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EEG Neurofeedback Brain Training for Epilepsy to Reduce Seizures

Jayasankara Reddy[1]*, Sneha C. S.[1]

[1]Department of Psychology, CHRIST (Deemed to be University),
Central Block, Hosur Road, Bengalur - 560 032, India.
*Corresponding author: : jayasankara.reddy@gmail.com

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Abstract

To review papers on epilepsy and the use of neurofeedback therapy to reduce seizures. Papers searched were from Pubmed, Proquest, Science Direct, etc. including the review of relevant journals e.g. Annals of Indian Academy of Neurology, HHS Public Script, Basic and Cinical Neuroscience, Current Opinion in Neurology, International Journal of Neurorehabilitation, Neurofeedback and Neuromodulation Techniques and Applications, Measurement Science Review, Journal of Neurotherapy. Common treatments such as surgery, pharmacotherapy, neurostimulation and diet therapy were used for epilepsy but had some limitations. Neurofeedback therapy was found, among those treatments, to be useful for epilepsy. There were two key points of successful protocol used in neurofeedback therapy: sensorimotorrhythm and slowcortical potential enabling a reduction of seizures.

Keywords: Epilepsy, EEG, Neurofeedback, Sensorimotor rhythm, Slowcorticalpotentials

Introduction

Epilepsy is a neurological condition in which seizures are present. Seizures are understood as abnormal brain activity wherein there is abnormally excessive or synchronous neuronal activity in the brain (Stafstorm & Carmant, 2015) Chronic predisposition to epileptic seizures with secondary consequences related to psychological, social and cognitive consequences are the main features of epilepsy (Ding, Gupta & Arrastia, 2016). By definition, epilepsy means having two unprovoked seizures within 24 hours of the two epileptic episodes (Shin, Jewells, Hadar, Fisher, & Hinn, 2014). Looking at statistical understanding, worldwide 70 million people have epilepsy of which around 12 million people are expected to reside in India. Prevalence has been reported as 3.00 – 11.9 per 1000 of the population,while incidence was 0.2 – 0.6 per 1000 of the population. Looking at gender and socio-economic background, male gender, low economic group and rural background were noted as having higher prevalence. In terms of age-specific occurrence, preponderance towards older age has been reported (Gururaj, Satishchandra, & Amudhan, 2015). All these statistical characteristics imply that there is a greater need to understand the problem, provide psychoeducation and at the same time understand different treatments that are available for epilepsy.

Objectives

a. To review papers on epilepsy and treatments available for epilepsy

b. To review papers on neurofeedback therapy and popular protocols in neurofeedback therapy

c. To review specific neurofeedback protocols and their mechanisms used for epilepsy

Methods

Keywords such as Epilepsy, EEG, Neuro feedback, Sensorimotor rhythm, Slow cortical Potentials etc. were used for the review. Papers on the same subjects were reviewed from Pubmed, Proquest, Science Direct, etc. and included Annals of Indian Academy of Neurology, HHS Public Script, Basic and Cinical Neuroscience, Current Opinion in Neurology, International Journal of Neurorehabilitation, Neurofeedback and Neuromodulation Techniques and Applications, and Measurement Science Review Journal of Neurotherapy, which were used for the review.

Results

Results revealed some treatments available for epilepsy, Neurofeedback therapy – commonly used protocols in neurofeedback therapy and specific protocols in neurofeedback therapy for epilepsy.

Commonly used treatments.

Treatments that are available for epilepsy currently include Pharmacological, surgery, neurostimulation therapy and diet therapy. Regarding pharmacological therapy, currently there are 29 anti-epileptic drugs that are available. Despite such an advancement, about one third of patients suffer from what is known as medically intractable or refractory seizure (Shin et al., 2014). This refers to the inability of complete or acceptable control of seizures with Anti-epileptic Drug Therapy (ADT) (Berg, 2009). Regarding surgery, there are many types of surgeries including focal receptive surgery, anterior corpus callosotomy, multiple Subpial transections and hemispherectomy. Surgery is mostly considered if the origin of seizure is identifiable and suitable for resection. Otherwise, if seizures originate from multiple parts of the brain, it will not be amenable for resection. Another major disadvantage is detection of the epileptogenic location through neuroimaging scans (Shin et al., 2014). However, improvement in radiographic detection has been accomplished through 7T MRI, Diffusion Tensor Imaging (DTI), volumetric analysis, aetrial spin labelling and PET. Hence making it either impossible if the epileptogenic location goes undetected, or gets detected but is too risky in terms of surgery causing damage to adjacent parts of the brain leading to other impairments. However, it has been very useful in temporal lobe epilepsies with reference to anterior temporal lobectomy (Shin et al., 2014). Furthermore, in terms of neurostimulation, there is vagal nerve stimulation, responsive neuros timulator, deep brain stimulation, investigational stimulation, transcranial magnetic stimulation and electroconvulsive therapy (Shin et al., 2014). However, neurostimulation, especially deep brain stimulation, has proved efficacious in treating medically intractable seizures.

Diet therapies include the Ketogenic Diet, Adkins Diet, Modified Adkins Diet and others with a low glycemic index. This form of therapy has also proven to benefit those who are diagnosed with medically intractable epilepsy. The Ketogenic Diet and Adkins Diet have especially proven to be very beneficial (Neal & Cross, 2010). After reviewing current available treatments,there was one further treatment, namely, Neurofeedback therapy, which this paper will focus on.

***Neurofeedback Therapy*.**

Learning the ability to consciously control brain waves is one of the main objectives of neurofeedback. (Marzbani, Marateb, & Mansourian, 2016). Based on desirable or undesirable behavior, positive or negative feedback is also given. It can be given through visual or audio feedback, or a combination of both (Marzbani et al., 2016).

Demonstration of electrophysiological components in Neurofeedback is possible through EEG. These electrophysiological components are separately demonstrated. With these recordings, subjects are able to view the frequency band through bar graphs and in turn become aware or conscious of their brain activity. With the help of this audio or visual feedback of their brain activity they can consciously try to alter their brain waves with training provided by a therapist, hence progressing to an optimum level of performance (Marzbani et al., 2016).

Brain waves and protocols in neurofeedback. Different patterns of electrical activity are present in our brains. These are recognized by fluctuations in their amplitude and frequency (Marzbani et al., 2016). These brain patterns are in wave shapes which are usually sinusoidal and ranging from 0.5 – 100 µVin amplitude. The range is recorded by measuring from one wave peak to another (Teplan, 2002). However, beta brain patterns are different, being irregular and arrhythmic in presentation. Brain waves are usually measured by Hz, which is the number of waves per second, and the term frequency which indicates the same, where it provides information about how fast the wave oscillates (Marzbani et al., 2016). We have understood that there is a continuum of brain waves and their classifications. However, we should also not forget that individual differences will exist in terms of dominance of certain bands of waves i.e. some individuals will have one brain wave which is more dominant than the otherswhile other individuals will have a different brain wave which is more dominant than the other waves (Teplan, 2002). Delta waves range from 1 – 4 Hz and are observed when a person is sleepy. Other characteristics of this wave include sleep, repair, complex problem solving, deep unconsciousness and unawareness. Theta waves range from 4 – 8 Hz and can be observed when a person is almost sleepy. Other characteristics include an optimal meditative state, unconsciousness, deep states, creativity, insight, anxiety and depression. Alpha waves range from 8-12 Hz and are present when a person's body muscles are loose, relaxed and active. Physiological correlates of alpha waves are deep relaxation, meditation, alertness, recall, optimal cognitive performance, etc. The sensorimotor rhythm (SMR) ranges from 13 – 15 Hz and includes characteristics of mental alertness and physical relaxation, when measured over the motor cortex (C3, C4, and Cz). Finally, beta waves range from 12– 32 Hz, whereas gamma waves range from 32 – 100 Hz. Beta waves are associated with tension, thinking, focusing, sustained attention, alertness, excitement, hyper alertness and a nxiety, while gamma waves are associated with learning, problem solving, cognitive processes and mental sharpness (Marzbani et al., 2016). However, there is not broad agreement on the beta band range which mostly starts at 12 – 12.5 Hz and increases up to 25 - 30 or 25 - 35 Hz. This definition of band ranges depends on who is defining it. Database constructors however divide beta into Beta 1 / Low Beta, Beta 2, Beta 3 and High Beta. Hence most people use definitions which are of close approximation. Similarly, there is not broad agreement in the field as to the definitions of each band component. Furthermore, the Fast Fourier Transform enables us to break the complied wave form into component bands.

Based on all of these, there were different treatment protocols such as the Alpha Protocol, Beta Protocol, Alpha/Theta Protocol Delta Protocol, Gamma Protocol, SMR training, Theta Protocol, andlow frequency versus high frequency training. Each of these has specific brain sites on which electrodes should to be placed, enhancement and inhibition of specific frequencies as goals, specific numbers of sessions, and specific outcomes.

Protocols that are useful in treating Epilepsy. Sensorimotor rhythm training has been very useful in treating epilepsy. Research, especially in the United States emphasizes up training at 12-16 Hz. This protocol could be done with or without down training simultaneously with slow rhythms (Tan, Corydon Hammond, Walker, Broelz, & Strehl, 2011). SMR training was first found by Prof Barry Sterman of UCLA School of Medicine (1967). Since then it has been studied and used widely. The authors of the paper "Neurofeedback treatments enabled the EEG-normalization anecdotalseizure control of epilepsy – A Case Study," have reviewed various papers by by Sterman, (1974), Cott et al. (1979), Kalpan (1975), Finley et al. (1975), Lantz & Sterman (1988), and Andrews & Shonfeld (1992) as cited in Sela & Toledano, (2014), all of which showed great efficacy in terms of using SMR training for epilepsy as a treatment protocol (Selaa & Toledano, 2014). The same authors also provided a possible explanation as to why SMR training works. They were of the opinion that SMR emanates from the ventrobasal nuclei of thalamus which was also responsible for conducting afferent somatosensory information. During SMR training, the firing pattern of thalamic nuclei becomes systematic and rhythmic. This, according to the authors Selaa & Toledano (2014),was because of inhibition of the somatosensory information passage. Their reviews also suggested that nonspecific cholinergic and monoaminergicneuromodulation affects excitation in thalamic nuclei, and that SMR training controls this excitation. They also stated that epilepsy is a result of excitation of cortical and/or thalamocortical structures, hence the excitation threshold itself is raised in these areas during SMR training,thus providing a therapeutic effect (Selaa & Toledano, 2014).

In Europe however, Slow Cortical Potentials has been widely used (Strehl, 2009) which reflects the level of excitability underlying the cortex and also lasts several hundred milliseconds. According to the author,negative SCP shifts are observed before and during seizures, and positive shifts are observed once the seizures abate. According to the authors' review, slow cortical potentials protocol is efficacious in treatment of epilepsy (Tan et al., 2011). However, the neural mechanism of slow cortical potentials is very interesting. It is also one of the event related potential. Event related potentials are time locked and cannot occur simultaneously. They have Negative and Positive Shifts. While negative shifts convey excitation of postsynaptic potential, positive shifts convey abatement of negative shifts that decrease in the excitation of cells. Further, it consists of CNV – Contingent Negative Variation which is a prolonged negative potential which consciously helps the subject in perceiving another stimulus which the subject is intending to respond to Strehl, (2009) had put forth that it is like a phasic tuning mechanism helping mostly in the regulation of attention (Strehl, 2009).

Discussion

In view with the objectives of this paper, a number of papers were reviewed on epilepsy, treatment available for epilepsy, popular protocols available in neurofeedback therapy and finally specific neurofeedback protocols available for epilepsy. Based on the review, it is understood that most commonly used treatments for epilepsy are Pharmacological, surgery, neurostimulation therapy and diet therapy (Shin et al., 2014). It is also understood that epilepsy cannot be treated with any single treatment option available, such as surgeries, pharmacology, neurostimulationor diet therapy. All of them have their own limitations: 1) being able to use surgical treatments just for some conditions of epilepsy (Jette, Reid, & Wiebe, 2014); 2) pharmacoresistant epilepsies do not respond to drugs (Galindo-Mendez, Mayor, Velandia-Hurtado, & Calderon-Ospina, 2015); and 3) only certain types of diet therapy have higher efficacy rates (Ye, Li, Jiand, Sun, & Liu, 2015). However, neurofeedback therapy has demonstrated that it is possible to consciously control one's brain waves (Marzbani, Marateb, & Mansourian, 2016). Different treatment protocols that were identified as a part of this review paper under neurofeedback are: Alpha Protocol, Beta Protocol, Alpha/Theta Protocol Delta Protocol, Gamma Protocol, SMR training, The a Protocol, and low frequency versus high frequency training (Marzbani et al., 2016). Specific neurofeedback protocols for epilepsy include sensorimotor rhythm and slow cortical potentials which are indicated as effective treatment protocols for epilepsy (Nagai, 2011). Regarding these two mechanisms for epilepsy, sensorimotor rhythm controls excessive excitation in cortical and/or thalamocortical structures which is addressed in neurofeedback therapy by regulating the rhythm in a systematic manner in the same areas (Selaa & Toledano, 2014). Furthermore, slow cortical potentials help the patient to be consciously aware of positive (abatement of excitation in cells) and negative (excitation of postsynaptic potential) shifts which further acts like phasic tuning for regulation of attention of the patient, which in turn helps the patient to consciously control his/her brain waves. Thus, it will help medical professionals to understand and use slow cortical potential and sensorimotor rhythm as protocols, since the mechanism is explained clearly (Strehl, 2009).

Limitation

This review focuses only on the mechanism of sensorimotor rhythm and slow cortical potential and does not review the efficacy of these two protocols on epilepsy patients. It only mentions mechanisms of using these two protocols for epilepsy.

Conclusion

While statistics show millions of people are affected with epilepsy of whom one third are pharmaco-resistant or have medically retractable epilepsy, non-pharmacological treatments should be widely studied, researched and also practiced. With very efficacious treatments being available through neurofeedback, with specific reference to SMR training and SCP, it should be psychoeducated to patients for its positive benefits and efficacy as pointed out by the reviews of various researchers.

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