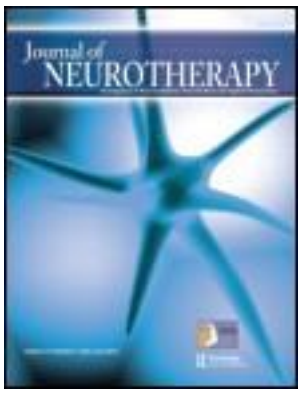

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THE RIGHT TO WRITE: EEG NEUROFEEDBACK TRAINING IN FRONTAL LOBE AGRAPHIA—A CASE REPORT

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Frontal lobe agraphia is a rare condition. Rehabilitation for frontal lobe agraphia is not well documented. The primary objective of this study was to examine the effectiveness of an electroencephalogram neurofeedback training (NFT) intervention in improving cognitive functions and resolving frontal lobe agraphia following a traumatic brain injury. A single-case research design was used. Cognitive deficits and symptom severity were recorded at baseline. Alpha-theta enhancement training was conducted at the O1 and O2 scalp locations. Postintervention assessment indicated improvement in several areas of cognitive functioning and resolution of frontal lobe agraphia. Results indicate that NFT holds promise as a neuropsychological rehabilitation technique in resolving cognitive deficits and frontal lobe agraphia.

INTRODUCTION

In 1865, Louis Victor Marce was the first to hypothesize that there might be an underlying cerebral mechanism for writing. Albert Pitres was the first to provide a detailed description of isolated agraphia (Henderson, 2010). Our understanding of agraphia has evolved since that time. The primary brain structures involved are the Exner's writing area and Broca's area of the left frontal lobe, the Wernicke's area in the left temporal lobe, and the superior and inferior regions of the parietal lobe. The frontal lobe is believed to mediate the expressive aspects of the written word, and the temporo-parietal regions are responsible for writing comprehension. The parietal lobe is also implicated in the conversion of phonemes to graphemes (Joseph, 2000; Maeshima et al., 2003). There have also been reports of agraphia following left thalamic lesions (Maeshima et al., 2012). Frontal lobe agraphia is a subtype of agraphia, characterized by difficulty spelling, perseveration, and cursive writing that is generally poorer than printed writing (Joseph, 2000). Frontal agraphia is a rare condition that is not well documented and can be attributed to dysfunction of the frontal lobe (Vernea & Merory, 1975).

Traditionally, rehabilitation of agraphia has involved increasing stimulation of the linguistic and motor procedures required for writing as well as the use of behavioral compensatory mechanisms (Nadeau, Gonzalez Rothi, & Crosson, 2000). More recently, resolution of phonological agraphia has been reported following repetitive transcranial magnetic stimulation involving theta burst stimulation over the left supramarginal gyrus (Nardone et al., 2012). Neurofeedback training (NFT) has been reported in an individual with alexia

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without agraphia resulting from thalamic and cortical infarctions. The protocol involved inhibition of 4–8 Hz theta activity in left hemisphere locations; results indicated clinical improvement in reading (Bearden, Cassisi, & Pineda, 2003). Neurofeedback training has also been associated with significant improvement in cognitive functioning.

DESCRIPTION OF THE PARTICIPANT

The participant was a college-educated 31-year-old male of upper-middle socioeconomic status. He had an alleged history of a road traffic accident 1 year prior to initiation of rehabilitation. The patient had sustained a moderate head injury with a Glascow Coma Scale score of 9. A Computed Tomography scan revealed a bifrontal contusion for which he underwent a bifrontal craniotomy. Primary complaints at the time of referral for rehabilitation included difficulty writing, memory loss, and emotional and behavioral disturbances that manifested as anger outbursts and violent behavior. The patient was high functioning prior to the occurrence of head injury and was employed as a software engineer in a reputable information technology company.

METHOD

A single-case research design was used for the current study. The training protocol was alpha-theta enhancement at the O1 and O2 scalp locations, as described by the International 10–20 System. Baseline measurements included assessment of cognitive deficits and electroencephalogram (EEG) recordings of theta, alpha, lobeta, and beta amplitude averages that were recorded at O1 and O2 scalp locations in the first neurofeedback session. A Visual Analogue Scale of Symptom Severity was also rated by the patient's father. The National Institute of Mental Health and Neurosciences (NIMHANS) Neuropsychology Battery was used to assess cognitive deficits (Shobini, Rao, Subbakrishna, & Gopukumar, 2004). The Finger Tapping Test was used to assess motor speed, and the Animal Names Test was used to assess category fluency. The Verbal N Back Test and Spatial Span tests were administered to assess Verbal and Visuo-spatial Working Memory, respectively. The Tower of London Test was used to assess planning. The Wisconsin Card Sorting Test was used to assess concept formation, set shifting and maintenance of set. The Stroop Test was used to assess response inhibition, and the Token Test assessed verbal comprehension. Rey's Auditory Verbal Learning Test was used to assess verbal learning and memory. The Complex Figure Test assessed visuospatial construction, visual learning, and memory. The Bender Gestalt test comprises nine designs and is used to assess visuospatial construction using the principle of the perceptual tendency to organize things into a whole (Gestalt). Focal signs assessed include Finger Agnosia, Visual Object Agnosia, Tactile Agnosia, Ideational Apraxia, Ideomotor Apraxia, Dressing Apraxia, Construction Apraxia, Body Schema disturbances, Route-finding difficulty, Alexia, Acalculia and Agraphia.

INTERVENTION

The patient was administered 20 sessions of EEG NFT. Two-channel training was used to reinforce alpha and theta frequencies at (occipital) O1 and O2 scalp locations as described by the International 10–20 System. Auto-threshold settings were maintained throughout the sessions.

RESULTS AND DISCUSSION

Baseline assessment of cognitive deficits on the NIMHANS Neuropsychology Battery indicated deficits in mental speed, sustained attention, category fluency, verbal working memory, concept formation, set-shifting, response inhibition, verbal comprehension on complex instructions, verbal learning and memory, and visual memory (15th percentile was taken as the cutoff for determining cognitive deficits on these tests). All parietal focal signs assessed, except for frontal Agraphia (Figure 1), were absent. The written sample, as characteristic of frontal lobe

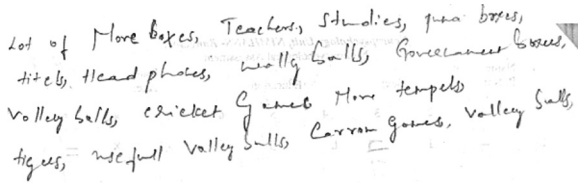

FIGURE 1. A sample of the patient's writing at baseline with evidence of frontal lobe agraphia.

agraphia, is riddled with perseveration and spelling errors. Adequate cognitive functions at baseline included motor speed, visuo-spatial working memory, and planning. On the Visual Analogue scale, the patient's father reported anger outbursts, aggressive behaviour, and memory deficits.

Postintervention assessment indicated deficits in mental speed, category fluency, and verbal working memory. At postintervention assessment, normalization was defined as a shift of percentile from the deficit range to the normal range, improvement was defined as shift of percentile to a higher level by one quartile or more, and decline was defined as a shift of percentile to a lower level by one quartile or more.

Results indicate improvement in the following cognitive functions: motor speed, sustained attention, working memory, concept formation, set-shifting, response inhibition, verbal and visual retention, and visuospatial construction. Agraphia was found to be resolved (Figure 2).

Attention has been known to be affected in traumatic brain injury (TBI) even in the absence of other cognitive deficits (Toyokura, Nishimura, Akutsu, & Watanabe, 2012). However, the patient demonstrated improvement in sustained attention following NFT. Working

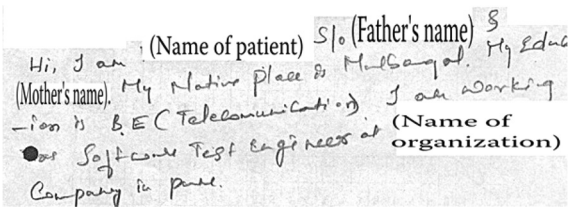

FIGURE 2. A sample of the patient's writing following EEG neurofeedback training with evidence that frontal lobe agraphia has resolved.

memory is another important facet of higher executive function. Deficits in working memory, often seen in individuals in TBI (McDowell, Whyte, & D'Esposito, 1997), greatly affect day-to-day living. Improvement was observed on working memory as well, which may have significant bearing on the patient's future. The Wisconsin Card Sorting test is used to assess one's ability to form concepts and shift them when required, as stipulated by a changing environment. Research indicates that impaired performance on the Wisconsin Card Sorting test is associated with dorso-lateral prefrontal cortex impairment. Post-NFT assessment indicates that the patient has significantly improved in the ability to form concepts as well as the ability to shift sets where required (Table 1). Response inhibition refers to one's ability to suppress a habitual response in favor of an unusual one,

TABLE 1. Comparison of Cognitive Functions from Baseline to Post Neurofeedback Training

Neuropsychological Test	Pre NFT	Post NFT	Difference
Finger Tapping Right	40	75	35
Finger Tapping Left	15	70	55
Digit Symbol Substitution	3	3	0
Digit Vigilance Test- Errors	3	100	97
Animal Names Test	5	5	0
Verbal N Bank - 2 back hits	5	50	45
Verbal N Bank - 2 back errors	3	3	0
Spatial Span	30	95	65
Tower of London- Total No. of problems solved in min. Moves	70	90	20
Wisconsin Card Sorting Test-Perseveration	3	59	56
Wisconsin Card Sorting Test-No. of categories completed	5	95	90
Stroop Test	3	73	70
Token Test	5	25	20
Auditory Verbal Learning test-Encoding	5	25	20
Auditory Verbal Learning test-Immediate Recall	5	15	10
Auditory Verbal Learning test-Delayed Recall	5	40	35
Auditory Verbal Learning test-Recognition	5	25	20
Complex Figure Test-Construction	15	95	80
Complex Figure Test-Immediate Recall	5	15	10
Complex Figure Test-Delayed Recall	5	30	25

Note. Table 1 represents the results of the cognitive function tests (in percentiles) prior to and following training. The shaded rows indicate a difference greater than or equal to 25 percentile.

depending on the changing needs of the environment. Response inhibition was assessed using the Stroop Colour Word Test. Lesion studies implicate bilateral superior medial prefrontal damage in impaired performance on the Stroop Test. Results indicate significant improvement in response inhibition post training.

Verbal learning refers to recent memory, learning capacity, and efficiency in retaining newly learned information. Verbal memory includes both immediate retention and retrieval of long-held information, also known as remote memory. Individuals with left temporal lesions perform significantly worse on verbal memory tasks than those with right temporal lesions. Assessment of visual memory generally requires a visuomotor response, and the Complex Figure Test assesses both immediate and delayed recall. Patients who have right hemispheric damage tend to lose several details of the figure and tend to perform poorly on this task. The patient has shown improvement on both verbal and visual delayed recall. Visuospatial construction, too, was found to be improved on the Complex Figure Test.

Moreover, frontal lobe agraphia appears to have resolved. In the written sample taken prior to NFT, it was found that the writing was riddled with spelling errors (e.g., the word ''titles'' was spelled ''titels'') and perseveration (e.g., the words ''volley balls'' appearing four times; see Figure 1). However, in the written sample taken post-NFT, the language is coherent, free from spelling errors and perseveration.

CONCLUSION

EEG neurofeedback intervention appears to be an effective treatment procedure for rehabilitation of cognitive deficits in TBI. Incidentally, frontal lobe agraphia was found to resolve following NFT.

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