

EEG biofeedback for traumatic brain injury

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Prevalence and costs

An estimated 5.3 million Americans currently live with disabilities that resulted from traumatic brain injury (TBI). Each year, 1.5 million Americans (2% of the population) sustain a TBI, with a new case added every 21 seconds, which leads to 80,000 new cases of long-term disability and 50,000 deaths. Although the causes of TBI are many, the leading causes are car accidents (44%) and falls (26%), which involve adolescent, young adult, and elderly populations [25]. The costs of TBI in the United States are estimated at \$48.3 billion a year, with hospitalization costs of \$31.7 billion and fatality costs of \$16.6 billion.

Commonly reported cognitive and psychological consequences of TBI include difficulties with orientation/concentration, overload-breakdown of comprehension, reasoning and problem solving, organizational skills, rate of processing, rate of performance, perseveration (a tendency to repeat a response or activity after it has proven ineffective), staying on task/topic, motivation, generalization, agitation, fatigue, stress and memory (possibly the most common residual effect of brain injury and one that families often find very troubling.)

Efficacy research on standard intervention programs for traumatic brain injury The research literature on memory improvement in patients with brain injury generally has found minimal to mixed results for several intervention approaches.

Memory is not improved by simple, repetitive practice [29] or by repetitive recall drills [30]. Specific techniques, such as visualization, method of loci, and cognitive strategies, have shown different degrees of effectiveness. Researchers generally agree that the subject does not continue the use of the strategy after treatment ends [31]. Significant improvements from internal memory aids, such as imagery instructions, are used less than external memory aids, but patients on their own generally use neither.

More recent reviews of the literature report similar mixed to negative conclusions on the efficacy of cognitive rehabilitation therapy for memory and other areas of cognition and behavior [32-34]. In their exhaustive review, Carney et al [32] concluded that "specific forms of cognitive rehabilitation reduce memory failures (notebook training/electronic cueing devices-results didn't hold 6 months post treatment) and anxiety, and improve self-concept and interpersonal relationships for persons with TBI." A recent Defense and Veteran's Head Injury program study did not find any significant improvement on their measures as a result of cognitive rehabilitation (compared with control group) in patients with moderate to severe TBI [34].

In conclusion, no definitive scientific evidence indicates that cognitive rehabilitation leads to sustained improvements in memory.

What is electroencephalographic biofeedback?

Neurotherapy (or EEG biofeedback) is the operant conditioning of the EEG. Electrodes are placed on the scalp of a subject, and the electrical information is sent to a recording unit. The unit uses a software interface to present the status of selected EEG variables to the subject in visual or auditory modality. When the subject's EEG signal meets the desired goal, the subject is presented with a reward in the form of selected sounds and displays. When the subject's EEG signal produces a value that is not desired, a different sound or visual image is presented to the subject to inhibit that particular signal. Because the brain is an adaptive organ, it attempts to satisfy the demands made on it by the software and changes its activity to meet these requests. The exact mechanism is unknown.

Efficacy of electroencephalographic biofeedback with TBI

Frequency interventions:

In a single case study, Byers [59] found that with 31 sessions of EEG biofeedback a patient who had mild TBI improved cognitive flexibility and executive function. Hoffman et al [60] used EEG biofeedback techniques on 14 patients with TBI and reported that approximately 60% of the patients with mild TBI showed improvement in self-reported symptoms or cognitive performance after 40 sessions. The degree of improvement noted ranged from 23% to 62%.

The authors also noted significant normalization of the EEG in subjects who showed clinical improvement. There were no controls in this study. A subsequent open trial case series with 14 patients showed significant improvement after five to ten sessions in self-report symptom checklists [61,62].

Keller [63] demonstrated with a group of 12 patients with TBI that ten sessions of EEG biofeedback improved attentional abilities (in 8 patients) and was superior to ten 30-minute sessions using two standard software computerized attention training programs [64,65].

Walker et al [66] studied 26 patients with MTBI within 3 to 70 days of injury. EEG biofeedback treatment protocols applied until the patient reported significant improvement or until 40 sessions were completed. Significant and substantial improvements on a global improvement self-rating scale were reported by 88% of the patients. All patients were able to return to work.

In summary, EEG biofeedback interventions have proved to be useful in remediating cognitive difficulties in patients with TBI.

Clinical case examples:

Neurotherapy for the patient with traumatic brain injury.

Case 1 involves that of a 37-year-old woman (with a PhD) who experienced a mild TBI during an auto accident. She was particularly concerned that she recover her auditory memory ability to return to work as a psychotherapist. The subject was involved in neurofeedback on a weekly basis for more than a year. Improvements in cognitive functioning at 13 months after initial testing were as follows: verbal IQ score improved from 101 to 123, Wechsler Logical Memory improvements (35% to 84% overall ranking); raw score increases showed a 54% improvement. She also increased total memory score from 47 to 61, while the rest of the measures changed in a positive direction.

Case 2 involved a female patient with mild TBI. She entered neurofeedback 3 years after the accident. The subject's neurofeedback treatment notes showed 2 SD in improvements. Her auditory memory score improved 110%.

Case 3 involved a 69-year-old woman who was hit by a car at a shopping mall and remained unconscious for 3 months. An MRI evaluation revealed a left frontal hematoma. Neurofeedback began 24 months after the accident. Her auditory memory improved from 10 to 34 (340%) pieces of information. The case is of particular importance because it involved structural damage to the brain in an elderly patient, factors that would intuitively be thought to be negative treatment indicators.

Summary

Our society has spent billions of dollars on efforts to remediate the cognitive and behavioral dysfunction in individuals with TBI through various cognitive-based strategies. The evidence accumulated to date indicates that few of these intervention efforts demonstrate efficacy. Research completed to date and clinical reports show greater improvements with EEG biofeedback.

More work has been reported on the assessment of the efficacy of neurofeedback for TBI. The results of these studies indicate that neurofeedback shows significant promise. Clinical work using neurofeedback with patients with TBI has been consistent with the indications of efficacy found in the research. Given the significance of the problems and the absence of proven alternatives for remediating the cognitive and behavioral effects of TBI, efforts to complete the needed research for clinical use are warranted.