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Rapid functional improvement and generalization in a young stroke patient  
following computer-based cognitive prosthetic intervention

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### INTRODUCTION

A previously well 33 year old left handed woman experienced several months of repeated episodes of neurologic dysfunction of unknown etiology. Despite frequent and chronic anticoagulation she suffered several venous strokes that left her with damage in the putamena, corona radiata, subcortical white matter, pons and pontomedullary. After her final TIA, a hematologic consultant discovered polycythemia vera, she was treated with hydroxyurea, and since then has had no further strokes.

She was left with a neurobehavioral syndrome manifested by executive dysfunction; poor information retrieval; visually guided constructional difficulties; unilateral neglect with shifting laterality, dominantly left sided; slowed information processing; impaired ability to manipulate several pieces of information simultaneously; impaired visual and verbal memory for new information; impaired language, including reading and word retrieval; impaired arithmetic skills; and bilateral, right more than left, spasticity and dystonia resulting in spastic circumductive gait and spastic contracture in all muscles of her right upper extremity. Areas of strength were the ability to verbalize her thoughts and ideas; insight and the ability to benefit from supportive counseling; strong motivation and tenacity to improve her level of functioning; and broad interests.

The impact of these deficits was profound. Premorbidly, she was a talented and successful artist. After the strokes she was deprived of the dignity of privacy, both physically and mentally. She was reduced to no use of one hand and only limited motion and digit control of the other. She was unable to independently perform many activities of daily living, such as toileting, bathing, dressing, and eating - and had to depend on her parents or a companion for assistance. Written expression was important to her but anyone scanning her notepad could read her thoughts;

writing was also both painful and tedious. She was unable to read more than a few sentences at a sitting, and spend much of her unstructured time watching television. Her rehabilitation history is extensive, and includes in-patient, day hospital, community re-entry, and comprehensive outpatient services of cognitive, physical, occupational, recreational, speech and psychotherapy. At the time of this intervention, no further cognitive rehabilitation was said to be indicated despite substantial cognitive deficits.

### METHOD

This is a single subject case study with a quasi-experimental design. A Computer-Based Cognitive Prosthesis (CBCP) was introduced as an intervention to compensate for deficits preventing her from performing a type of activity which she desired to perform. Her CBCP has targeted two major activities: first, writing; and a month later, graphic design. User requirements were defined and a prototype developed. Human Factors usability testing was applied to identify and resolve design errors. A key performance goal was to use a prosthetic application self-sufficiently on delivery. After delivery, software was modified to resolve new design errors and to provide new features.

### RESULTS

The intervention's goals were met and substantially exceeded.

A number of functional improvements occurred, some in the neurocognitive area and some in the neuromotor area. There were measurable improvements in spelling and grammar within two weeks. Also, within the first few days, perseverance and stamina for reading and working on cognitively demanding tasks markedly improved to the point that the patient was able to sustain effort for 3-5 hours per session.

Unexpected improvements in visual scanning and reading were also observed. Initially she required double spacing for all text. After three months her visual scanning improved so that single spacing was sufficient. In addition, she became able to read 100 book pages in three hours.

In the neuromotor area, there have been marked improvements in hand control which suggest generalization. She is now able to toilet independently at night, and during the day when she wears accessible clothing. She is now able to bathe herself, and to shampoo her hair. She is also able to dress herself, depending on the outfit. She can now hold and eat finger foods such as a sandwich or piece of fruit. Thus, the intervention afforded her a degree of privacy, control, and independence that she had not experience since her illness.

Use of a mouse (for the graphics program) proved a challenge for her, and she spent many hours experimenting with it, learning how to control it. It was also remarkable for her, given the neuropsychological findings, to be able to produce and rotate 2-dimensional design by translating her hand movements through manipulation of the mouse.

Improvements were also seen in the follow-up behavioral neurological examination.

Six months after the intervention began, she enrolled in a college continuing education course.

## **DISCUSSION**

These findings show that this patient's level of functioning has increased during the time she has used her CBCP. Improvements occurred in areas targeted by the intervention, but more significantly, in areas not directly targeted by the intervention. The magnitude and breadth of these changes in this

patient is striking, given the severity of brain damage she suffered, the time elapsed since her strokes, and the prior rehabilitation efforts. These improvements are contemporaneous with the intervention and cannot be easily attributed to other explanations such as spontaneous recovery or lack of rehabilitation.

Improvements in non-targeted behaviors were first reported by the patient two weeks after the intervention was introduced, and have continued. This strongly suggests that her use of the CBCP, which targeted reading and drawing behaviors, produced generalization or a process akin to generalization. An especially striking example of this is the increase in level of function for visual scanning and reading. At the beginning of the intervention, which was designed to improve her writing, double spacing was required for reading the computer screen and printed text. Her reading sessions were laborious and brief. While her writing improved as planned, she also became able to read single-spaced text on the screen, and can read books and magazines for hours with increased accuracy, comprehension, and of course, sustained attention.

In our lab, we have seen a number of other cases where patients, long after a brain injury and who were believed to have limited rehabilitation potential, have experienced increased functioning in areas not directly addressed by their CBCP interventions, in addition to rapid achievement of targeted goals. These results are generated by patients functioning in their natural environment and performing compound and complex tasks. These results have implications for plasticity of the damaged brain.