INTERFACE DESIGN AS A PROSTHESIS FOR AN INDIVIDUAL WITH A BRAIN INJURY

ELLIOT COLE
PARTO DEHDASHTI

ABSTRACT

This is a case study demonstrating how interface design was applied to make personal productivity software accessible and appropriate for an individual with learning disabilities from a head injury. Substantial customization was required, and nine months of data are presented.

INTRODUCTION

Traumatic brain injury (TBI) leaves many people with permanent cognitive deficits which prevent their return to normal living, even after completing rehabilitation therapies (cf. Wilson and Moffet, 1984; Glisky and Schacter, 1989). The deficits leave them dependent on caregivers for help in daily activities which they performed independently before their brain injury. Personal productivity software assists people in performing cognitive tasks, both in home and office settings. The computer-human interaction (CHI) area, by increasing ease of use, has played a major role in the widespread adoption of this type of software.

It was hypothesized that personal productivity software could assist TBI individuals who had acquired cognitive deficits. However, too frequently brain injured individuals' cognitive deficits interfere with their use of standard software interfaces. Consequently, the interface would have to be redesigned for the characteristics of the brain injured individual in order for the personal productivity software to be able to deliver its functionality (Cole *et al*, 1987).

Recently a few investigators from other fields have reported success in the use of highly customized applications for individuals with brain injuries (Henry *et al.*, 1989; Kirsch *et al.*, 1988; Steele *et al.*, 1989). What is notable these applications is that they have generally required relatively few training sessions (between one and two dozen). Glisky and Schacter (1988) have reported success in highly customizing training procedures for individuals with severe memory disorders.

The research reported here describes the use of CHI tools for a patient with permanent brain injury from head trauma. A Self-Sufficiency Model is developed as a means by which CHI design can help individuals with cognitive deficits perform target activities.

USER MODEL FOR HEAD TRAUMA SUBPOPULATION

TBI individuals with cognitive damage have lost the ability to independently perform at least some work and home activities, a behavioral manifestation of the various deficits. Traumatic brain injury results in diffuse damage, i.e. involves a number of brain areas and functions, from a blow to the head, automobile accident, or industrial accident (Brooks, 1984). Individuals with a TBI exhibit one or more of the following: memory deficits; impairments in sustaining attention; impairments in initiating activity;

impairments in structuring an activity; impairments in eye-hand coordination; visual perception distortions; language disorders, including impairments in reading, writing, or comprehension; low stamina; pain experienced with performing ordinary tasks. These cognitive deficits become the cause of learning disabilities.

Cognitive impairments and deficits affect an interface's performance, although there is scant CHI literature on this topic (cf. MacArthur and Shneiderman, 1986). Damage to cognitive functioning creates challenges to CHI designers, because so much of the 'toolkit' is based on normal-range functioning of human cognitive structures and processes. Off-the-shelf designed to be easy to use for the novice and occasional user may, paradoxically, be work in the opposite manner with users who have cognitive deficits.

A number of the deficits which are treated in the CHI literature as physical disabilities are behavioral manifestations of cognitive deficits (cf. Buxton *et al.*, 1986; Jennett, 1984). These impairments and deficits, which effect the individual's performance, have implications for design of appropriate interfaces.

SELF-SUFFICIENCY MODEL

A Self-Sufficiency Model is a means by which CHI design can help individuals with cognitive deficits perform target activities. The model addresses the situation where a TBI individual relies on care-givers for the performance of a task which could be easily done alone before the injury. In the initial state, the individual must have others assist in task performance. This assistance is necessary because damage to the individual's cognitive processing structures impedes the performance of necessary subtasks. In the Self-Sufficient state, the TBI individual performs the task with the assistance of computer technology, which takes over some of the subtasks performed by the care-giver. This approach is particularly significant in situations where the TBI individual views the care-giver as being intrusive in the performance of the task.

The model conceptualizes an activity as consisting of two types of tasks. Essential tasks must be accomplished in real time, when the TBI individual wants to perform a targeted activity. Secondary tasks are associated with the activity, but can be done at some other time. Self-sufficiency is achieved when the TBI individual can perform the activity's essential tasks when the care-giver is not present. Interface design becomes the mechanism by which computer technology provides assistance in performing essential steps in an activity which the TBI individual cannot or chooses not to perform. Failure analysis is applied to identify subtasks which the TBI individual cannot perform self-sufficiently, and therefore needs redesign. The target activities are selected on a basis of what is clinically appropriate for the individual.

METHODOLOGY

The research design is a quasi-experimental field study of a single subject. The single subject case study is frequently used in the study of traumatic brain injury because each individual's combination of deficits are unique (Luria, A. R. *et al.* 1969; Wilson and Moffet 1984). A quasi-experiment was possible because the single Subject of this research had been working with a computer system for two years before the beginning of the research intervention. The Subject used both the first computer, and after its removal, the research intervention computer in her home, i.e., a field setting. Consequently, tasks performed with both computers were applied to activities of daily life in a natural setting, as opposed to experimenter-designated tasks.

The intervention was planned for tasks which were clinically relevant and which were important to the Subject. Home finance was the Subject's priority; successfully managing home finances was symbolic of being a responsible adult.

This project began because the original computing system was not serving the needs of the Subject. Data on the usage of that system consists of work products, hard copy logs of finance transactions, reports of the Subject, reports of the Subject's companion and aide, and videotaped sessions demonstrating use of the hardware and software. Hardware was an Apple IIe with dual floppy drives, tractor-feed printer, a popular basic word processor, and a popular check writing application.

Data on usage of the intervention included videotaped design prototyping sessions, videotaped work sessions, a system monitor, a transaction log, work products, reports by the Subject, reports by the Subject's companion and aide, and the Subject's family members.

The Computing Environment

The intervention system is an IBM PS/2 Model 80 with an 80386 processor, 2Mb RAM, a 44 Mb disk, color VGA monitor, Hewlett-Packard DeskJet printer, modem, specially designed check-mailer, DOS with a multi-tasking environment. The keyboard was modified by software. The computer had a dedicated telephone line and remote access software. The system unit was on 24 hours a day, 7 days a week, and was placed in a closet 30 feet away from the keyboard and monitor. A user-controlled power switch was kept by the keyboard and only controlled the monitor and printer.

Interface Design

Design prototyping sessions with the Subject were videotaped and kept to about a half-hour duration.

The procedure was to assess the interface on single screens, and then on the working system. There were about a dozen sessions each in the preparation of text editor and finance applications.

Interface design features included: considerable transparency, use of three dialog styles, using the right half of the screen, reducing screen complexity, drastically reducing the Subject's view of application functionality, tones for stimulating attention, relocation of function keys to the key pad (via software), selectively manipulating the keyboard's typamatic repeat.

In addition, interface design was used to structure activities which the Subject was unable to do herself, i.e., when she was unable to map her task to appropriate personal productivity tools (See Card, Moran and Newell, 1983). This involved restricting navigation within an application, and on-screen instructions for manual steps in completing the activity.

Design modification continued for some months after an application was installed. We estimate that well over 1,000 changes were made to the software. Performance goals were elimination of pain, reduction of stress, and ease of state-to-state transition. Also, because of the Subject's acquired memory deficit and acquired learning disability, a training goal of learning in one to three half-hour sessions was set; rehabilitation centers frequently allow weeks to months of training to accomplish the same degree of learning.

Characteristics of the Subject

The user who is the subject of this case study is a 54 year old woman with a number of strengths and a number of deficits. She was 4 years post-trauma, and her deficits had remained stable for over two years. She has a moderate to severe memory deficit, which is not global but does interfere with her remembering instructions and events. She is unable to organize tasks which require more than a few steps. She has an arousal deficit, which allows her to lose her focus of attention for the task at hand. She has a visual-spatial deficit, which limits eye-hand coordination. She also has a moderate to severe left-neglect, which impairs attention to and processing of visual information in the left-half of her visual field. Among her strengths are superior language, spelling and calculation skills, color appreciation, and interpersonal skills. She has a graduate education. This Subject was selected in part because there were no further rehabilitation options which promised additional behavioral/functional improvement. She lives at home with significant support from family members and a personal aide. She has excellent speech, excellent social skills, a good sense of humor, and is very good at practical problem solving. When meeting her for the first time one is unaware of her deficits.

RESULTS

Pre-Intervention System

The pre-intervention system had been purchased to assist the Subject in some daily activities. Personal productivity software had been selected for this purpose. Despite training sessions over a two year period, the Subject generally needed a caregiver's help when using either application. The pre-intervention condition involved personal productivity software, a word processor and home finance package. Other findings were:

- Experienced pain after a few minutes of software use (due to left-neglect)
- When using the word processor, she frequently forgot what work she wanted to do because of the demands of the computer and application start up process.
- Was unable to understand and navigate "novice" interface styles, e.g. pull-down menus.
- Was unable to feed or retrieve output from the continuous-form printer
- Was able to erase checkbook entries from the database
- Was unable to organize the check writing task into a sequence of steps
- Became exhausted after 60 ± 15 minutes (3 sessions).
- Sometimes would continue to work for hours while exhausted, struggling unsuccessfully to complete a task
- Lost self-esteem because she was unable to use the hardware and software described to her as easy-to-use.

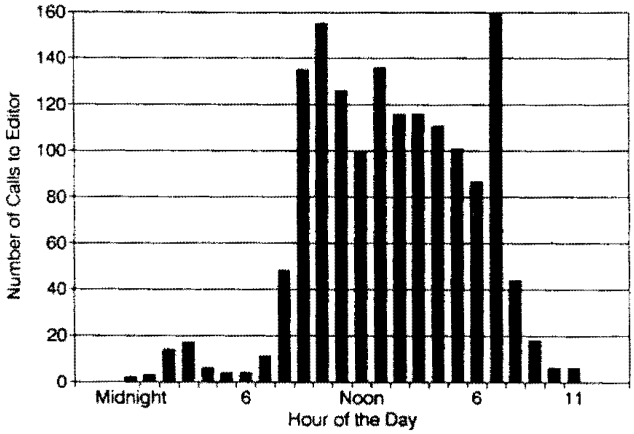
In short, the Subject was dependent on her aide and family to use the personal productivity software which was supposed to give her greater independence. Both the pain and exhaustion are attributable to a mismatch between user characteristics and interface design. We are unaware of other reports of software interfaces causing pain of the type found in use of hardware interfaces. Additionally, the user was rarely able to complete the intended work with the pre-intervention applications. As a consequence, the Subject reported that the software constantly reminded her of her disability.

The Intervention: The Cognitive Prosthesis

Data are presented for a 314-day period for the text editor and 205 days for home finance. The Self-Sufficiency Model is supported for each application when unassisted usage is documented without evidence of failure. Figure 1 shows that the Subject was able to use the text editor at all hours of the day and night. This data from the system log provides evidence that the Subject was using the applications at a time when she was unattended, or family members were asleep.

FIGURE 1

Frequency of Hour of Text Editor Use To Show Self-Sufficiency (N=314 Days)



Further supporting self-sufficient use were work products -- such as printed checks and receipts --, self-reports by the Subject and by the Subject's companion.

During the 205 day period reported here she was able to write 225 checks, of which four were unusable and were voided by the Subject. Additional results are summarized as follows:

- The design goal of learning applications by the end of three 30-minute training sessions was achieved for the text editor and finance applications.
- Self-sufficiency in text editing was achieved. The Subject demonstrated substantial self-sufficient use of the text editor at all hours of day and night. She uses the text editor for a variety of purposes, including writing lists to herself for things to do, purchase, or remember; taking notes during telephone conversations; and writing letters and memos to her family and friends.
- Self Sufficiency in home finance transactions was achieved. The Subject was able to write her own checks, examine account history, make deposits, and record bank card withdrawals.
- Increased self-esteem and a sense of pride in her accomplishments.

There were also results which went beyond the design objectives. The Subject:
1) recognized features of her face for the first time since her accident 4 1/2 years earlier; 2) began to manage her monthly cash flow; 3) had the capability of providing emotional support for her daughter during a difficult period, and 4) the emotional tone in her household changed from one of constant chaos to one which is considerably calmer.

System logs showed patterns which suggested that the Subject had failed to properly perform the bill-paying task. However, work products and reports from the Subject and companion suggest appropriate though unanticipated behavior. The Subject discovered ways to use the software which allowed her to do tasks that had been unintended by the designers and clinicians. Among them were 1) proofreading names, addresses, and account numbers which were in a database used by the finance application, 2) checking bank balances, 3) checking histories of merchant accounts without writing a check. There are other reports of users going beyond the designed functionality of systems (cf. Pyburn and Curley, 1982; Cole and McCain, 1985).

DISCUSSION

This study addresses two broad sets of issues, one related to interface design for individuals with disabilities and the other for interface design generally.

This study found that CHI can, in a unique way, help individuals with cognitive deficits: CHI models and methods were able to help restore a level of daily functioning to a brain injured individual. The individual had failed at using off-the-shelf software packages because of cognitive deficits acquired from her injury. The success of the CHI-based intervention is particularly noteworthy because by the beginning of this study, all of the traditional rehabilitation options had been exhausted. These results were achieved in part because of extensive customization of the interface requiring over 1000 modifications to three applications; modification continued for a period of about 6 months following software delivery. The need for extensive customization is supported by the few studies from other disciplines and other theoretical perspectives (Kirsch *et al.*, 1988; Steele *et al.*, 1989; Glisky and Schacter, 1987).

An additional finding is that CHI designs which are considered to be "user friendly" to the able bodied population may be just the opposite to individuals with learning disabilities. This Subject's characteristics and deficits were the cause of pain and exhaustion from software use.

The two findings taken together again support the notion that the effectiveness of an interface is dependent on the match between user characteristics and interface characteristics. The impact of a mismatch may particularly strong when user characteristics include cognitive deficits. This raises the question of when off-the-shelf software is inappropriate and even harmful for individuals with learning disabilities and cognitive deficits. On the other hand, appropriate interfaces can empower the individual, providing the means of overcoming limitations from a handicap.

Some of the findings have significance for interface design generally. This study provides support for the contention that interface consistency increases the user's ability to learn a software system, to increase the "intuitiveness" of the software. Indeed, one would hypothesize that an individual with cognitive inflexibility coupled with other cognitive deficits would do best when the interface design was consistent.

The results are just the opposite for a Subject whose memory deficit greatly impaired learning retained from one session to the next. Design objectives were to reduce learning time for specified application functionality. Design prototyping sessions with the Subject demonstrated that a combination of two major interface styles were the most effective, exceeding the performance of either alone.

The psychology of human information processing has contributed to understanding of the CHI phenomena and vice versa. Research using subjects with these characteristics may provide a greater understanding of human information processing and of computer human interaction.

Finally, it is evident that there are rich opportunities for CHI contributions which can help increase the capabilities of individuals with learning disabilities and cognitive deficits.

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Elliot Cole's research interests are in user assistance, usability testing, and information systems. Recently he formed Adaptive Computers for Living Inc. to develop paresthetic software for individuals with learning disabilities and cognitive deficits. He is also a research associate at the University of Pennsylvania's Graduate School of Education, where he is principal investigator of the Instructional Decision Support Systems Project. He received his bachelor's degree from Clark University, and Ph.D. in Information Science from Syracuse University.

Parto Dehdashti is a researcher and designer at Adaptive Computers for Living Inc. where she develops systems for individuals with disabilities from brain injury. She is also a Visiting Assistant Professor at Drexel University, where she teaches systems analysis and supervises senior design projects. Her research incorporates mental model for improving interface performance in information systems. She was a member of the 1988 Doctoral Consortium.