Mobile Wireless Technology: Research and Design of Interfaces for Individuals with Cognitive Impairments.

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As technology devices become more powerful and portable, they are able to combine with wireless networks to support a myriad of applications with on-the-go support. These digital applications aim to replace analog methods and enhance the capabilities and efficiency of their user. Using mobile wireless technology as a platform, a compensatory aid is being developed to support community re-entry for persons with cognitive impairments resulting from acquired brain injuries (ABI). A human-centered design approach is combined with research in other disciplines, including computer science and rehabilitation engineering to help resolve the central concern of designing a user interface that is both understood and operable by individuals with significant cognitive impairments.

Components of the human-device interaction, including the optimal input and output modalities, appropriate prompt wording and levels, and optimal device storage are explored with the goal of developing a set of guidelines for designing interfaces for persons with cognitive impairments. It is expected that much of what is learned through this project will also be beneficial in enhancing the usability of mobile wireless technologies for users without disabilities.

Through observational research, focus groups, and structured interviews, a fundamental difference between using a mobile wireless device as a cognitive aid or prosthesis and using it as a Personal Information Manager (PIM) has become apparent. For the most part, with a PIM, the user accesses the device when he/she wants to use it or feels the need for it. With a cognitive prosthesis, the device must “call” the user and remind him/her to use it. This distinction establishes the need to evaluate the human-device interface on an individual basis to ensure that the addition of technology provides an advantage over traditional compensatory methods.

Based on research findings, the hardware and software of a mobile handheld has been customized to create a device to examine the optimal human-device interface for a cognitive prosthesis. The altered handheld is designed for use as an evaluation device in a series of exercises conducted in real-life situations including both visually crowded and physically crowded environments where the effects of noise, glare, weather, and other factors can be assessed. The project aims to bring awareness to the needs of individuals with cognitive impairments, as well as introduce the basis for developing interfaces for individuals with cognitive impairments. Obstacles encountered during the research are discussed, including how to navigate a field of technology that is constantly changing and how to understand the user needs of a population whose characteristics vary widely. The synthesis of information from other fields is presented along with how design influences and broadens the understanding of individuals working toward the same goals in other disciplines.

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Introduction

Using mobile wireless technology as a platform, a compensatory aid is being developed to support community re-entry for persons with cognitive impairments resulting from acquired brain injuries (ABI). A human-centered design approach is combined with research in other disciplines including computer science and rehabilitation engineering to help resolve the central concern: the design of a user interface that is both understandable and operable by individuals with significant cognitive impairments. It is expected that much of what is learned through this project will also be beneficial in enhancing usability of mobile wireless technologies for users without disabilities.

Background

Acquired Brain Injuries

Acquired brain injuries (ABI) result in functional and psychosocial changes where cognitive impairments are the most common and perhaps the most debilitating result. ABI is defined as an injury to the brain that occurred after birth and is inclusive of traumatic brain injuries (TBI), those that are caused by external forces including vehicular accidents, falls, and violence (National Institutes of Health, 1998). ABI also accounts for injuries resulting from anoxia, aneurysms, brain infections, and stroke. All brain injuries and therefore, cognitive impairments, are unique and vary depending on the type, strength, and location of the affecting force (*Types of Brain Injury*, 2004).

The most prevalent cognitive consequences resulting from ABI include memory impairments and organization deficits, as well as attention, concentration, initiation, and task completion difficulties. In addition to cognitive changes, emotional or behavioral problems often result from ABI. These changes stem from an individual's impaired ability to sense and perceive his or her surrounding environment and react appropriately (Page, 1998). Improper reactions are further enhanced by impulsivity and egocentricity (*Brain Injury*, 2001).

Initiated actions and reactions are based on past experience and cognition as well as the current sensation and interpretation of surroundings (Bellenir, 1997). While cognitive impairments are seen as a primary consequence of brain injuries, impaired sensation and perception dramatically impact an individual's ability to perform the complex physical and intellectual activities of daily life. Precise injury types and outcomes remain unique per the individual with secondary conditions broadly defined by their relationship to the sensory receptors and processors.

Commonalities exist in the affects to vision, movement, audition, and language abilities post ABI. Specific vision difficulties following a brain injury may include the following: blurred vision, light sensitivity, double vision, and aching eyes (Cohen, 2000). In addition, individuals may find diminished abilities with eye tracking, saccadic movement, accommodation or focusing, and binocular vision.

In more severe cases, an individual may ignore one side of their body and fail to "see" anything on that side. Through therapy and treatment, this condition can improve and shift to more of a "neglect" or "inattention" to one side of the body. At this state, an individual may only notice something on their neglected side if it is explicitly indicated.

Individuals may be clumsy on one side and because of the lack of perception may bump into walls, people, or other objects in the environment (Gronwall, Wrightson, & Waddell, 1998). In addition, motor functions or accuracy, fine dexterity, performance speed, strength, and balance can be impaired following a brain injury (Fraser & Clemmons, 2000). These sequelae may solely result from the brain injury, or in trauma incidents, may be effects from wounds sustained in the initial accident. Both the cognitive and sensory-perception consequences of ABI lead individuals to need the support of others to perform daily living activities. The dependence on a caregiver can result in a loss of privacy and a sense of frustration from involved parties (Mihailidis, 2001). Through the use of compensation methods, individuals are able to re-gain some independence, relieve caregiver burden, and move toward self-sufficiency (M. M. Bergman, 1991).

Cognitive disabilities that result from acquired brain injuries can be mediated by training the individual to use compensation methods through cognitive rehabilitation. The severity of the cognitive consequences as defined by an individual's physiological state, perceptual abilities, emotional state, motivation level, and social support are key factors to the acceptance of assistance techniques (Parentâe & Herrmann, 1996). Accordingly, cognitive rehabilitation has the largest impact with a multifaceted approach where each of these factors is addressed.

It is through social support, including the environment and supportive devices, where design has the greatest impact. External aids are the primary method of compensation for individuals with memory impairments (Parentâe & Herrmann, 1996). Traditionally, these methods fall under two categories: electronic and non-electronic devices, where the functions included in the former evolved from the latter. As these technology devices become more powerful and portable, they are able to combine with wireless networks to help support a myriad of applications with on-the-go support.

User Needs Assessment

In September 2002 two focus group meetings were held with individuals with acquired brain injuries, their caregivers, and clinicians to help establish an explicit list of user needs. Held at 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, the conversations focused around difficulties currently faced by individuals with acquired brain injuries. In addition the techniques currently used to help compensate for injuries, and the pros and cons to current electronic compensatory devices were discussed.

Beyond the cognitive difficulties outlined through literature reviews, one of the major difficulties mentioned during the meetings was time management. Potential users voiced concerns over the usability, functionality, and appearance of the device. If a device does not fit into an individual's lifestyle, it will not be used consistently. Focus group participants also mentioned the need for the devices to be durable and be carried in a manner that helps prevent loss.

Combining information from literature reviews, observational research, focus groups, and structured interviews, the need emerged for a mobile electronic device to assist in the support of individuals returning to the community following an acquired brain injury. Based on the analysis of user characteristics, this device, or cognitive prosthesis, must "call" the user and remind him/her to use it. Here, traditional personal information mangers (PIM) or personal digital assistants (PDAs) fall short. For the most part with a PIM or PDA, the user accesses the device when he/she wants to use it or feels the need for it. The ideals that guide design for individuals without disabilities are insufficient to address the needs of individuals with a brain injury (M. M. Bergman, 1991). To ensure that the addition of mobile technology provides an advantage over the traditional analog compensatory methods, it is necessary to evaluative the human-device interface on an individual basis.

Existing Electronic Compensatory Aids

As handheld organizers came to market, they were modified for use as compensatory aids. Of note are the 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 each of these devices has strengths, each targets a narrow niche of the population and fails to recognize the capabilities of technology to, while using a common application, reach a wider audience.

Customization of the prompts and prompt wording is permitted on existing compensatory aids; however, some only permit the prompting of simple tasks and others clutter the screen with excess information. Current devices are limited in the techniques used to transition the user from heavy reliance on caregiver support to active community member. Each only utilizes one method of input, limiting their application to a specific task set and not allowing self-evaluation and selection of a preferred method.

The ability to use different methods to perceive information allows technology to match preferences for visual, audio, or textual experiences (Fogg, 2003). It is also through the combination of these effects that the optimum impact can be made. Individuals are influenced, not only by the information itself, but the method or modality by which it is presented. In further refining the definition for a mobile cognitive prosthesis, it is important to incorporate this understanding and include the ability to enter, receive, and interpret information in the interface definition.

Assessment Device Design

The design for a small screen on a handheld device brings challenges. There are two conflicting design goals (E. Bergman, ed., 2000); fast access to all functions and the need for no clutter. Programmable screen space is minimal and a strong balance between enforcing consistency and maximizing predictability is needed. Guidelines for interfaces, and the use of telecommunications products by individuals with cognitive impairments, are established; however, they fail to expand on the preferred methods of interaction for hand-held products.

The guidelines stem from research in rehabilitation engineering and computer science and emphasize the use of redundant, user-controlled interaction modalities (Francik, 1999). Also stressed is content organization; however, the guides do not outline explicit items or techniques effective in improving the level of independence and quality of life for device users. The guidelines are taken into account during the development process and combined with knowledge of product design and human-factors as well as innovations in the field of human-computer interaction to establish device organization and layouts.

In *Persuasive Technology* (Fogg, 2003), B.J. Fogg discusses *captology*, the study of computers as persuasive technology where persuasion is defined as an attempt to change attitudes and/or behaviors. Fogg states that *captology* investigates how people are motivated or persuaded when interacting with computing products. *Captology* is applied to defining the interface for a cognitive prosthesis by exploring methods for proactively motivating and influencing its user to accept and rely on a computing device for support. The device needs to be developed so that there is a positive dependence between the user and device. Key aspects to this relationship include appropriate prompt wordings and levels and optimal device storage. Additionally optimal input and output modalities are vital to its utility. Through exploring these areas, it is the goal to arrive at a set of guidelines for designing interfaces for persons with cognitive impairments and to create an assessment tool for prescribing cognitive prostheses.

To evaluate the preferred input and output modalities for navigation, information, alerts, and reminders for an individual with an ABI, the hardware and software of a mobile wireless handheld were customized for use in a series of structured exercises. Each interaction modality is linked to the same underlying structure allowing participants to select their own options while maintaining continuity within the evaluation. The exercises are to be conducted in real-life situations including both visually crowded and physically crowded environments where the effects of noise, glare, weather, and other factors can be assessed. The user is expected to keep track of the device throughout the half-day exercise by using their own carrying method or choosing one of the provided options.

The full assessment includes an initial briefing with the participant and his/her caregiver, device training sessions including a sample task exercise, three task exercises, a time-out period, a reminder request, and a debriefing. During the initial briefing and the subsequent training sessions, the user is informed that they are participating in an activity where they are to interact with the researcher (acting as a "caregiver") and the device. The user will be asked to accomplish all tasks while interfacing only with the device. In trying to strike a balance between gathering objective data and maintaining a comfortable setting, the subjects should not feel that they cannot talk to the "caregiver." However, they should avoid discussing the test or asking for help unless they feel the device can no longer help them. In addition to researcher observations during the assessment, the device is programmed to record all user interactions including buttons pushed and time intervals.

Based on the initial assessment protocol and prior to completing the device programming, a paper prototype was developed and tested by individuals without cognitive impairments. These trials lead to the modification of tasks and the resolution of logic flaws. Through the preliminary walk-throughs, certain prompts were determined inappropriate for the selected environment. In addition, early feedback was sought from clinicians who helped validate the scenarios and modify both the wording used in the device and the wording used within initial conversations. This feedback process helped ensure comprehension of the device by users.

The PocketPC platform was chosen for the device based on 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. A weakness of this model, accepted as part of the goal to incorporate all modalities into one device, is a four-way navigation controller that requires more dexterity than desired. The other navigation input options outlined in the protocol include touch and voice control. The implementation of voice recognition technology is beyond the current capabilities of the chosen mobile platform. While it is understood that this is a viable interface option for a cognitive prosthesis, for first-round device testing, voice navigation has been eliminated. However, voice input is available for reminders by using voice recording and playback technology.

The reminder section is conceptually separated from the task exercises and is designed to be accessible throughout the series of three exercises of increasing difficulty. It is capable of holding three entries and the user is able to set alerts for each. 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 was a) able to remember the request on their own and give 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.

The user can select any combination of the following alert outputs: flashing light (visual), volume adjustable sound (auditory), and/or vibration (tactile). For the output of information, text always appears on the screen; however, the user can select to have the text read aloud through the built-in speaker or optional headphones. If the user is unclear of the exact meaning of the prompt, they are able to navigate to a corresponding help menu. If they are still confused by the task, they are guided through a series of hints ending with the ability to request help from the “caregiver”. If the user fails to access the "caregiver" when necessary it is an indication that the individual may have difficulties if out alone in the community, and further evaluation is necessary.

Future Directions

Programming of the assessment device is nearing completion, and testing is to commence with a trial of twenty subjects. Both the quantitative and qualitative results will be analyzed for translation into mobile cognitive prosthesis guidelines for dissemination and implementation. In addition, it is the goal to distribute the results to both mobile device designers and manufacturers to impact the usability of mobile technologies for users without disabilities and broaden accessibility by those with functional impairments. As technology continues to evolve, aspects of the original protocol, previously constrained by limits of technology, will be revisited in hopes of implementing them during the next phase of research. With the implementation of knowledge from the first-round interface modality investigations coupled with new technology, applications for mobile wireless technology to be explored include: methods for making a mobile device a "friend" for an individual, methods for giving users confidence in a device's abilities, and methods for creating a communication network between devices, users, caregivers, and their supporting data structures.

Summary

As the technology and design of handheld electronic devices evolve, it is important to examine their accessibility for individuals with disabilities. Using a multi-faceted approach, the needs of individuals with acquired brain injuries are defined for application to these mobile products and to the development of cognitive prostheses. Through the evaluation of the input and output modalities as well as prompt wording, prompt levels, and device storage, a set of guidelines for developing cognitive prosthesis is being established. By developing these guidelines to increase the usability of handheld devices for individuals with cognitive impairments, it is expected that products will become more accessible for individuals without disabilities.

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