

Neurofeedback & Memory Functioning: Rehabilitation & Enhancement

Menezes, R¹, Kacker, P^{2*}, Mukundan, C. R³

ABSTRACT

Memory is an important element of cognition and plays a crucial role in the daily routine of an individual. Impairment in memory may occur due to aging or due to neurological disorders such as stroke, dementia, traumatic brain injury and so on. Neurofeedback training is a technological advancement in the field of neuropsychological rehabilitation. It is a non-invasive technique that aims at resolving issues in the neural networks of the brain instead of repressing them. It is based on the concept of training one's brain to control the different brain waves and involves strengthening as well as suppression of certain frequencies of brain waves. Neurofeedback training has found a major application in remediation of cognitive deficits as well as enhancement of memory functions. This aim of this paper is to briefly review the potential and the duality of the therapeutic role played by neurofeedback training in remediation of memory deficits and enhancement of memory in normal individuals of any age group. It is an approach that needs serious consideration and wide acceptance in the field of neuropsychological rehabilitation as well as in enhancement of memory.

Keywords: *Neurofeedback, Memory, Neuropsychological Rehabilitation, Enhancement*

Neurofeedback training (NFT) has been termed as an exceptional magical instrument by some researchers. It is a process that is based on the operant conditioning methods and initiates an attempt to revamp or alter the amplitude and frequency along with the coherence of waves in the brain. NFT employs real time computer display to supervise and obtain information about the physiological functioning of an individual and facilitates the subject to develop the skill of controlling his or her brain waves purposefully. The basic procedure includes digital recording of brain waves using Electroencephalography (EEG). Usually the International 10-20 Electrode system is used. This system has letters assigned to different

¹ Institute of Behavioural Science, Gujarat Forensic Sciences University, Sector-9, Nr. Police Bhavan, Gandhinagar, Gujarat, India

² Assistant Professor, Institute of Behavioural Science, Gujarat Forensic Sciences University, Sector-9, Nr. Police Bhavan, Gandhinagar, Gujarat, India

³ Professor, Institute of Behavioural Science, Gujarat Forensic Sciences University, Sector-9, Nr. Police Bhavan, Gandhinagar, Gujarat, India

[*Responding Author](#)

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positions on the scalp and certain numbers are allocated indicating their location. According to the requirement of the treatment, electrodes are placed at appropriate locations on the scalp and training relevant to the issue is provided. The electrodes measure the electrical activity in the brain areas and with the help of a computer, the same information is provided to the patient. The amplitude of the brain waves is measured in microvolts (mV). The number of cycles of waves per second, termed as the frequency of the wave is used identify the wave and measured in Hertz (Hz). The brain waves in human-beings are categorized based on their frequencies as follows: a) Delta (1-4 Hz): It is fundamentally associated with sleep. At times, in the context of pathology, delta activity in the brain implies injury in the brain. Abnormal activity of delta waves in the brain has been observed in children suffering from attention deficit hyperactivity disorder (ADHD) or learning disorder. b) Theta (4-8 Hz): Theta waves are closely associated with creativity and spontaneous behaviour. It is also linked to distraction, anxiety, lack of attention, day-dreaming and even depression. c) Alpha (8-12 Hz): Alpha waves have strong association with relaxation and meditation. They are mostly seen in the occipital, parietal and posterior areas of the temporal lobes. The activity of alpha waves is high when the eyes are closed and significantly reduces with open eyes. d) Beta (13-21 Hz): Beta waves are usually associated with anxiety, depression or the use of sedatives. Increase of beta activity in the frontal cortex of the left hemisphere is indicative of depression whereas when beta activity significantly drops down in the right frontal cortex, it indicates anxiety and e) Gamma (26-100 Hz): Gamma waves are closely associated with higher mental activity like problem-solving, perception, consciousness and fear (Rajeswaran, J., Bennett, C. N., Thomas, S., Rajakumari, K, 2013).

For every task that an individual performs, there is a transition in the state of the brain waves. When some dysfunction occurs in the brain, either there is over arousal or reduced responsiveness due to which appropriate response or action is not given. NFB training attempts to resolve this issue and enables the brain to change states accordingly. The neural activity that takes place in the brain is fed back to the participant in some format usually visual. The feedback may be auditory or visual, usually videos or animations which is presented and the threshold value is set which is closely associated with the frequency range of the brain waves. It is non-invasive and independent of any kind of drugs. NFB training has been used effectively in alcohol addiction, traumatic brain injury (TBI), stroke, dementia and ADHD. It is also used for memory enhancement in normal population (Rajeswaran, J., Bennett, C. N., Thomas, S., Rajakumari, K, 2013).

NFB TRAINING AND MEMORY ENHANCEMENT

A strong association has been discovered between memory functioning and the alpha activity in EEG by many researches. Researches and studies have been conducted to improve the functioning of short term memory by designing a protocol for increasing the amplitude of alpha waves. A positive correlation has been found to exist between NFB training for increase in upper alpha waves and enhancement of short term memory. Effectiveness of NFB training has also been proved in enhancing the cognitive and artistic performance of healthy individuals (Egner and Gruzelier, 2003; Gruzelier et al., 2006; Gruzelier, 2009). NFB is

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based on the principle that there exists a correlation between specific bands of EEG frequencies and different dimensions of information processing (Klimesch, 1999; Klimesch, Vogt & Doppelmayr, 2000; Klimesch, Schack, & Sauseng, 2005; Sauseng, & Klimesch, 2008). Theta waves are thought to be associated with working memory processes and episodic memory. Similarly, lower alpha waves are linked with attention and beta waves with motor activity. In 1976, Bauer (1976) studied the effect of Neurofeedback training for fixed alpha frequency band (8.5-12.5 Hz) on short term memory in young individuals. Participants were encouraged to produce alpha waves to the best of their ability. Two tasks namely, a digit span task and a verbal free recall task were administered to evaluate the performance of short term memory. The percentage alpha was found to have increased significantly after four sessions however, there was no improvement found in the digit span and verbal free recall tasks. Vernon (2005) explained that the use of a fixed frequency band could be the reason for this failure. Klimesch (1999) suggested that an individual range of frequency for the alpha waves should have been used. There exists a large difference in range of frequency for the alpha waves, varying from individual to individual and hence, in order to find any changes related to the alpha frequency band, customization of this band is necessary (Klimesch, 1999; Klimesch, et al., 2003). Another factor that contributed to the failure was percentage alpha, the feedback parameter which was measured in terms of time and should have been substituted by alpha power which has direct relation with memory functioning (Klimesch, 1999). NFB training helps individuals to train themselves to increase the amplitude of upper alpha frequency waves across several sessions. Research has demonstrated that NFB training using individual upper alpha frequency band has positive correlation with enhancement in short term memory. Thus, with the help of a suitable protocol and correct administration of NFB sessions, an individual can be trained to increase the amplitude of the alpha waves and possibly short term memory as well. Intense research is required in the area of the effectiveness of NFB training in the enhancement of memory using different NFB protocols designed for a specific condition.

Neurofeedback in Neurorehabilitation: The functioning of the brain remains a mystery that has not been unfolded. Neurorehabilitation (NR) is an attempt to remediate and nurture the cognitive, behavioural and emotional deficits resulting from any kind of brain damage. It plays a critical role in any intervention related to brain dysfunction. NR plays an important role in several brain-related conditions such as Traumatic brain injuries (TBI), tumours, neurodegenerative conditions, psychiatric disorders, etc. Rehabilitation is planned and conducted in a very systematic manner that varies from patient to patient. NR attempt to recover functions that have been lost, pertaining to the brain. Computerized training, cognitive retraining along with EEG NFB training are some of the interventions used for rehabilitation and have proved their effectiveness.

ALCOHOL ADDICTION

Excessive consumption of alcohol is an issue of concern in almost every part of the world. Alcohol addiction can cause grave physical as well as mental health related issues. There are several indicators of alcohol dependence such as tolerance, withdrawal, craving, salience. An

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alcohol addict continues to excessively consume alcohol in spite of being aware of the harmful consequences. It has been found that alcohol causes a damage to the central nervous system. Many researchers have demonstrated that severe damage is caused to the frontal lobes of alcohol dependent individuals. The structural changes that occur within the brain structures such as the hippocampus, cerebellum and the prefrontal cortex become almost irreversible and remain unchanged even on abstinence from alcohol. Alcohol dependent individuals exhibit drastic changes in memory and frontal lobe functioning. This accounts for the disorders related to the working memory, planning, solving complex problems, executive functions, critical decision-making etc. Several researches performed on alcohol-dependent individuals have established the fact that the levels of alpha and theta waves are low in such individuals whereas the amount of beta brain waves is greater in their EEGs. This is the reason they are unable to attain a state of relaxation. Alcohol consumption increases the levels of alpha and theta waves which is the major reason for individuals to indulge in excessive alcohol use. Many studies have been conducted using NFB to train alcohol-dependent individuals to increase the levels of alpha and theta waves; which contributes significantly in the reduction of alcohol consumption and prevention of relapse. Alpha and beta wave training using NFB has proved its effectiveness in the rehabilitation of alcoholics: remediation of cognitive deficits like attention, memory along with prevention of relapse and improvement in the quality of life.

TRAUMATIC BRAIN INJURY

Traumatic Brain Injury (TBI) occurs from an impact to the brain due to the exertion of an external mechanical force; resulting in cognitive deficits, physical and psychosocial impairments along with altered consciousness state which may be of a permanent or temporary status. Patients suffering from TBI exhibit cognitive deficits such as memory, lack of concentration and attention-related problems. Several studies conducted have suggested the occurrence of inability to focus and sustain attention. Commonly observed changes are reduction in speed of performance of tasks including complex mental activity, forgetfulness and low speed of processing information. Higher cognitive and executive functions such as reasoning, problem-solving, decision making, judgement, control of emotions are affected on a large scale. Hence, neuropsychological rehabilitation and retraining plays a very important role for TBI patients.

NFB Training in TBI

NFB training has found to be an effective tool for remediation of cognitive deficits occurring in TBI patients. Hoffmann et al. through his study pointed out that after providing 40 sessions of NFT, about 80% of the patients who suffered from mild posttraumatic head injury exhibited improvements in neuropsychological parameters. Ham and Packard, performed a research to find the effect of NFT sessions on 40 individuals with posttraumatic head injury. Positive results were obtained wherein, 80% improvement in the ability to attain a state of relaxation was achieved and 53% of suppression of the symptoms was observed. Many studies have stated that patients who have been provided with NFT have exhibited excellent improvement in attentional aspects. Using a single case study approach, Reddy et al.

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conducted a research to investigate the effectiveness of NFT in the enhancement of verbal and visual learning along with memory functioning in a TBI patient. At the end of the last session of NFT, the neuropsychological profile of the patient before and after NFT was used for comparison. The patient, a 30 year old male having a mild head injury was provided with NFT sessions for 5 days, a week with 45 minutes each day. A video feedback was employed to increase the frequency level of alpha waves and reduce activity of theta waves. Assessments performed prior to the NFT sessions indicated deficits in verbal learning and functioning of memory. Post sessions of NFT, it was found that there was significant improvement in verbal learning and memory. Many researches and studies conducted in the arena of NFT have proved the effectiveness of NFT in the remediation as well as the enhancement of cognitive impairments in TBI and other disorders. The intensity of TBI results in patients exhibiting various deficits such as cognitive, psychosocial, behavioural, emotional etc. Thus, NFT is an important component of cognitive rehabilitation with a powerful potential and which is crucial for TBI patients.

STROKE

Stroke occurs when there is a sudden obstruction to the flow of blood in the brain resulting in loss of brain functions. Patients who have suffered a stroke and survived it need an effective neurorehabilitation. The cognitive deficits found in stroke patients are attention, executive functions and visuospatial impairment, problem solving and memory. Neurofeedback has been used as an effective tool in stroke rehabilitation. NFT facilitates direct access to the neural networks and their activity enabling restructuring of the cortical functions contributing majorly to the swift recovery of functions in stroke patients. Questions about what effect can neurofeedback have on specific cognitive deficits such as attention, memory which arise due to focal lesions after stroke are unanswered. Further research is required in the field of stroke rehabilitation so that NFT can be used with better planning to strengthen the cognitive deficits.

DEMENTIA - ALZHEIMER DISEASE (AD)

Dementia is a disorder which shows a recognizable pattern of symptoms such as gradual increase in the impairment of cognitive functions like memory, visual perception, executive functioning and language etc. Alzheimer's disease is the most frequently occurring type of dementia. The ratio is such that approximately 70% of the people who suffer from dementia have Alzheimer's disease. Other types of dementia are vascular dementia, frontotemporal dementia, dementia resulting from Parkinson's disease etc. Theta activity increases to a great extent in patients with Alzheimer's disease in comparison to healthy population. Several studies have stated increased delta activity and reduced alpha and beta activity in patients suffering from Alzheimer's disease.

In Alzheimer's disease, modification takes place in the neural networks in the brain that are associated with memory and other cognitive functions, at structural as well as at functional levels. The protocol usually designed for patients suffering from Alzheimer's disease call for an increase in the alpha and beta activity and significant decrement in the delta and theta

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activity. With the help of increment and decrement of a specific brain wave frequency using NFT, it is possible to get a positive outcome and strengthen the cognitive deficit including memory of Alzheimer's disease patients. Research conducted by Becerra et al. has examined the efficacy of neurofeedback on healthy population in the elderly age group with excessive theta activity. Positive results were obtained and significant improvement was observed in various domains of cognition including memory. Similar improvement was found in the control group as well.

Neurofeedback has the potential to impede the decline in memory and other cognitive functions of patients suffering from Alzheimer's disease. Another study done by Angelakis et al. involved augmentation of alpha activity which gave a positive correlation with cognitive performance. The results of this study helped to draw a conclusion that neurofeedback plays an important role in enhancement and improvement of memory.

CONCLUSION

This aim of this paper was to briefly review the potential and the duality of the therapeutic role played by neurofeedback training in remediation of memory deficits and enhancement of memory in normal individuals of any age group. Several researches have evidenced the strong potential of neurofeedback training as an intervention for the rehabilitation of various disorders affecting the cognitive functioning of individuals. It has not only been effective in the field of rehabilitation but also proved its worth in the enhancement of memory to a certain extent. Future research may be done to explore the potential of neurofeedback training to the core so that it can be widely accepted as an intervention to help patients with different cognitive deficits.

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