EEG Neurofeedback Training Among Adult with Attention Deficit: A Review Article

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Abstract. Neurofeedback is considered a promising therapy for boosting cognitive skills, which 10% of the US medical sector is using as a new training method among patients. Attention is a significant mechanism for learning and is essential for life in general. As the person grows up the level of responsibilities also increases, which needs high concentration in doing normal activities. To succeed in any activity, neurofeedback therapy needs to check brain waves to locate the problem in the brain and train it. This paper aims to review the attention deficit treatment based on neurofeedback using a systematic review method. The results found that the common features are the area of EEG (Frontal, central) in the brain, type of tools and software, time of training and the impact upon the trainer. Neurofeedback showed improvement of brain attention-ability for a longer time as well as reduction in recovery time in case of a disturbance interruption.

1. Introduction

Brain waves are made up of a set of signals divided into five waves, namely delta, theta, alpha, beta, and gamma, which are classified based on frequency [29]. Each wave is linked with specific mental states, with varying values. The classifications of brain waves using electroencephalographic (EEG) separated bands based on frequency found that beta waves are used for focused mental work, attention, and sensory data processing. EEG is a non-invasive neuroimaging technique that has been employed broadly to study many resting states and cognitive processes in the brain [21]. Knowing the elements of the standard EEG is a prerequisite for obtaining expertise in analyzing an abnormal recording and describing the frequency bands and individual waveforms for the waking and sleeping states among adults [23]. Figure 1 shows a typical example of using and utilizing EEG.

In this figure, a standard training (in this figure is a video playing) takes place, using EEG/BCI equipment attached to the head capturing brain signals. Later those captured signals will be processed to figure out patterns. The brain reacts to different stimuli, and the captured brainwaves are usually divided into different frequency rhythms by EEG signals. These band waves are ever-present in different portions of the brain [16]. To capture EEG signals, there is a 10-20 internationally standard placement system [16]. For example, to capture the Emotiv Epoc+ signal, the neuro-sensor headset system is the

most used device. The typical electrodes positions over the scalp are shown in figure 2, and there are 16 electrodes [31]. The sampling rate of the band using Emotiv Epoc+ was 128 Hz, and the EEG data are segmented using one second time interval [16].

Figure 1. An example of EEG usage (source: [16], [48])

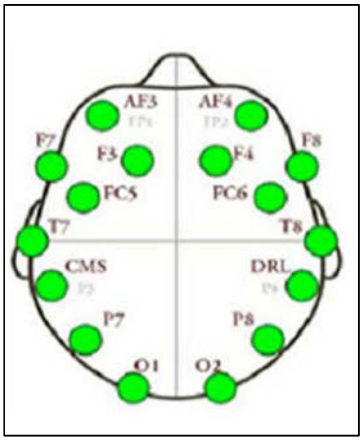

Figure 2. Electrode placement system using Emotiv Epoc+ [16]

2. Attention Study using Neurofeedback

Many approaches and methods have been used to conduct experiments related to attention using EEG. Randomized controlled trials (RCTs) are techniques that employ EEG with those diagnosed with ADHD. The trails involve theta and beta bands training, which target increasing beta band (13–20 Hz) activity while reducing theta band (4–8 Hz) activity. The trails also involve slow cortical potential (SCP) training, which is linked to bidirectional regulation of cortical excitability. Thomas and Vinod [44] investigated the effect of neurofeedback on enhancing the attention and cognitive function of healthy people using games. The researchers experiment took five days, in which they used Neurofeedback-based game played using EEG brain signals related to recognition. They measured the level of attention using entropy values of EEG and compared the cognitive test results. The findings revealed the benefits of utilizing neurofeedback using games in the treatment of attention disorders or improving cognitive skills. Yildirim & Varol [48] used EEG-based games, mainly 'Matching Mind Math' to enhance students' attention. When the student starts the timer, then the average attention is reset, to measure average attention rates. The student maps mathematical equations with relevant answers with a drag and drop button game. The result is then used for further analysis to measure the attention level and its duration. The measurement method used a student's mood to study his/her mediation and attention level.

The frequencies used in detecting and enhancing attention using EEG feature extraction are theta, alpha, and beta frequencies. For instance, Vasiljevic and de Miranda [46] and Thomas and Vinod [45] employed EEG in alpha waves only. They measured the differences in the alpha waves as indicator for increasing in the attention levels. Their findings showed a positive correlation between attention level and game difficulty while some studies focused on in beta waves as in [18, 35, 52]. However; Theta and alpha frequencies get less focused on enhancing attention [17]. Regarding the tools used with EEG, the most used tool is Emotiv Epoc. Another tool, Neurosky/MindWave, is cheaper and easy to use- as it has only one channel for collecting signals. However; different tools with different areas and channels give different results for attention. Meanwhile the prior studies focused on detecting attention by checking the attention level using different stimuli [5]. For instance; Thomas [43] trained participants to enhance their attention level by putting participants under pressure-via exposing them to many questions that they should answer as fast as possible. He found that the attention score increases. In continuing with training for better attention, Ochi et al., [35] employed a game to keep participants' attention all time they used a stricter level of games in each session

The frequency chosen; for EEG during training time; was different for various purposes. EEG-based therapy most of the time rely on increase/ decrease the frequency. Beta frequency rises with healthy adults and reduces with attention deficit group. The arguments among those studies was regarding the length and periodically of the training session; in overall, the arguing to do it with less than one week with 30 minutes per session. To conclude that to produce measurable results in biofeedback therapies, a mean of 30-minute session; three day a week is needed. [50]. All previous work discussed in this study used various stimulation to enhance attention. Sometimes, they employ visual or audio effects, while others put some pressure to motivate participants to increase their concentration. However, most of the studies were observing not interfering, i.e., they try to measure waves related to attention and the various changes occurring during the experiment session but without interfering. On other hand, the theta/beta protocol cannot be used with high expectations because it is not a good index with maturation and it cannot solely be used to describe attention disorder [21]. Thus, it could be said that theta/beta can be an extra diagnostic marker mostly for children but not for adolescents. The theta/beta protocol analysis showed that children could be differentiated from normal people by absolute theta, but this was not the case for adults [24]. This proves the significant role of EEG in diagnosing attention. Some related studies summarized using the different methods without using EEG as a measurement tool to improve the focus. The methodology used no electronic devices whatsoever attached to participants to train their attention. They either used surveys [8], results from playing games [34, 36], or used a questionnaire [2]. Some emphasize on physical activities to improve not only health but also attention [2, 36].

3. Research Gap

The attention of people is influenced by the distraction and the temptations surround them, which the students are among the most affected people due to their interest in social media and video games. Researchers employ EEG-based techniques as they are accurate in reading brain activities-related waves. For the sake of finding threshold values for (alpha, beta, and theta) that tell whether a student has attention issues or his/her attention improved, this study conducted an extensive literature review to students' attention improvement studies. The results have shown that currently, researchers use EEG-based tools and techniques to study the variances in waves emit from the brain, yet, this after employing other methods to train students and enhance their attention. There is inconsistency regarding the most significant wave type and frequency range that describes whether is attention issues or improved. EEG was found to be a quick and objective tool for evaluating attention levels [5]. Yet, EEG works with brain waves that are fairly weak, subject to interference and noise, vary depending on the individual, the subject's physiological status and time [5]. Moreover; a simple action while EEG tool capturing the waves such as fatigue, pain and even closed eyes probably can distort the measurements [26]. Consequently; this brings difficulties to collect brain waves cleared of errors. Due to that investigating

techniques employed in prior studies to overcome those challenges; in addition to values that claimed by researchers to be the threshold and can be standardized.

Many studies have designated that different brain activity frequencies in the frontal lobe are highly associated with personality, emotion, attention, rationality, and creativity [39]. EEG signals can be studied in the time, frequency domains, and the most discussed features are waveform, band and band power in the alpha, beta, and theta bands [5]. Researchers have focused on various wave types with multiple justifications. They mainly focused on changes in the wave's strength during the session. For instance; [15] reported that an upsurge in attention marked by an increase in alpha waves and a decrease in theta waves. Moreover, many studies indicate that an increase in beta waves and a decrease in the theta band is a significant sign of good attention/ concentration and memory [53]. Another study reported that alpha amplitudes an increase in frequency, meanwhile means high attention or deep concentration [46]. Sauseng et al., [37] have found that an increase in theta-waves, claiming that means focused attention [5]. Due to no an agreement among researchers regarding using specific wave types (alpha, beta, theta), specific frequency and/or regions of brain to measure people's attention level; many studies focused on power densities in alpha, theta and beta frequencies such as in [5] with attention. Researchers tend to measure attention improvement using several blocks of the games where the first blocks look like training, other blocks to measure attention improvement. Simultaneously, they record waves emit from the brains of the players. Later and using t-test and ANOVA with players' scores to find positive differences. Then after those statistical procedures confirm positive differences in players' ratings, they studied the changes in alpha, beta, and theta. The results presented in table 1, show entirely different and sometimes contradicted findings regarding the changes in waves particularly alpha and theta. Yet, there is no specific range of values that may not use as a trigger for attention problems or improvement. Researchers again have quite a long time to come up with stable and valid EEG-based measurements regarding attention. Studies yet rely a little bit on brain waves reading to confirm attention-related problems, which is most of the time using it as a supplementary method.

Table 1. Monitoring Differences in waves to prove an improvement in attention

Author	Attention improvement signs
(Chiang et al., 2017)	Calculated the relationship between each feature (theta, beta, alpha) and attention
(Zolubak et al., 2018)	An increase in beta waves and a decrease in theta waves
(Sauseng et al., 2007)	Theta waves up and beta down
(Kawatake et al., 2017)	Alpha amplitudes decrease and increase in frequency
(Lansbergen, Van Dongen-Boomsma, Buitelaar, & Slaats-Willemse, 2011)	Increase in theta waves
(Yao et al., 2017)	Alpha power increases
(Zamora Blanón et al., 2016)	Different in alpha and beta declines
(Lim et al., 2019)	High alpha power, beta power and theta power
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(Zamora Blanón et al., 2016)	Different in alpha and beta declines
(Lim et al., 2019)	High alpha power, beta power and theta power

4. The Attention Deficit

Attention issues link mostly to paying less concentration or recalling information in time whenever needed [17]. Attention Deficit (AD) is a condition characterized by the presence of a variety of symptoms that cannot be diagnosed without clinical examination [49]. Some of the symptoms are related to memory, inattention, impulsivity, executive function, trouble with multitasking, minor planning, low frustration tolerance, frequent temper swings, troubleshooting and completion of obligations, and trouble managing stress [38]. These symptoms vary in magnitude and degree from one person to another and need daily activity to test the level of disorder [12].

4.1. Attention Representation

Neuroglia and neurons are two types of cells [29] in the brain, which the function of neuroglia cells is to back up the neurons to supply them with the required oxygen and nutrients [29]. On the other hand, the neurons are in charge of information transmission through nerve impulses, i.e., biochemical and electrical urges. This continuous flow of electrical current in the brain, caused by synaptic excitation of the dendrites in the neurons, produces electrical signals that spread from the encephalic mass to the scalp, which are called brain waves. The first example of a disorder that is similar to AD was inspected by the Scottish physician Sir Alexander Crichton in 1798 [19], wherein he validated the observations of 43 clinic cases of mental illness [19]. Attention deficit affects children and adolescents and may continue until the end of their lives [40]. Boys are more prone to getting attention issues than girls and are usually discovered during the early school years [19, 35]. Individuals may display problems in various ways, and these behaviours interfere with school and home lives [43]. Adults may have trouble managing time, setting goals, being organized, and holding down a job, and they have low self-esteem and self-efficacy [27]. Usually, symptoms of AD disorder may change as a person gets older [45].

4.2. Attention Measurement Tools

A Brain-Computer Interface (BCI) is a medium that allows a human to interconnect with devices using brain signals. Several studies have investigated an EEG and/or BCI as a control system for several tenders [31]. Any individual can have an experience without using physiques [3] as EEG/BCI transfers the command to the device from the brain, rather than the particular way of tensions or physical fitness [22]. EEG-BCIs have been utilized as rehabilitation tools, as assistive technology, and others [32]. Many EEG applications utilize EEG signals. In contrast, other applications use other recording modalities such as magnetoencephalography (MEG), electrocorticography (ECoG), intracortical microelectrode recording of single-neuron action potentials or local field potentials, functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS) [28]. EEG works with brain waves of different bands [10, 28, 31]. For instance, when people are exposed to video stimuli, the detected brain waves are gamma and beta wavebands from the frontal lobe [16, 42]. It has been noticed that for different training purposes with different protocols, using different channels can provide different results. For instance, using EEG for attention detection, Chouhan et al. [6] and Kaur, Singh and Roy [16] used alpha and beta wave bands from Fp1, Fp2, F3, and F4 channels. Meanwhile, other channels were used to detect other cognitive skills [44]. Likewise, developing an EEG-based game for attention-deficit treatment aimed to enhance the level of the player's engagement, whether in education for students, work for employees, or medical response for patients [46]. According to Zolubak, Pelc and Kawala-Janik [53], there is a long history of EEG studies with attention, with the first study on resting-state brain oscillations in children with behavioral problems consistent with Attention Deficit Hyperactive Disorder reported in 1938 [20]. The first observations described as the frontcentral slowing in the EEG of affected children, which revealed that a rise in the power expressed slower frequency oscillations (theta band, 4-7 Hertz) over the frontal and central lobe [21]. Consequently, more concentration was given to high theta power, low beta power, and theta to beta band ratio (TBR) [41]. It is worth mentioning that theta power is related to the slowing of brain activity, while low beta power is related to faster frequencies.

5. The Attention Treatment

Using brain training or altering its status are effective means in attention improvement, and the ability to change brain attention to remote tasks is still a topic of concern. Thus, training the brain on a single task may lead to enhancing and elevating its sense of cognition; nevertheless, training the brain on a group of tasks, which could boost and increase attention generally, is still a prospect. The tools may be different, but the goals lead to improving brain cognitive skills. Hence, individuals start with medicine and physical activity (i.e. sport, games, activities) [35]. However, if cognitive skills are not treated, then the researcher moves to another option of using neurofeedback as an alternative method for treating disorders [33, 35].The usage of drugs such as Methylphenidate, Clonidine, Atomoxetine has been approved for the treatment of attention-deficit due to reducing the relevant symptoms. For example, Methylphenidate is a synthetic central nervous system stimulant drug based on the clinical analysis, and it proved to be the most effective treatment available for attention deficit [1]. Another intervention used for AD is cognitive training, which focuses on training the working memory by incorporating adaptive schedules that are hypothesized to strengthen attention neuropsychological processes [4]. In this regard, Furley and Wood [9] concluded that the control of attention by the activated contents in the working memory might not only apply to situations in sport but might generalize to a whole range of other activities. However, they acknowledged that sport could be considered as serving and stimulating attention during physical performance. A study by Han [11] in Taiwan on attention training conducted on 116 college students, where their focus was tested by standardized tests (WMS-III, 1997), found that 15 minutes of walking or jogging while engaging in nature increases their emotions and concentration.

6. Neurofeedback Treatment

Biofeedback or neurofeedback utilizing brain activity has attracted a great deal of attention as self-control therapy for adolescents with developmental disorders, multiple body disorders, and brain disorders. There are seven types of neurofeedback used for the treatment of various kinds of mental and psychological disorders [25]. These types of treatment are usually based on either EEG or magnetic resonance imaging (rtfMRI) in real-time [13]. The First and most commonly used frequency/power is biofeedback, also called surface neurofeedback, which involves using 2-4 surface electrodes. It is used for adjusting the rate or speed of specific brain waves to handle diseases in particular brain locations [25]. Second, the Slow Cortical Potential Neurofeedback (SCPNF) strengthens the course of slow cortical potentials for treating epilepsy, ADD, and migraines [7]. Third, the Low-Energy Neurofeedback System (LENS) generates a mild electromagnetic stimulus to adjust the brain waves of the patient when his/her eyes are closed and motionless [51]. This form of neurofeedback was used for treating traumatic brain injury, ADHD, insomnia, fibromyalgia, syndrome of the restless legs, anxiety, depression, and rage. Fourth, the Hemoencephalographic (HEG) neurofeedback provides data on migraine treated cerebral blood flow [25]. Fifth, the Live Z-score Neurofeedback introduces the continuous comparison of variables of brain electrical activity to a systematic database to provide continuous feedback [25], and it is used to treat insomnia. Sixth, the Low-Resolution Electromagnetic Tomography (LORETA) involves the use of 19 electrodes to monitor phase, power, and coherence [17], and it is used to treat addictions, depression, and obsessive-compulsive disorder. Seventh, Functional Magnetic Resonance Imaging (fMRI) is the most recent type of neurofeedback to regulate brain activity based on the activity feedback from deep subcortical areas in the brain [14].

The primary usage of EEG-BCIs was as a communication tool for disabled people or patients with severe motor impairment [28, 30]. Many EEG-based studies have concentrated on using EEG to re-establish communication and control to patients paralyzed due to chronic neuromuscular disorder [28]. Neurofeedback allows users to improve their dynamic abilities and cognitive skills by employing specific training strategies [44, 46]. Neurofeedback remedial results using neuroplasticity as a therapeutic approach with individuals suffering from AD, Attention-Deficit Hyperactive Disorder (ADHD), stroke, and dementia have been reported in many studies [46]. With children diagnosed with AD, diverse neurofeedback (NF) protocols have been practiced, with the most protuberant difference between EEG frequency-band (theta/beta) training and slow cortical potentials (SCPs) training [10].

Computer interfaces based on brain attention are designed to measure the attention level of the user to facilitate communication [46]. When it comes to computer games, the player's level of attention is used as a means to increase his/her interaction and involvement in the game [46].

Markovska-Simoska and Pop-Jordanova [24] conducted a study to compare children and adults' diagnosed attention highlighting that less concern was given to adults affected by the disorder. The EEG signal used EEG absolute/relative power and theta/beta ratio to assist in treating the AD of both children and adults. EEG was recorded during an eyes-open condition. The findings showed a rise of absolute power in delta and theta frequencies in children, while there were no significant differences in adults compared to healthy subjects. For relative power, the results showed an increase in alpha and beta in adults compared to children. Classification analysis showed that attention disorders in children could be identified using absolute theta and theta-beta ratios from the central lobe of the brain (Cz channel). The authors suggested further research on any significant difference in cortical arousal between children and adults using different methods and features. Another study conducted by [6], using audio and visual stimulation, found that they enhance participants' attention levels. Similarly, the work of [47] targeted how EEG Neurofeedback training can enhance attention and memory, where they used a virtual reality system 3D game. The findings showed that first and second-order attentional control improved, yet SMR and theta training showed no effect. Using different measurements that keep eyes open, [15] employed games to enhance the attention level among 85 children. They found that there is a minor enhancement in two of the six near-transfer measures, particularly: Go-No Go and Focus. In their experiment, they employed 12 channels and used emotiv epic. Outcome assessments include latency (the speed of response of the participant), the number of correct patterns selected, and a statistical measure that provides the frequency of an error following a correct or incorrect answer [33].

7. Conclusion

The article reviewed the available literature on attention deficit based on neurofeedback and it revealed many approaches and different results regarding handling the attention. To come with a conclusion from those studies regarding a specific case, it will be difficult due to variances among those studies. Therefore, this work intends to develop a neurofeedback training system that assists in identifying attention with any case based on prior scholars. EEG-based measurements can be described as the most accurate method to capture waves related to brain activities. However, currently, researchers are in the learning status; they are trying to find the relationship between attention and changes in waves emit from the brain. Yet, there is no confirmation regarding the ranges of frequencies that can reveal attention-related issues or improvement. Moreover, researchers have to overcome a lot of errors related to capturing and analysing brain waves.

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