Usability in the Real-World:
Design of Mobile Wireless Technology for Individuals with Cognitive Impairments

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Introduction

Through the integration of research and design, mobile wireless technology (MWT) has the potential to impact the level of independence of individuals with cognitive impairments resulting from acquired brain injuries (ABI). Research in computer science and rehabilitation engineering is combined with industrial design to explore the central concern: the design of a user interface that people with significant cognitive impairments can understand and operate. Using a human-centered design approach to understand this specific arena provides a basis for enhancing the usability of mobile wireless technologies for all users.

Background

Acquired Brain Injuries

Acquired brain injuries (ABI) result in functional and psychosocial changes. Cognitive impairments are the most common and perhaps most debilitating psychological consequence. All brain injuries have unique characteristics; however, commonalities exist in impairments to memory, organization, attention, concentration, initiation, and task completion (*Types of Brain Injury*, 2004). Emotional or behavioral problems also emerge, stemming from an individual's impaired ability to sense and perceive his or her environment and to react appropriately (Page, 1998). The performance of complex physical and intellectual activities becomes limited, forcing the loss of personal identity and reliance on others. With the use of compensation methods, individuals are able to re-gain independence in daily activities, overcome limits to social interaction, reduce reliance on a caregiver, and move toward self-sufficiency (M. M. Bergman, 1991).

Traditionally, these methods fall under two categories of cognitive aids or prosthetics: electronic and nonelectronic devices. The functions developed for the electronic devices evolved from their analog predecessors. As technology becomes more powerful and portable, an electronic cognitive prosthetic is able to combine with wireless networks to support myriad applications with on-the-go support. To have the greatest impact, these devices must be both thoughtfully designed and successfully tested.

Stakeholder Needs

The MWT industry is limited in their resources for identifying and meeting the needs and wants of consumers. As a result, individuals with specialized needs encounter usability problems and design barriers that prevent them from accessing products. In order to explore appropriate designs for MWT and individuals with cognitive impairments, the researchers partnered with the Side by Side Clubhouse in Decatur, Georgia, a meeting place for people with brain injuries to transition from medical patient to contributing community member. An ideal setting for exploring the use of compensatory aids, the Side by Side Clubhouse provided an environment receptive to innovation and exploration. Over thirty clubhouse members, staff, and friends volunteered their time and expertise to partake in participatory research activities to provide insight into their technology needs.

For a period of six months, observational research was conducted at the Side by Side Clubhouse. In addition to outlining the potential for MWT to enhance the lives of individuals with cognitive impairments, current barriers to technology use were observed. Through this work, a preliminary understanding for stakeholder needs was established. To verify these findings and add to the understanding, two focus groups with individuals with ABI, their caregivers, and therapists were held.

The conversations centered on difficulties individuals with ABI face. In addition to discussing techniques used to compensate for injuries, the pros and cons of current electronic compensatory devices were also discussed. Potential MWT users voiced concerns about the usability, functionality, and appearance of devices. They particularly emphasized the need for the device to fit into an individual's lifestyle. It was explained that providing a device that meets these challenges would enhance the likelihood of consistent use. Focus group participants also mentioned the need for the design to be durable to prevent breakage and portable to prevent loss.

Cognitive Prosthetics

The field of cognitive prosthetics continues to evolve as technology is enhanced and evaluation methods are perfected. Knowledge gained through an ongoing literature review reflects this mercurial state and is summarized with the following conclusions: a) standardized neuropsychological tests are unlikely to be effective in establishing optimum input and output configuration of cognitive prosthetics for a given subject, although results of some auditory, visual, and motor skills tests may be helpful in making general decisions; b) the impact of environmental factors on the effectiveness of handheld cognitive prosthetic devices intended for use in the community cannot be predicted in a lab setting; c) the conditions for developing a usable device are best met when participants feel like "customers" taking a test-drive, rather than research subjects being evaluated; d) the most effective assessment protocol is likely to be a high-level screening of potential subjects, followed by trials, device modifications, and more trials.

Combining information from observational research, focus groups, and literature reviews, the need emerged for a mobile electronic device that will assist individuals with returning to the community after an ABI. Here, the traditional model of personal information mangers (PIM) or personal digital assistants (PDAs) falls short. The concept of a PIM or PDA is based on user-initiated action, requiring that the user understand when he/she wants or needs to use the device. The onus is on the user to initiate interaction with the device. However, this user responsibility is not appropriate for individuals with a brain injury (M. M. Bergman, 1991). A device for an individual with an ABI must signal or remind him/her that it is there, putting the onus on the device, rather than the user, to initiate action. Furthermore, to ensure the addition of mobile technology provides an advantage over traditional non-mobile compensatory methods, it is necessary to evaluate the human-device interface on an individual basis and to make sure the mobile aspect is indeed helpful and warranted.

Complementary Work

As handheld organizers come to market, rehabilitation engineers use the mobile technology to develop compensatory aids. Unfortunately, the expense of producing a specialized hardware device proves prohibitive, and practitioners are limited in creating customized software applications. Of note are devices based on the Pocket PC platform including: the Planning and Execution Assistant and Trainer (PEAT), an electronic calendar and address book designed to increase independence (Levinson, 1997); The Jogger, a mobile prompting and cuing device (*The Jogger System*); and Pocket Coach (*AbleLink Technologies, Handheld Solutions*, 2004), a verbal prompting device. While these programs support increased independence, the design barriers present in mainstream hardware prohibit the creation of a suitable interface and an optimal user experience. These limits are overcome through exploring how future technology devices can be designed to better suit the needs of individuals with cognitive impairments.

Two design goals conflict in meeting these needs (E. Bergman, ed., 2000): fast access to all functions and visual simplicity. Guidelines for interfaces and the use of telecommunications products by individuals with cognitive impairments do exist (Francik, 1999; Vanderheiden & Vanderheiden, 1992), but they do not include data on the use of mobile, hand-held products in real-life environments. By implementing the stakeholder needs in design explorations, the goal is to expand these guidelines to the area of mobile computing by an individual with an ABI. It is expected that these guidelines will also be beneficial in enhancing the usability of mobile wireless technologies for users without disabilities.

Preliminary design explorations were based on developing a device that proactively motivates and influences users to both accept and rely upon a computing product for support. These explorations were influenced by the study of computers as persuasive technology, “Captology,” as defined by B. J. Fogg (2003). This work complimented the findings of the participatory research by viewing positive device dependence as a predecessor to user independence. This relationship between device and user is reinforced through optimal input and output modalities for navigation, information, alerts, and reminders, as well as appropriate prompt working and levels and optimal device storage.

Methodology

Protocol Development

To explore a cognitive prosthetic as persuasive technology and examine design implications for future products, both the hardware and software of an existing device were modified for use in a series of structured exercises and evaluations. This assessment device and exercises were also designed to reflect upon the differences between a cognitive prosthesis and a PIM or PDA and to explore motivation for use. The exercise revolved around real-life scenarios involving a visit to the grocery store (Kroger), a visually crowded and physically crowded environment where the effects of noise, glare, weather, and other factors could be assessed.

An assessment protocol was developed to outline the full device evaluation including: an initial briefing with the participant and his/her caregiver, device training sessions including a sample task exercise, and a half-day session with three task-oriented exercises of increasing difficulty: a time-out period, a reminder request, and a debriefing. The user was expected to keep track of the device throughout the half-day exercise by using his/her own carrying method or choosing a provided method. Accompanied by a researcher acting as caregiver, the user was asked to accomplish all tasks while interfacing only with the device. To minimize the complexity of the information display, device navigation is broken down into three main areas: “OK” signifying completion and moving forward in the interface; “Help” signifying the need for additional information; and “Reminder” signifying the need to input information on the go.

The first exercise of the full device assessment requires that an item be placed into the shopping cart. The second exercise lists three items that need to be found, and the final list includes an ingredient, hazelnut extract, that is not available at the grocery store. By having hazelnut extract on the “Help” menu, the participant is forced to work through the levels of “Help” on the device. By accessing the “Help” menus, the user is guided through a series of hints ending with the ability to request help from the researcher/caregiver. If the user fails to ask the researcher/caregiver for help when necessary, it is an indication that he/she may have difficulties if alone in the community and that further evaluation is necessary.

The reminder section is conceptually separated from the task-orientated exercises and is designed to be accessible throughout the series of three exercises. During a pause in the program, the research assistant asks the user to remember a request. At the end of the assessment exercise, this prompt is used to determine if the user: a) is able to remember the request on their own and gives the information when needed; b) forgot the request and the information; c) chose to use the device to input the reminder but failed to use the device to retrieve the information when needed; d) chose to use the device to input the reminder and was able to retrieve the information when needed; e) chose to use the device to input the reminder and set an alarm to help in the retrieval of the information.

Device Development

Based on the initial assessment protocol and prior to commencing device programming, a paper prototype was developed and tested by individuals without cognitive impairments. These trials led to the task modification and the solidified assessment protocol. Certain prompts were determined inappropriate for the selected environment. For example, the initial easy task exercise prompt asked the participant to pick up a newspaper. However, in the grocery store used for the evaluations, the newspapers are hidden behind a display case and are not easy to locate. The prompt was therefore modified, asking the participant to place one glazed donut into the shopping cart, as the donut display case is visible from both store entrances. In addition to these walk-throughs, feedback was sought from clinicians to validate the scenarios and modify wording used in the device and wording used within initial conversations and debriefings.

The pocket PC platform was chosen because of its programming flexibility. When development began, the Hewlett Packard iPaq 5455 was the only model with a tactile or vibration alarm setting, a valid alternative for the alert output, and was therefore selected as the base model. Though the research team was limited by technology, and thus unable to implement all of the envisioned interaction methods, the users were able to select between touch screen or four-way controller for navigation and an on-screen keyboard or voice recorder for the reminder section. Also, users could choose between visual and audio alerts. On-screen text was always given for the prompts and the user was able to select to have the prompts read out loud and use optional headphones.

RESULTS

Device Assessment

During the summer of 2004, twenty participants evaluated the modified device, completing the assessment, including device training and half-day of task-oriented exercises. To limit the variable of additional recovery or gain in ability, participants were required to be 18 years of age or older and at least one year post injury. During the training exercises, the researcher and participant selected appropriate input and output interaction modalities and determined a preferred method for carrying the device. By conducting the assessment in “real-life” rather than in a lab, key user experiences arose including: travel-route accessibility, background noise, and participant impulsivity. The knowledge gained through these unexpected occurrences increased the understanding of user needs and device specifications.

Initial data analysis examined participants' progress during the device training, completion of each task, success during the reminder exercise, and thoughts on device usage. Through this analysis, findings spanning hardware, software, and training aspects of the assessment emerged. Each covered cognitive, physical, and emotional aspects of product interaction and included the need for enhancing the distinctions between the functions of "OK," "Help," and "Reminder." Using feedback and analysis as a guide, minor changes were made to the protocol including: modifying the four-way navigation button to enhance feedback and control; adding a transparent cover to the "Help" button to give it a tactile distinction; and creating a training dialogue that stresses the differences between the three navigation areas.

In December 2004, five participants assessed the modified device. There were marked improvements to both the physical and cognitive aspects of the device and in navigating the prompts. The results from both testing series demonstrate the impact of design and environment on product usability.

Design Implications

During both trials, all participants were successful in getting to the grocery store; however, success with the three main tasks varied. Success during the training sessions was not necessarily an indication for success during the half-day exercise. Two participants, both of whom struggled through training, surprised the researchers by successfully completing all tasks and the reminder exercise. Unpredictable events such as these accentuate the need for individual evaluation and the importance of evaluating interfaces in real-world situations.

The assessment also deepened understanding of knowledge transfer. During the training, one participant appeared to understand the device capabilities and operation; however, when given the device for the full exercise, he ignored the active prompts and instead recalled activities and items from the training exercise. By memorizing the task sequences and not learning the logic behind the device's operation, he was unable to transfer the knowledge to the real-life exercise. This led to the design implication that visual, auditory, and tactile cues need to be used to direct the user toward the task at hand. The strength of the cues needs to be customizable and adjustable depending on a user's need for direction and coaching on new or different tasks.

Prompt wording also impacted user success. Participants were first prompted to "Go to Kroger [the grocery store]. When you get there, get a shopping cart." Following the long break in the assessment, they were asked to return to Kroger for additional shopping. Participants felt they had already completed the task and therefore did not return to the grocery store as instructed. When tasks are repeated, additional information needs to be provided to differentiate the second round from the first. Wording needs to be clear and concise and include effective descriptors.

Hardware limitations continued to be evident through the research findings including the erratic feedback of the iPaq 5455 standard four-way navigation button. This controller does not provide accurate cursor navigation, limiting its use by individuals with limited hand dexterity. Because of this shortcoming, all users were forced to use the touch screen for operation. Also noted was the importance of a desirable and portable device. During the first round of testing, 13 of the 20 participants needed the researcher to prompt them to look at the device following the time-out period. When not in immediate use, participants placed the device on a table and moved to another location. Those that did continue to carry the device did not hear the alarm following the long break because a) they were using headphones that they took out of their ears without unplugging from the device; or b) could not hear the alarm due to environmental noise. These observed experiences indicate a further need for exploring *captology* to enhance the desire for a use to rely on the device and to keep it with him/her at all times.

During the debriefing session, participants actively gave suggestions about the device. Of particular interest was the suggestion of adding entertainment characteristics to provide the device with added value, and thus added incentive not to misplace or neglect the device. To further strengthen this suggestion, one participant mentioned, “The more this device has, the less things you would have to carry.” A participant noted that he was already wearing headphones so that when the device was not giving him instructions, he would like to listen to his music.

The design implications based on user experiences and event circumstances from both testing series formed the structure for guidelines on designing MWT for individuals with cognitive impairments. Through the knowledge and understanding that the situations encountered during the design exploration trials reach beyond individuals with cognitive impairments, researchers hope to utilize the findings and proposed solutions to impact the usability and market of mobile wireless technologies. As further research is conducted and technology capabilities expand, these guidelines will grow to include new findings.

Future Directions

Using the guidelines as a starting point, researchers aim to work with industry on methods for integrating the needs of individuals with cognitive impairments into their design processes. By continuing to focus on the user and stakeholder needs, on the environment(s) of use, on interface research, and on emerging technology, information relayed to industry remains current. Additional explorations aim to add to the set of disseminated information. These include: methods for making a mobile device a “friend” for an individual, methods for giving users confidence in a device’s abilities, methods for creating a communication network between devices, users, caregivers, and their supporting data structures, and methods for evaluating individual’s needs and prescribing appropriate devices. It is the hope that by relaying the voice of the consumer to industry user satisfaction with mobile wireless products and services will increase.

Acknowledgments

The researchers would like to extend a special thank you to the members of the Side by Side Clubhouse. This is a publication of the Rehabilitation Engineering Research Center on Mobile Wireless Technologies for Persons with Disabilities, which is funded by the National Institute on Disability and Rehabilitation Research of the U.S. Department of Education under grant number H133E010804. The opinions contained in this publication are those of the grantee and do not necessarily reflect those of the U.S. Department of Education.

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