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A Literary Review of ADHD Treatments: An Advocate for Neurofeedback

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Abstract

Attention deficit/hyperactivity disorder (ADHD) is a common behavioral disorder affecting a tremendous portion of children in the United States. Medication and traditional Behavioral interventions have remained the primary forms of treatment. Research has demonstrated that brain wave frequencies are directly associated with behavior. Children diagnosed with ADHD have abnormal EEG profiles compared to their peers. EEG Neurofeedback developed as an operant conditioning treatment for brain waves to influence behavior. Neurofeedback has been found as effective as medication without the negative side effects or high percent of non-responders. Unlike medication and Behavioral Treatments, Neurofeedback offers long-term effects following the conclusion of treatment. This review analyzes studies investigating the effects medication, traditional Behavioral treatments, and Neurofeedback have on symptoms of ADHD.

Attention Deficit-Hyperactivity Disorder (ADHD) is a psychological disorder primarily characterized by inattention and/or impulsivity and hyperactivity. ADHD affects approximately 3–5% of school-aged children in the United States (Monastra, Monastra, & George, 2002; The MTA Cooperative Group, 1999;Watson & Gresham, 1998). ADHD is subdivided by the DSM-IV-TR into three types: Combined, Predominantly Inattentive, and Predominantly Hyperactive-Impulsive. As implied, Combined Type is characterized by symptoms of both inattention and hyperactivity-impulsivity. Predominantly Inattentive Type is characterized by inattention. Predominantly Hyperactive-Impulsive Type is characterized by hyperactivity and impulsivity Inattention can appear as failing to pay close attention to details, sustaining attention in tasks or playing, failure to listen when spoken to, disorganized behavior, forgetful, and easily distracted. Hyperactivity is described as fidgety/squirmy, failure to stay in one's seat, running/climbing during inappropriate times/situations, difficulty engaging in activities quietly, and excessive talking. Impulsivity is characterized by blurting out answers prematurely, difficulty taking turns, and frequent interruption/intrusion.

ADHD often results in high rates of comorbid disorders such as conduct, mood, anxiety, and tic disorders, social skill deficits, problems with parents, low academic functioning, and poor self-esteem (Spencer, Biederman, &Wilens, 1999; Lazzaro, Gordon, Li, Lim, Plahn, & Whitmont 1999). Without effective treatment, children with ADHD are at an increased risk for accidental injury, and developing academic, behavioral, mood, and anxiety disorders. As they age, these children are more likely to have a higher incidence of expulsion, substance abuse, psychiatric disorders, and criminal behavior in comparison to their peers without ADHD (Monastra et al., 2005). These momentous problems socially, academically, and functionally have resulted in significant efforts toward the development of effective treatments for individuals with ADHD.

The two most well documented treatments for ADHD are stimulant medication and behavioral treatment (Arnold, Chuang, Davies, Abikoff, Conners, Elliott, Greenhill, Hechtmen, Hinshaw, Hoza, Jensen, Kraemer, Langworthy-Lam, March, Newcorn, Pelham, Severe, Swanson, Vitiello, Wells, & Wigal, 2004). The MTA Cooperative Group (1999) conducted a study following a group of 579 children between the ages of 7 and 10 with a diagnosis of ADHD Combined Type. The goal of their study was to determine the most effective treatment strategies for ADHD. Their design separated the children into four groups for a 14-month period: Medication Management, Behavioral Treatment, Combined Treatment, or Community Care. The Medication Management participants were given one of several medications determined and approved by a physician. Those in the Behavioral Treatment group underwent parent training, child focused treatment, and school-based interventions. The Combined Treatment participants received both medication and behavioral treatment. Those in Community Care received no treatments and were given a report of their initial study assessments and a list of community mental health resources. The utilization of such resources was documented at follow-up.

The results of the MTA study found that all four groups showed significant reductions in ADHD symptoms over time. However, those in the Combined Treatment, Medication Management, and Behavioral Treatment groups showed greater improvement than those in the Community Care group. Medication management was found to be superior over Behavioral Treatment. In addition, although combined treatment was more effective than Behavioral Treatment alone, results did not differ significantly with Medication Management alone (MTA, 1999). It is important to reaffirm that although the results are interesting, the MTA study and consequently, those results, implicate only those with ADHD Combined Type.

Behavioral modification is a widely accepted treatment for ADHD. Behavioral interventions for ADHD focus on either the antecedent or the consequence of a particular behavior in order to alter that behavior. In Antecedent-Based interventions modifications are issued to prevent attention difficulties. These modifications include reducing the amount of work the child is expected to complete, ensuring the student fully understands the topic before being asked to begin a task, providing extra time to the student, and teaching study and note taking skills (Watson & Grasham, 1998). Antecedent-based interventions are advantageous due to the ease of application. It is not difficult to incorporate these slight manipulations into a classroom. A study investigating the effectiveness of a peer-tutoring program found that utilizing Antecedent-based interventions on children with ADHD to be effective. DuPaul, Hook, Ervin, and Kyle (1995) found that active engagement, measured by attentional behavior and academic accuracy of students, increased from a baseline of 21.6% to an average of 82.3% when the intervention was implemented.

Another behavioral intervention involves Consequent-Based interventions. Two primary approaches have proven to be effective in addressing ADHD behaviors: response-cost contingencies and reinforcement contingencies. Reinforcement contingencies involve praise, television time, snacks, and desired activities for appropriate behavior. Response-cost is the removal of desired reinforcers following an inappropriate behavior. Response cost is most effective when the treatment involves a token economy because the consequence is immediate. In a token economy, an individual is provided a set number of tokens for appropriate behavior and is penalized for inappropriate behavior by deducting a token. When the child participates in an appropriate behavior (target behavior), s/he will gain tokens at particular intervals (reinforcement). If the child exhibits inappropriate behavior, s/he will lose tokens (response-cost). At the end of each particular session, the student is able to trade tokens for preferred activities, treats, or other reinforcers (Malott, 2008; MTA, 1999; Watson & Grasham, 1998.)

A number of children do not respond to behavioral treatments. Training is often difficult to generalize to the different situations the child might find his/herself in. There is often little carryover from the home to the classroom (and vice-versa). Once the treatment and the contingencies are no longer in place, the terminated behaviors return to baseline in 50% of cases. Cooperation between parents and teachers is also generally very limited and negatively affects the benefit of the treatment. With respect to Antecedent-based interventions, the children are not taught how to fit in with their peers, abide by similar rules, or accomplish similar tasks. Rather, what is expected of them is decreased during treatment. This is problematic because when the intervention is over and their responsibilities are reinstated, the child may not have learned valuable skills needed to accomplish their tasks successfully (Fox et al. 2005).

The primary treatment for individuals with ADHD today is Methylphenidate (MPH), a psychostimulant medication (Dupuy, Clarke, Barry, McCarthy, & Selikowitz, 2000). Psychostimulants increase the arousal of the central nervous system by stimulating the release and inhibiting the reuptake of the dopamine and noradrenalin neurotransmitters (Duston, 2003). Behaviorally, this increases attention while simultaneously decreasing impulsivity and motor activity (Yildiz et al., 2007). However, approximately 35–45% of patients with ADHD Inattentive Type and 10–30% of those with ADHD Combined Type do not respond to medication as a treatment (Barkley, 1998). Additionally, medication has failed to treat the co-occurring tribulations such as cognitive, academic, and social functioning that ADHD patients experience (Bennett, Brown, Craver, & Anderson, 1999). Psychostimulant medication also has many side effects that occur in 20-50% of individuals. These side effects can be severe and include anxiety, depression, headaches, irritability, stomachaches, decreased appetites, and insomnia (Goldstein & Goldstein, 1990; Jensen, Arnold, Richters, Severe, Vereen, Vitielle & Schiller, 1999). Long-term use of stimulants has been shown to cause Bruxism, increases in blood pressure, and hallucinations (Gunkelman & Johnstone,2005). Medications do not cure ADHD, they simply mask the symptoms and therefore, the benefits of psychostimulants do not last upon termination thereof (Masterpasqua & Healey, 2003).

The limitations, inconsistencies, and failures of medication and traditional behavioral therapy as a treatment have resulted in new research to develop better ways to treat each of the ADHD subtypes. ADHD is typical described as a behavior disorder and there is evidence that these behavioral symptoms are strongly associated with metabolic, circulatory, and electrophysiological abnormalities (Fox, Tharp & Fox, 2005; Monastra, Monastra, & George, 2002). Researchers have utilized electrophysiological differences in ADHD individuals to develop effective means of treating individuals on a case-by-case basis.

Through dilation and constriction of blood vessels, the brain controls its own blood supply. The blood flow travels to areas that are more active and self-regulated. Perfusion is a measure of the blood flow, the oxygen and glucose that are utilized and carried by the blood throughout the brain. Positron Emission Tomography (PET) is one technique that uses radioactive materials injected into the bloodstream to follow the flow of blood in the brain (Gunkelman & Johnstone, 2005). A UCLA study found the electrical activity of the brain correlates with the perfusion in the brain and that electroencephalogram (EEG) mapping accurately reflects local perfusion and brain function as compared to PET and other invasive methods of mapping. EEG mapping is what neurologists commonly use today to detect, measure, and research brain activity (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998).

The human brain utilizes electrical activity in the form of brain waves. Brain wave types are determined by the number of cycles they make per second, known as hertz. Waves with a frequency of 1 to 4 cycles per second are Delta, 4 to 7 cycles per second are Theta, 8 to11cycles per second are Alpha, and 12 to 30 cycles per second are Beta. (Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Konareva, 2006). Differing wave frequencies affect behavior differently depending on the neural location of the waves. Typically, Delta waves are associated with relaxation. Delta waves occur when individuals are in deep sleep. Theta waves are associated with dreaming/day dreaming, creativity, and sociability. Individuals with high theta tend to show frustration, rich imagination, social openness, and high emotional excitability. Alpha is associated with learning, anxiety, inspiration, and feelings of well-being. Those with low alpha wave occurrence tend to have higher anxiety, disorganization, and social awkwardness. Beta waves are associated with attention and aggression. High levels of beta waves are associated with high aggression and moodiness (Clarke et al. 2001; Goldenson, 1970; Konareva, 2006; Saxby & Peniston, 1995).

Over the past 30 years, research has found that children with ADHD characteristically have different brain wave activity. Tremendous research has shown that individuals diagnosed with ADHD typically have a surplus of slow brain wave activity (theta and delta bands), and decreased alpha and beta activities (Clarke, Barry, Dupuy, Heckel, McCarthy, Selikowitz, & Johnstone, 2011; Fox, Tharp & Fox, 2005; Lazzaro et al. 1999). Beta activity generally increases during physical and mental activities; however, children diagnosed with ADHD have lower beta activity during cognitive tasks and a general deficiency of alpha and beta bands overall (Fox, Tharp & Fox, 2005; Lazzaro et. al 1999; Sander, Arns, Olbrich, & Hegerl 2010). Although individuals with ADHD tend to show an increase in slow wave activity and a decrease in fast frequencies, studies have also shown that 15-20% of children diagnosed with ADHD combined type have significantly elevated beta levels (Clarke et al. 1998). It is reasonable to assume, and it is the case, that the severity of behavioral problems vary across clinical subtypes and positively correlate with the degree of EEG abnormality (Chabot et al., 1999; Clarke, Barry, McCarthy, Selikowitz, 2001).

Since 1998, Clarke, Barry, McCarthy, Selikowitz, and colleagues have investigated whether or not EEG differences can account for behavioral differences among a variety of populations. In 1998, Clarke et al. conducted a study that determined that children with ADHD have an increase in slow brain wave activity and a general decrease in beta wave activity. Clarke et al. (2001) investigated behavioral differences between children with EEG profiles of increased theta activity and a group of children with excess beta activity. Investigators found that children with excess beta activity were more moody, prone to temper tantrums, more likely to physically attack, and commit acts of vandalism than other children with ADHD. These children showed far less remorse and guilt than other children with ADHD, suggesting a high degree of antisocial behavior in children with ADHD to be linked with excessive beta activity.

In a study conducted in 2011, Clarke et al., identified five distinct clusters of EEG profiles of 155 boys diagnosed with of ADHD combined type between the ages of 7 and 13 years. Five EEG clusters were found. Of the participants, Cluster 1 consisted of 23.2%, which was characterized by elevated beta activity with less theta and alpha activity in the frontal regions. In addition, theta was low in the central regions when compared to control subjects. Cluster 1 was associated primarily in children with ADHD combined type and children in this cluster tended to exhibit more aggressive, mood, and antisocial behaviors. Cluster 2 consisted of 11% of the sample and was characterized by elevated theta with lower all over alpha and beta activity and lower delta in the central regions. Individuals in this cluster tended to act very age-appropriate, and are not very fearful or antisocial. Cluster 3, comprised of 24.5% of the total sample, and demonstrated an increase in delta and theta activity with reduced alpha activity. Cluster 3 was labeled the “Maturational lab group” due to the individuals’ impulsive behavior, increased inattention, and preference for spending time with younger children-which demonstrates developmental delay. Individuals in Cluster 3 were more likely to use bad language, but were not likely to have further conduct problems. Cluster 4 comprised 24.5% of the total sample and demonstrated an elevation in theta and a reduction in all over beta activity, central and posterior delta, and frontal and posterior alpha. Clarke et al. originally concluded that Cluster 2 and 4 were to be combined into one because their EEGs were so similar. However, behaviorally the two groups were distinctively different. Where Cluster 2 individuals represented the most docile of the groups, Cluster 4 represented the “typical” ADHD child demonstrating a full range of behaviors commonly found in individuals with ADHD. Approximately 17% of the sample made up Cluster 5 with reduced delta, frontal and central decreases in theta, and frontal and central increases in alpha activity. Behaviorally, this group was found to be described as “confused or in a fog.” This cluster also tended to arrange objects, prefer strict routine, and engage in only one or two interests.

As determined and described in the aforementioned studies, behavior of the individuals with ADHD highly correlates with their EEG subtypes. This tremendous neurological and behavioral variation makes it difficult for a non-dimensional treatment to be effective across all ADHD subtypes. In 1976, the first Neurofeedback sessions were conducted as an attempted remedy for these complications (Arns et al. 2009). Neurofeedback, which is understood as operant conditioning of brain wave frequencies to allow the client to better self-regulate his/her brain, is often referred to as EEG operant conditioning (Gunkelman & Johnstone, 2005; Masterpasqua & Healey, 2003). Neurofeedback materialized after Sterman et al. (1972; 1974) and Kamiya (1969) discovered that humans were able to successfully control their brain waves through operant conditioning.

The process of Neurofeedback begins with electrodes placed on the scalp to detect neuroelectrical activity. This activity is processed by computer software that provides auditory or visual feedback contingent on brain wave frequencies (Vernon, Frick, & Gruzelier, 2004). The majority of Neurofeedback sessions for children with ADHD focus on theta, Sensorimotor Rhythm (SMR), and beta. Theta and beta waves are conditioned to either increase or decrease, depending on the client. Nearly all children with ADHD work to increase the Sensorimotor Rhythm (SMR, 12-15 Hz), which is associated with hyperactive behavior when too low (Arns, 2009). Some software plays a chosen movie or television show, while other programming works as a videogame. For example, if a client was diagnosed with ADHD and demonstrated high theta and low beta, the program would be adjusted for his particular needs. This client would need to have his theta restricted and his beta increased. When the client maintains waves over 12 Hz above a certain threshold, the movie will play without interruption. If the power of the beta waves falls below that threshold, the movie will pause until the threshold is maintained again. When the client’s waves between 4-7 Hz surpass a particular threshold, the movie will mute, but continue playing without sound until the threshold is reestablished (Masterpasqua & Healey, 2003). The brain eventually adapts to the consequences of producing certain frequencies. In this example, the brain is rewarded for producing more beta waves and fewer theta waves. As the brain consistently produces the desired frequencies, the thresholds are made more difficult. Neurofeedback training sessions range from 15 minutes to an hour 2-3 times per week. The training can last between 20 and 40 sessions. The goal is to teach the individual what specific states of arousal feel like and how to activate each state voluntarily (Vernon et al., 2004).

Neurofeedback has reported success rates from 60-90% in eliminating behavioral problems (Gunkelman and Johnstone, 2005). This range should be compared to 50-75% of individuals who respond positively to stimulant medications (Evans, Pelham, Smith, Bukstein, Gnagy, Greiner, 2001; Rapoport & Denney, 2000). Monastra et al. (2002) conducted a study with one hundred children, ages 6–19 to determine whether Neurofeedback or stimulant medication was more effective. All participants were diagnosed with ADHD (24:ADHD inattentive type; 76:ADHD combined type) by a licensed clinical psychologist. The study found no significant differences between stimulant medication and Neurofeedback when conducting a mean standard score analysis following interventions. Arns et al. (2009) found that Neurofeedback was “equally efficacious” as stimulant medication. Studies summarized by Monastra et al. (2005) reported the effects of EEG operant conditioning on improving attention and behavioral problems, improving scores on intelligence tests, and increasing academic achievement. Fuchs, et al. (2003) also found that Neurofeedback and methylphenidate had highly comparable benefits during a study on 8-12 year old children with ADHD. Both the Neurofeedback and the methylphenidate groups significantly decreased impulsive behavior and inattention. Masterpasqua and Healey reviewed many other studies (e.g. Nash, 2000; Rossiter & LaVaque, 1995; Shouse & Lubar, 1979; Tansey, 1993) that demonstrated significant positive effects of Neurofeedback, closely comparable to those of medication.

There is no doubt that stimulant medication has short-term effects. However, there is little evidence demonstrating the effects produced maintain over years. After 2-3 years of medication use, the benefits appear to dissolve while the negative side effects do not (Brown, Antonuccio, DuPaul, Fristad, King, Leslie, Pelham Jr., Piacentini, Vitiello, 2006). Unlike medication and other behavioral interventions, the benefits of Neurofeedback remain long after treatment (Fuchs, et al. 2003; Vernon et al., 2004). Strehl, Goth, Klinger, Hiterberger, and Birbaumer (2006) reported that after a 6-month follow-up, the subjects' scores on impulsivity, inattention, and hyperactivity had improved even more that compared to the conclusion of treatment measures. After a 2-year follow-up Strehl et al. found all measured improvements were constant. This stability and even improvement of symptomatology following treatment is significant. In comparison, stopping stimulant medication and traditional Behavioral treatment results in initial symptoms resurfacing (Monastra et al., 2002).

In addition to lasting effects, Neurofeedback also offers a highly desirable alternative to the potentially severe side effects medication often induces. As mentioned previously, medications for ADHD can result in unwanted side effects including anxiety, depression, headaches, irritability, stomachaches, decreased appetites, changes in sleep patterns, hallucinations, and increased blood pressure (Goldstein & Goldstein, 1990; Gunkelman & Johnstone, 2005; Jensen, Arnold, Richters, Severe, Vereen, Vitielle & Schiller, 1999). Neurofeedback, in contrast, has no documented adverse side effects. There have been hypothesized ideas of inducing seizures through Neurofeedback, but there has never been a documented instance (Vernon et al., 2004).

In summary, Neurofeedback produces equally significant results in children diagnosed with ADHD when compared to stimulant medication (Vernon et al., 2004). Neurofeedback avoids unwanted side effects and time commitments of other treatments. Neurofeedback also offers a more individualistic approach when compared to medication. Human error presents a problem with Neurofeedback that has not really been investigated. Technicians are responsible for adjusting the thresholds of each client. It would be useful to know the amount of error that occurs and the effect it has on effectiveness of treatment. More research may also be needed to determine the ideal number of therapy sessions to produce the most significant results. Determining whether auditory or visual feedback is more effective would also be a worthwhile investigation for future research. As it stands, Neurofeedback is an effective treatment for ADHD and offers promising effects for other behavioral disorders and symptoms.

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