations will be combined from the user's current situation (their current task and goal), environmental factors (such as weather and bus positions), as well as public and private schedules and calendars maintained by the user, caregivers, family members, or community organizations (e.g., along the general lines of Google calendars).

CONCLUSION

We believe that assistive technology for wayfinding is a significant element in significantly improving the quality of life for many individuals with cognitive impairments. We have realized initial systems that demonstrate some of the positive effects that can be gained. We are expanding the capabilities of the devices to make them autonomous and more robust to failures. Furthermore, we are considering enhancement to help with other important functions besides wayfinding such as planning for the day, reminding about social events, and generally improving and individual's situational awareness through integrated databases and synthesized instructions in combinations of video, images, and audio. There are many technical challenges to realizing such systems and these will require advances in user interfaces, data integration, and machine inference.

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