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Treatment of Plateaued Traumatic Brain Injury Patients By Using Computer-Based Cognitive Prosthetics: A Field Study.

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Introduction

Traumatic brain injury leaves many patients with cognitive deficits which endure beyond the period when spontaneous recovery can be anticipated. Too often, these deficits continue to block a return to premorbid activities even with intensive rehabilitation and the design of compensatory strategies geared to functional restoration. Computers can be viewed as cognitive machines, and concepts from computer science can be applied to the problem of providing cognitive support for these individuals who have acquired cognitive disabilities. A goal of this research is to determine if it is possible to develop computer software which achieves partial functional restoration in plateaued patients.

Method

This is a single-subject case study, with each subject a replicate, and N=9. Subjects were outpatients, 1½ years or more post injury. Consequently, each subject was able to be his/her own control.

To be eligible, an individual needed to have received rehabilitation which failed to achieve functional restoration for one or more activities. Subjects enduring deficits included memory, orientation to time, visual scanning, attention, concentration, and executive functions, such as initiation, organization, planning, cognitive flexibility and control of impulsivity.

The experimental intervention goal for a subject was an activity which the subject was unable to perform without supervision, and which was a priority for the subject. It was desirable to have a wide range of activities, so that the prosthetic software could be shown to respond to patient's actual needs. It was also necessary to place some limitations on the software for this study. This was achieved by requiring that the target activity could be addressed by a software engine which used a clock, such as for a schedule or To Do List.

Each subject's behaviors were then analyzed to determine which subtasks of the target activity were problematic for the subject. Software functionality and interface features were specified so that the subject would be able to perform the activity without supervision.

Although there was a software system designated as a starting point, the intervention system was designed for each subject based on that subject's need. Performance measures for the software and interface included: 1) minimal training time for the subject to learn how to use the software, 2) no confusion in use of the software to perform the target activity, and 3) self-sufficiency in activity performance.

Subjects participated in software and interface testing and redesign, resulting in more complex designs. Testing involved an analysis of each screen as well as the whole system. Sources of confusion were identified, and modifications agreed upon by therapist, patient, and computer scientist. Subjects were invited to chose the colors for the screens used in their system.

When design issues were resolved, subjects were trained on the final system. This was done in the subject's home, where each computer was installed, along with a dedicated telephone line for a modem.

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Software redesign was ongoing, and was responsive to subjects' requests. Some requests involved resolving design problems which emerged during actual system use. Other redesign was responsive to enhancement requests.

Results

The rehabilitation goal was achieved for seven of the nine subjects (78%). When the intervention goal was achieved, it was achieved within three weeks. Each patient's rehabilitation goal addressed by the prosthetic software involved more than one cognitive dimension.

Subjects required a substantial amount of customization in order to achieve performance criteria. Initially, functionality of the individual applications was starkly limited, and was only added when it was necessary for the subject to successfully perform a subtask.

In general, the prosthetic software could be developed and modified in a time frame appropriate for rehabilitation, which is up to several days. Some modifications could be made and tested in less than an hour.

Subjects were able to participate in the design of their software. Design/redesign sessions were interactive with the subject, computer scientist, and therapist. Subjects appeared to be the best "meter" for fine-tuning the software.

Anomalies were present in the design of many prosthetic software applications of subjects who achieved their goal. Examples include a need for substantial cognitive simplicity in one aspect, but an ability to easily manipulate cognitive complexity in another aspect.

On average, 20% of the computer code was unique for each subject. The average number of lines of code is 8747.

Discussion

There are several aspects of these results which deserve comment and elaboration. First and most important, these results demonstrate that plateaued patients can achieve a significant increase in function using a Computer-Based Cognitive Prosthesis. The 78% of patients achieving the rehab goal are substantial, even in a small-sample study. The conventional wisdom in brain injury rehabilitation is that there will be little rehab progress after the 2-year mark.

Second, intervention success was achieved very rapidly, which suggests that the functional change can be attributed to the intervention rather than spontaneous recovery.

Third, intervention success was achieved on an activity which was a priority for the patient. This attests to the robustness of the fundamental approach. Patients were asked about priority activities, and those selected for the experiment involved some use of the computer's clock. This limitation still left considerable functional range for the rehabilitation goal. Also, functional goals typically involved multiple cognitive deficits, including memory, executive areas, and visual processing.

Fourth customization -- fitting the system to the subject -- was an important factor in achieving these results. Customization was important in delivering the minimum functionality required to perform the target activity, rather than full functionality found in commercial software. Determining needed and unnecessarily functionality often rested on small details of activity performance. This phenomenon is well understood in the information systems literature. Software testing revealed that each subject had difficulty with at least some of the software conventions customarily found in commercial software; customization was necessary to remove the barrier to usability. Typically, subjects requested further customization to resolve problems of confusion. The computer system was installed in each subject's home. Attention was paid to the placement of the hardware.

Fifth, there are substantial advantages to treating the patient in the environment where they will be using the prosthetic system. Indeed, it is difficult to imagine how details of functionality can be determined without evaluating and treating the patient in their actual setting and context.