A Multi-Functional Computer-Based Cognitive Orthosis For A Traumatic Brain Injured Individual With Cognitive Deficits

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INTRODUCTION

Computers serve as an external aid providing cognitive support for managers and professionals. This paper addresses the problem of providing cognitive support for individuals with enduring cognitive deficits from traumatic brain injury. There has been several decades of work on external cognitive aids (Wilson and Moffat, 1984). Recently, a few investigators have applied computer technology to the problem of external aids for memory and constructional deficits. The term "cognitive orthotic" has been applied to computer-based external aids because of the difference in scale and scope compared to manual external aids. Some have focused on task guidance and cuing in well-structured everyday tasks (Kirsch et al, 1987; Levine et al, 1989) while others have focused on support for scheduling, a relatively unstructured task (Henry et al, 1989). Additionally, Chute et al (1988) have proposed that the constellation of deficits associated with head trauma may require a prosthesis to be multi-functional.

The present research approaches the issue of support for cognitive deficits as a problem in computer human interaction. The interface is the user's access to computer system functionality, i.e., provides input to the application and receives output from the application. The performance of the interface depends on three sets of variables 1) user characteristics, 2) task and situational characteristics, and 3) computer system characteristics.

Our approach to the problem is taken in part because of the importance of cognitive structures and processes to interface design. Cognitive deficits could cause a failure in the interface, reducing the ability of the software to deliver its underlying functionality. It was believed that the failure could be resolved by a good match between user's cognitive capabilities and interface characteristics.

There are several interface performance measures which are appropriate to the evaluation of systems for cognitively impaired users. Among them are: 1) learning time 2) knowledge retained from 1 training session to the next, 3) number of user errors, 4) time to recover from errors, 5) time to complete task, 6) endurance (working time without fatigue or stress), 7) working memory load, and 8) robustness (ability to perform under shifting conditions).

Self Sufficiency

A Self-Sufficiency Model is presented as a means by which interface 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. We have defined self-sufficiency to mean that the individual can effectively perform a targeted task with the support of a computing environment.

This case study demonstrates the application of the model and measures to an individual with enduring cognitive deficits. It also demonstrates the use of a computer-based cognitive orthotic in a field setting, i.e., in the Subject's apartment over a period of 12 months.

METHODOLOGY

This is a system design and development effort which is conceptualized as a single subject case study quasi-experiment. The quasi-experiment was possible because of the Subject's pre-intervention computer and software which was used as an adaptive strategy during the previous two years. This implementation had failed, and is the basis of the pre-intervention evaluation and data. Sources of failure were identified, and a new intervention (computer system) designed to overcome those deficiencies. We chose to view the failure as a failure of the technology design rather than a failure of the individual.

The subject is a 54 year old woman, 4 years post-trauma, a fairly typical traumatic brain injury (TBI) constellation of debilitating cognitive disturbances in: attention and concentration, planning, organizing and sequencing, executive functions, endurance, memory and reasoning. She has an impressive left neglect, with associated scanning defects; she was left dominant prior to her injury. She retained left hemisphere functions including 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.

Data collection included system logs, videotaped design and usage sessions, and interviews with the Subject and the Subject's in-home aide interview.

Pre-Intervention System Performance

The data showed, among other interface usage problems, that the user:

0 Frequently forgot what work she wanted to do because of the demands of the computer and application start up process.
0 Was unable to understand and navigate "user friendly" interface features.
0 Was unable to feed or retrieve output from the printer
0 Experienced pain after a few minutes of software use
0 Became exhausted after 60+15 minutes (3 sessions).
0 Lost self-esteem through reinforcement of individual's limitations.
0 Was frustrated at the inability to effectively use a prescribed computer system.

In short, the Subject was dependent on her aide to use the personal productivity software which was supposed to give her greater independence.

The Intervention

Computer Human Interaction concepts were applied to design the intervention and its target performance measures. The intervention system was designed and implemented using rapid prototyping. The design of individual screens was tested in a number of design sessions. Screen design was evaluated on state to state transition time, level of pain, as well as self reports of confusion by the Subject. Sessions were limited to about half-an-hour. Redesign and modification continued for months after each module was introduced. Some modifications were aimed at improving interface performance, especially reducing energy required. Some modifications allowed the Subject to use application features which had been hidden from her.

Two applications were initially anticipated. The home finances program is a structured task, similar to the task guidance systems (Kirsch et al, 1988; Steele et al, 1989). The text editor is an unstructured activity, yet one which can provide substantial cognitive support (Abbot et al, 1989). Two other applications were added, a time orientation window and a TO DO list.

The computer system consists of an IBM PS/2 Model 80 using a multi-tasking operating system, color monitor, reconfigured keyboard, and Hewlett-Packard DeskJet printer. A special check form was also designed. The system is always on, although the Subject uses a power switch attached to the printer and monitor.

RESULTS

The Self-Sufficiency Model is supported for each application when unassisted usage is documented without evidence of failure. The system data log provides evidence that the Subject was using the applications at a time when she was unattended, or family members were asleep. Further supporting self-sufficient use were work products, self-reports by the Subject and by the Subject's companion. The results are summarized as follows.

0 The design goal of learning applications by the end of 3 30-minute training sessions was achieved for the text editor and finance applications.

0 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.

0 Self Sufficiency in home finances transactions was achieved. The Subject was able to write her own checks, examine account history, make deposits, and record bank card withdrawals.

0 The Subject showed an increased comprehension in time orientation.

0 Has increased her self-esteem, and produced a sense of pride, that were substantially greater than anticipated.

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) the emotional tone in her household changed from one of constant chaos to one which is considerably calmer, and 4) had the capability of providing emotional support for her daughter during a difficult period.

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.

DISCUSSION

This study supports the contention that interface design can serve as a basis for the design of a cognitive orthotic. A reliance on Computer-Human Interface concepts and performance measures allow the clinician to specify clinically desirable objectives and translate them into system performance. Equally important, the framework can be applied to identify applications -- particularly commercially available applications -- which can cause physical and emotional harm. The study found considerable customization was necessary in order to "fit" the prosthesis to the

Methodological differences between this field study and other studies using an experimental approach should be noted. First, the Subject developed additional uses of the prosthetic software which went beyond designers' specifications and intentions. The Subject's behaviors viewed from the system log were initially interpreted as a failure. In fact, the Subject's ability to manipulate the system to serve her needs is highly desirable. Second, some effects emerged rapidly after system use began, while others took many months to emerge. The field design provides the careful research to identify unanticipated outcomes.

The study demonstrates the feasibility to building a prosthesis, and having it become part of a TBI individual's life. Several applications – treated as replications -- were selected because of their clinical appropriateness, and were able to show the same pattern of results. Thus multiple applications from a single system were tested. The subject succeeded at self-sufficiency for targeted activities.

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