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ABSTRACT

This document presents a review of the most recent literature regarding the efficacy of electroencephalographic biofeedback, more commonly known as neurofeedback, in the treatment of attention deficit hyperactivity disorder (ADHD). The studies reviewed indicated that neurofeedback can be a successful component of treating attentional deficits and can potentially enhance IQ scores, academic improvement, pro-social behaviors, and decrease behavioral and cognitive difficulties typically associated with ADHD. Standard treatment with neurofeedback can take anywhere from 20-80 sessions or more depending on the individual. The review also incorporates a new trend in the literature to add an adjunctive procedure known as Instantaneous Neuronal Activation Procedure (INAP), a form of active alert hypnosis. The subset of studies reviewed that combine INAP with neurofeedback provide evidence in support of successful treatment of ADHD at a greatly accelerated pace. The literature review also considers this new technique and the subsequent implications for treatment. The paper concludes that while the studies did not prove conclusively that neurofeedback is guaranteed to remediate all of a child's or adult's attentional symptoms, they definitely demonstrated a large degree of success as an alternative to the more traditional treatments. (Contains 35 references.) (CR)

REVIEW OF THE LITERATURE REGARDING THE EFFICACY OF NEUROFEEDBACK IN THE TREATMENT OF ATTENTION DEFICIT HYPERACTIVITY DISORDER.

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Doctor of Psychology

by

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The following is a review of the most recent literature regarding the efficacy of EEG neurofeedback in the treatment of attention deficit hyperactivity disorders. The studies reviewed indicated that neurofeedback can be a successful component of treating attentional deficits and can potentially enhance IQ scores, academic improvement, pro-social behaviors, and decrease behaviors and cognitive difficulties typically associated with ADHD. Standard treatment with neurofeedback can take anywhere from 20-80 sessions or more depending on the individual. The review also incorporates a new trend in the literature to add an adjunctive procedure known as Instantaneous Neuronal Activation Procedure (INAP). The subset of studies reviewed here that combine INAP with neurofeedback provide evidence in support of successful treatment of ADHD at a greatly accelerated pace. The literature review also considers this new technique and the subsequent implications for treatment.

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REVIEW OF THE LITERATURE REGARDING THE EFFICACY OF NEUROFEEDBACK IN THE TREATMENT OF ATTENTION DEFICIT HYPERACTIVITY DISORDER

Introduction

The decade of the 1990s was declared by former president Ronald Reagan to be the "decade of the brain." Over the past 10 to 15 years, technological changes have advanced the exploration of the brain further than was previously thought possible. Not only is it possible to study the structures of the brain in more detail, it is now also feasible to begin to study the effects of disease, drugs, and affective experience as they actually affect the brain's physiology. These insights occur in a day when psychiatrists and psychologists are caught up in a trend toward ever more refined differential diagnosis. At the same time, there is also an intensive search for the physiological and even the genetic bases of behavior. These newer insights may help to formulate a more comprehensive understanding of the interplay of biology and psychology as it relates to all areas of a person's ability to effectively manage cognitive, emotional, and social functioning (Othmer, Othmer, & Kaiser, 1999).

One of the tools that has helped to provide some of the recent insights into the brain's activity is a technique known as electroencephalographic biofeedback (EEG biofeedback), more commonly known as neurofeedback. Neurofeedback has its roots in the science of biofeedback and it was first introduced on a more international scale in the 1970s. Biofeedback technology allowed scientists and patients to learn to manually regulate some of the body's autonomic functions, such as blood pressure, body temperature, and circulation. During this same time period, this technology was also applied to the study of brain wave activity. Unfortunately, somehow EEG biofeedback became associated with the new age movement as a vehicle for attaining a state of higher consciousness or "nirvana." This association seemed to dampen the scientific communities' enthusiasm and interest in pursuing the possible applications for neurofeedback in the areas of medical and mental health. The focus of this literature review will be to review the current empirical research regarding the treatment of attention deficit disorders with neurofeedback. An attempt will be made to determine if neurofeedback seems to be a viable alternative to more traditional pharmacological and behavioral approaches to attentional difficulties.

History

Neurofeedback began to regain scientific credibility during the 1970s through the work of a researcher by the name of Barry Sterman. Sterman, who studied neurology and psychology at the University of California, Los Angeles (UCLA), became interested in the study of the interplay between physiology and psychology. He became an expert in the use of the EEG to understand the electrical activity of the brain and mind. Early in his career, he spent many hours studying the brain electrical activity of cats and was one of the first researchers to identify a certain brain wave frequency now known as the sensorimotor rhythm (SMR), a rhythmic signal peaking in the range of 12 to 15 hertz (Hz). Sterman discovered that a cat could willfully alter a physiological condition thought previously to be out of the cat's control, in this case, the maintenance of the calm state induced by the production of the SMR brain wave frequency (Robbins, 2000).

Although Sterman's discoveries were interesting, there were no current theories regarding the application of his research to humans. Later Sterman became involved in cat research working for the government that attempted to analyze the toxic effects of rocket fuel. During the course of this process, Sterman discovered that cats that had previously been trained to produce the SMR brain wave state fared better physically when exposed to the toxic fumes than other cats without the training. This finding seemed to provide a clear connection between the mind and physiology (Robbins, 2000).

A researcher in the early 1900s named Hans Berger advanced the notion that abnormal activity in the EEG reflects psychopathology in an individual. Sterman, Joseph Kamiya, and many others trained in the use of neurofeedback, have continued to do research that actually supports Berger's notion. Since then, psychopharmacological, learning, and basic behavior theories have been employed to propose that functions of the autonomic and central nervous system functioning in humans can be retrained for better adaptive functioning (Cantor et al., as cited in Evans & Abarbanel, 1999). More recent theories indicate that one of the principal mechanisms of action of neurofeedback is to normalize autonomous management of arousal and to enhance overall nervous system stability. In this model, many conditions can be considered and treated in terms of their arousal dimension, and in terms of the stability/instability continuum of the nervous system (Othmer, Othmer, & Kaiser, 1999).

Current disorders treated with neurofeedback

Some of the disorders classified as disorders of underarousal include unipolar or reactive depression, attention deficit disorder (inattentive type), chronic pain, and insomnia. The condition of overarousal is associated with anxiety disorders, some sleep problems, hypervigilance, anger and aggression, and attention deficit disorder, impulsive subtype. Central nervous system instabilities are categorized on a continuum from a more internal or endogenous vulnerability to a more exogenous or external vulnerability. Nervous system instabilities are implicated in a variety of disorders such as tics, obsessive compulsive disorder, panic attacks, bipolar disorder, epilepsy, suicidal ideation and behavior, and multiple chemical sensitivities, among others (Othmer, Othmer, and Kaiser, 1999).

Othmer (1999) and Lubar (1991) indicate that there are many disorders treatable with neurofeedback as an alternative to more traditional methods of pharmacological treatment. They claim that depression, minor traumatic brain injuries, pre-menstrual syndrome, attention deficit disorders, childhood sleep disorders, and tension headaches are among the easiest disorders to remediate. Migraines, panic attacks, anxiety, sleep disorders, and some forms of chronic pain are a little more difficult to treat and require a wider variety of treatment protocols, but have reported a substantial amount of treatment success. The more difficult disorders to treat include oppositional defiant disorder, conduct disorders, bipolar disorders, epilepsy, stroke, major head injuries, chronic fatigue, and autoimmune dysfunction.

Attention Deficit/Hyperactivity Disorder and Neurofeedback Treatment

The following are some additional considerations in the study and review of the literature on ADHD. These include the definition of the disorder, traditional treatments, the etiology of the disorder.

Definition

As mentioned previously, the focus of this paper will be to review the literature surrounding the efficacy of neurofeedback as a treatment for attentional deficit hyperactivity disorders. In order to begin the review, it is first necessary to define some common terms used in the literature. Attention

Deficit Hyperactivity Disorder (ADHD), as defined in the Diagnostic and Statistical Manual of Mental Disorders (4th edition) is a condition of certain behaviors that manifest themselves in at least two different settings. These behaviors have two main features that include a pervasive pattern of inattention and an impulsivity more severe and frequent than other children at a similar level of development. The impulsive and inattentive symptoms must appear before the age of 7 years and must appear in more than a single situation, causing interference in social, academic, or occupational functioning (Diagnostic and Statistical Manual of Mental Disorders, 4th edition, APA, 1994).

In addition to the above-mentioned criteria, there are additional subtypes of attention deficit hyperactivity disorder. The diagnosis of attention-deficit hyperactivity disorder, predominantly inattentive type; attention-deficit hyperactivity disorder, predominantly hyperactive-impulsive type; and attention-deficit hyperactivity disorder, combined type. There has been some empirical research based on evidence obtained from brain imaging that has recently questioned the credibility of the division between inattentive and impulsive/hyperactive subtypes (Clarke, Barry, McCarthy, & Selikowitz, 1998). The implications seem to emerge that if the diagnosis is inaccurate, then the treatment attempts may be less efficacious as well. Although the refining of this diagnostic criteria may eventually influence the treatment modalities implemented, at this point, it is beyond the scope of the current study and therefore will not be discussed in detail (see Abarbanel & Evans, 1999).

Traditional Treatments

The most common form of intervention for the treatment of attention deficit hyperactivity disorder is the use of stimulant medication in order to remediate the symptoms of the disorder. These drugs include Ritalin (Methylphenidate), Cylert (Pemoline), and Adderall (Dextroamphetamine). Although drug treatment has shown to be effective in some individuals, it also has some potentially negative consequences. The first difficulty with drug treatment is that there are no long-term gains. The drug will help alleviate attentional problems only while the drug is in the individual's system. As soon as the drug diminishes, symptoms return. In other words, there are no lasting effects of drug treatment. A second difficulty is that ADHD is most frequently diagnosed in children and therefore there is an excess of children who are being treated long-term with stimulants. Some of the potential long-term consequences include the potential to inhibit growth; the problem of fostering dependence on the drug, both psychologically and physiologically; the concern that children will not be able to function normally without the drug as they get older; the possibility that the drug treatment will interfere with the child learning appropriate compensatory behaviors; and the potential that the child's ability to learn will never progress beyond the pre-morbid level of functioning and always be drug-dependent (Lubar, 1991).

There are also very practical difficulties associated with drug treatment. The short length of action (only 4 to 5 hours) limits the benefits and requires planning for administration at school or on overnight trips. The need for consistent medication can also potentially create problems with a child's self-esteem. Insomnia and poor eating are commonplace. Facial muscular tics frequently occur, and cardiovascular problems develop in a small percentage of children (Barabasz & Barabasz, 1996). High doses may also cause cognitive impairment, and there is evidence that responsiveness to positive reinforcements and rewards are significantly diminished in contrast to enhanced responsiveness to punishment therapy, making rehabilitation to a normal level of functioning less likely (Arnett et al., 1996, as cited in Barabasz & Barabasz, 1996). Additionally, there is no body of research that indicates the potential long-term side effects of the medications used to treat ADHD.

Other treatments for ADHD include behavior modification. This is undoubtedly the next most widely used therapy to manage the disorder. One of the strengths of this type of therapy is the collaborative efforts of working with parents and teachers on shaping a child's behavior. Behavioral interventions can be combined with stimulant medication for a more comprehensive approach, however the use of stimulant medication may actually decrease responsiveness to rewards (Arnett et al., 1996, as cited in Barabasz & Barabasz, 1996). Some of the limitations of behavior modification include the fact that it does not work for all children. Training also does not often generalize to non-traditional behaviors and there often is no carryover to the classroom of behaviors learned with parents. There also can be a return to the baseline after the cessation of the intervention. Probably the biggest difficulty with this approach lies in the dependence on parents and teachers to develop interventions and to work in cooperation with one another (Barabasz & Barabasz, 1996).

At this point, it is important to note that neurofeedback may provide an effective non-pharmacological intervention for children and adults. Neurofeedback is painless, completely safe, and will encourage and strengthen the individual's already existing capacity to relieve and reduce the symptoms of ADHD on his or her own. Additionally, once a child or adult learns to adjust his or her own dysfunctional brain wave patterns associated with the inattention and impulsivity, then the potential for long term gains is greatly magnified. Since these types of results are significantly reduced with the use of pharmacological interventions, it seems important to evaluate empirical evidence of the studies that use neurofeedback to treat attention deficit hyperactivity disorder in order to accurately evaluate the claims and decide if it is indeed the treatment of choice.

Etiology of ADHD

For many years, ADHD has been attributed to various social and behavioral sources such as prenatal problems, poor parenting, and improper diet (Ingersoll & Goldstein, 1993). The most recent and significant studies in brain research in ADHD individuals involves the use of brain imaging techniques. Zametkin et al., (1990) using PET scan technology, discovered that adults with hyperactivity of childhood onset had significantly lower cerebral glucose metabolism levels than the control group while participating in a continuous performance task. The study appears to be generalizable to the larger population of people with impulsivity and attention deficits as the sample was very controlled. The concluding remarks of the authors indicate that the prefrontal regions may play a vital role in the inhibition of responses, inattentiveness, and distractibility.

Another component of ADHD seems to involve the particular brain wave frequencies involved in cognitive tasks. In most EEG work, the range of frequencies is divided into four bands: delta (less than 4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12 Hz and above). There is one additional frequency noted earlier that is often used in EEG work, which is the sensorimotor rhythm (also known as SMR), and is located at 12 to 15 Hz. Delta frequencies are typically produced when an individual is in deep sleep. Theta frequencies are produced when an individual is in a rather light state of sleep. Alpha activity is usually the highest amplitude neural frequency produced when an individual is awake and in a fairly relaxed state. Beta activity, including SMR, increases as the individual becomes more focused or is involved in more complex cognitive processes (Plude, 1996). A further division is made in the beta frequency between SMR (12-15 Hz) and beta frequencies (15-18 Hz) (Lubar, 1999).

Methodological Considerations

The following is a discussion of some of the most common methodological considerations involved in the literature. These considerations include some differences in diagnostic criteria, a discussion of some of the more common instruments used in the literature, and a general discussion of some of the more technical aspects of neurofeedback.

DSM-III-R Criteria

In order to facilitate the review of the literature, it is important to call attention to the fact that many of the studies used in the literature were done before the most recent revision of the Diagnostic and Statistical Manual of Mental Disorders, (DSM-IV, 1994). Most of them used the DSM-III-R for obtaining diagnostic criteria for attention deficit disorders (Diagnostic and Statistical Manual for Mental Disorders, third edition, revised, 1987). At that time, the terminology was slightly different but the criteria for diagnosis were very similar. Therefore it was deemed that no clarification or adjustment was needed in the literature review to distinguish between the diagnostic criteria for either the DSM-III-R or the DSM-IV.

Neurofeedback Equipment

EEG instrumentation is very complex. There are several mechanical instruments used in the process of neurofeedback. The limitations of each of the individual neurofeedback systems is beyond the scope of this paper. However, the primary researchers in the field are much more familiar with the technology and did not feel the technological variations or limitations to be significant enough to affect results. In only one or two studies, the researchers noted some apparent difficulties with faulty equipment and subsequently addressed the effects of these technological problems on the study results. Some of the most commonly used manufacturers of neurofeedback equipment include Autogenics, Biocomp, Neurocybernetics, and Lexicor Medical Technologies. As is typical of any technology, as the complexity increases, the ability to measure discreet elements of functioning also increases. In each of the studies, the limitations and capabilities of the neurofeedback equipment are discussed.

QEEG

This acronym stands for Quantitative Electroencephalograph. This is a procedure that allows one to measure and monitor brain waves in real time.

The way this system works is through a standard placement of electrodes that is known as the 10-20 International System of Electrode Placement. The letters used in the system, F, C, T, P, and O refer to the frontal, central, temporal, parietal, and occipital cortical regions, respectively. Odd numbers refer to the left hemisphere sites, and even numbers refer to right hemisphere sites. Thus, "T3" refers to the left temporal region. The term "10-20" refers to the placement of electrodes placed 10% to 20% of the total distance between specified skull locations (Evans & Abarbanel, 1999).

One other technical term needed to understand some of the literature involves the choice of electrode placement for recording. One is called a referential recording. When employing referential recording, you are measuring the EEG activity at a single point on the head. The way this type of recording is usually done is to place a reference electrode on each earlobe (Lubar, 1999). The second recording type is called bipolar recording. Bipolar set-ups compare activity between two active scalp sites (Evans & Abarbanel, 1999).

Analogue versus clinical trials

Many of the studies presented for review use clinical trials to compare the efficacy of treatment programs for ADHD. Kazdin (1986, as cited in Rossiter & La Vaque, 1995) views analogue studies and clinical trials as being at the opposite ends of a continuum of research methodologies. Analogue studies refer to investigations of treatment procedures in the context of highly controlled laboratory conditions that often only remotely resemble the clinical situation. Analogue research is best suited to investigate more specific aspects of treatment such as the mechanisms responsible for change, factors that influence treatment efficacy, and other issues requiring meticulous experimental control (Rossiter & La Vaque, 1995).

Clinical trials, on the other hand, may be considered more appropriate to evaluate the effectiveness of alternative treatments under clinical conditions. Clinical trials are comprised of patients who come to a clinic seeking services as opposed to recruited volunteers who participate in a study. Because the research is conducted in a clinic, some compromises in research methodology must necessarily be made for both practical and ethical reasons. Treatment is tailored to the patient's problems rather than on the basis of the needs of the experiment to have a blind treatment condition or a placebo condition. In contrast to an analogue study, the patient, not the clinician, actually chooses the treatment. Although this choice compromises some of the generalizability of the results, the remedial effects on the clients seem to be above what could be contributed simply to the lack of more stringent controls. Most of the studies reviewed were clinical trials, and therefore it is assumed that there are some compromises in research methodology (Rossiter & La Vaque, 1995).

One of the general critiques of previous neurofeedback research has been the lack of a control group and the absence of a double blind procedure with a placebo treatment. Considering the nature of the experiment, these conditions would be difficult to create and could be considered unethical. Since neurofeedback can take up to 6 months and longer, it may be unethical to subject a person to 80 or more hours of being hooked up to equipment that is actually administering a placebo treatment. Additionally, it would be difficult to make it a double blind study as one would need to find a way to imitate the actual neurofeedback process via computer without actually treating the patient in order for the neurotherapist to believe that he is in fact administering treatment. Because of these complexities and subsequent ethical and practical considerations, there is a dearth of systematically controlled clinical studies.

Instruments

Test of Variables of Attention

Within the literature, there are several methodological considerations with respect to the instruments used that can be discussed here. The first involves a commonly used instrument in the EEG assessment of attention-deficit hyperactivity disorder known as the Test of Variables of Attention (TOVA). The TOVA consists of two continuous performance tests, both visual and auditory, in which two easily discriminated stimuli are presented for 100 milliseconds every 2 seconds for 22.5 minutes. During the TOVA, subjects are told to watch a computer screen and click a button whenever a "target" stimulus was presented. In the visual test, the target consists of a colored square appearing at the top of the screen. In the auditory test, the target consists of a higher pitched tone rather than the lower pitched tone of the non-target stimulus. When the non-target stimulus is presented in either test, subjects are instructed to refrain from clicking the button.

Scores derived from the TOVA are errors of omission (neglecting to press the button upon presentation of the target stimulus), errors of commission (pressing the button when the non-target stimulus is presented), average response time for correct responses, and variability or standard deviation of the response time for correct responses. (Greenberg, 1987, as cited in Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Rossiter & La Vaque, 1995). These four variables are interpreted as measures of inattentiveness, impulsivity or failure to inhibit response, speed of information processing, and variability in attention. Two additional variables, anticipatory responses and excessive commission errors, are used to determine if the TOVA results are valid (Rossiter & La Vaque, 1995). These variables have been shown to be significantly different between pretreatment and medication conditions when evaluating the effects of methylphenidate (Ritalin) on performance (Greenberg, 1987, as cited in Lubar et al., 1995). Greenberg (1987) also reported that there are no test-retest practice effects and subjects actually tend to perform more poorly when retested due to boredom.

The TOVA was standardized on over 1500 individuals ranging from 4 to 90 years of age and provides separate norms for males and females. The mean score is 100, and the standard deviation is 15. Therefore, in the literature review that follows, improvements in TOVA test scores for people with deficits in the areas measured would increase in mean score overall. For example, someone with a mean pretest score of 70 in the area of inattention is indicative of a deficit based on the fact that the mean for a person without deficits in attention or variability is 100. Therefore an increase in the measured mean would indicate an improvement of the deficit and hence produce a mean score more closely approaching the normal mean score of 100.

An increase in the response variability, however, does not necessarily imply the same type of improvement. Response variability is a measure of the consistency of attention. The response variability measure can signify several different things. If there is an increase in the mean scores on the TOVA and the variability also increases, this implies that some of the scores improved, but other scores lagged behind. If the mean scores increase and the variability remains unchanged, then this suggests that all of the scores between pre and posttest tended to improve. At times the means will increase, but the variability will actually decrease. This combination implies that the lower scores tended to improve or that the lower scores improved more than the higher scores. If the means decrease and the variability increases, some scores improved while others stagnated at elevated levels. Two other possible permutations involving the interpretation of the variability follow. The first is when the mean decreases and the variability remains unchanged. This suggests that all scores tended to decline. If, on the other hand, the mean decreases and the variability also goes down, then this pattern alludes to the possibility that the higher scores tended to decrease, or, they decreased more than the lower scores (John E. Kelley, personal communication, March 6, 2001).

The TOVA pattern consistent with features of attentional problems changes from childhood through adolescence. For example, excessive omission errors are a sensitive measure for younger children, but it is unusual to find deviant levels of omission errors in adolescents and adults. In contrast, comission errors are often the only aberrant finding for adults with ADHD. Because of these developmental differences, TOVA subjects were necessarily matched by normative age group. TOVA norms are in 2-year increments from ages 4 through 19 and in 10-year intervals for ages 20 and beyond (Rossiter & La Vaque, 1995).

The TOVA has been shown to differentiate between attention-deficit hyperactivity disorder, undifferentiated attention deficit disorder, conduct disorder, and normals (Waldman & Greenberg, 1992, as cited in Rossiter & La Vaque, 1995). The TOVA also appears to be unaffected by the presence of a comorbid reading disorder (Dupuy & Greenberg, 1993, as cited in Rossiter &

La Vaque, 1995), is sensitive to different dosage levels of psychostimulant medication (Crosby, Corman, & Greenberg, 1992 as cited in Rossiter & La Vaque, 1995), and is also sensitive to the effects of neurofeedback (Othmer & Othmer, 1992 as cited in Rossiter & La Vaque, 1995). The test is computer administered and scored, which reduces the likelihood of human bias or error regarding testing and outcome data. The TOVA, therefore, can provide a more objective measure that circumvents some of the potential difficulties inherent in relying on parent, teacher, and patient reports as the primary basis for diagnosing ADHD and assessing treatment effects (Rossiter & La Vaque, 1995).

WISC-R, WISC-III

The Wechsler Intelligence Scale for Children - Revised (WISC-R) and the third edition (WISC-III), will be discussed together. The WISC-R and WISC-III are standardized measures of intelligence. These measures are used frequently in the literature regarding neurofeedback treatment and ADHD and therefore it is appropriate to discuss the specifics of the instruments before actually beginning the review. Sattler (1992) indicated that the reliability coefficients for the WISC-R and the WISC-III are all above .90. The validity coefficients are derived by comparing the WISC with several other reliable intelligence tests and measures of achievement and school grades. Studies generally indicate that both the WISC-R and the WISC-III have satisfactory validity coefficients. Intelligence Quotients (IQ's) are usually reported to be lower using the WISC-III, by 3 points for the verbal score, and 7 points for the performance score. Additionally, usually an IQ score can be considered to be stable over time within 5 years. As children become more and more educated, their IQ's are likely to increase to varying degrees (Sattler, 1992).

K-BIT

Another intelligence test used in the literature is the Kaufman Brief Intelligence Test (K-BIT). This test is a brief, individually administered measure of verbal and nonverbal intelligence. The test requires approximately 20 to 30 minutes to administer and has two subtests: 1) vocabulary (including part A, Expressive Vocabulary, and Part B, Definitions) and 2) Matrices. Age-normed standard scores with a mean of 100 and a standard deviation of 15 are provided for the overall score on the K-BIT, known as the KBIT IQ Composite. The K-BIT's standard scores are comparable to other intelligence tests such as WISC-R (Kaufman & Kaufman, 1990, as cited in Linden, Habib, & Radojevic, 1996).

The construct validity of the K-BIT IQ Composite was compared to both brief intelligence tests such as the Slosson Intelligent Test and comprehensive tests such as the WISC-R. The K-BIT IQ Composite correlated highly with the WISC-R Full Scale IQ ($\underline{r}$ = .80), supporting the construct validity of the K-BIT IQ Composite Score (Kaufman & Kaufman, 1990, as cited in Linden, Habib, & Radojevic, 1996).

The K-BIT is usually selected because its use for repeated measures (test-retest) was better than the longer Wechsler IQ tests because of its brevity. According to Kaufman and Kaufman (1990), the K-BIT is recommended for use in measuring global intelligence of various groups for research purposes. Split-half reliabilities for the K-BIT IQ Composite score is acceptable, with values ranging from, $\underline{r} = .88$ to $\underline{r} = .94$, for ages 5 to 15 years. The test-retest reliability, quite important in this study of treatment changes over time, varies between $\underline{r} = .92$ and $\underline{r} = .93$, for ages 5 to 15. Overall, the test-retest correlation coefficients corroborate the split-half results, offering strong support for the reliability of the K-BIT Composite Score (Kaufman & Kaufman, 1990, as cited in Linden, Habib, & Radojevic, 1996).

Behavioral ratings

ADDES - Home Version. The Attention Deficit Disorder Evaluation Scale (ADDES) is a 46-item behavioral rating scale to assess males and females, ages 4 to 20. The scale is composed of three subscales: inattentive, impulsive, and hyperactive behavior. Parents are asked to rate a behavior on a 5-point scale ranging from "does not engage in" to "one to several times per hour." Responses to test items can be compared to those for children of the same age and sex. Test retest reliability involving 148 children and an assessment interval of 30 days yielded reliabilities of .91, .90, .92, for inattentive, impulsive, and hyperactive behavior, respectively. Interrater reliability was considered to be average with a correlation of .82 across all age levels (McCarney, 1989a).

ADDES- School Version. This rating scale is composed of 60 items that tap behaviors that are considered to be inattentive impulsive, and hyperactive. The same 5-point rating scale is used as in the Home Version. Test-retest reliability coefficients are .97, .89, .92 for inattention, impulsivity, and hyperactivity, respectively. Ratings of 481 students over a 30-day period were assessed in the reliability study. Interrater reliabilities compared ratings of 462 students by 237 pairs of educators. The average correlation was .85. The internal consistency coefficient is .90 (McCarney, 1989b).

The instructions specify that the persons doing the rating assign one of the following scores to each item: "0" = does not engage in the behavior, "1" = one to several times per month, "2" = one to several times per week, "3"= one to several times per day, and "4" = one to several times per hour. A standard score on each of three subscales may be obtained on this edition of ADDES-Home Version: a) inattentive, 19 items, b) impulsive, 15 items, and c) Hyperactive, 12 items. Evidence of content, construct, diagnostic, and concurrent validity is presented in the technical manual for the ADDES-Home Version. Content validity was addressed by having expert judges (diagnosticians and parents) participate in the development, revision and assessment of items for the item pool. Standard item analysis techniques were used to assure acceptable item-total score correlations. Construct validity was established using principal component analysis, diagnostic validity was demonstrated by comparing the mean performance of a sample of ADD and no ADD children, and concurrent validity was demonstrated by correlating scores on the ADDES-Home Version with scores from the same 179 children and youth on the Connors Parent Rating Scale (McCarney, 1989a).

Test retest reliability of the ADDES-Home Version over a 30-day period was computed for a sample of 148 children and youth. Resultant coefficients were as follows: Inattentive Subscale, $\underline{r}$ = .91; Impulsive subscale, $\underline{r}$ = .90; Hyperactive Subscale, $\underline{r}$ = .92; Inter-rater reliability estimates, obtained from a sample of 172 parents, ranged from .80 to .94 with a mean coefficient of .82.

Family assessment

Lubar & Lubar (1999) also discusses the importance of obtaining an accurate assessment of family functioning in order to properly treat children with ADHD. A child may be experiencing a reactive depression to family situational stressors and it can be fruitless to attempt ADHD treatment with neurofeedback without also addressing the underlying mood disorders. Children also react intensely to family drug and alcohol problems and the likely possibility exists that the child's behavior is related to the family system rather than to a specific underlying neurological condition of ADHD. In many of the studies surveyed, the only family variables cited were socio-economic status, race, and occasionally whether the family was intact or disrupted. There was no indication of overall family functioning such as modes of discipline, or the presence of mood disorders either within the child or the parents. These factors may account for some of the variability in treatment outcomes and the lack of success in some cases.

Comorbidity of other disorders

Another clinical issue that may unknowingly affect treatment outcome, both in the studies reviewed and in society in general, is the high prevalence of other comorbid disorders in individuals diagnosed with ADHD. Othmer, Othmer, & Marks (1991) indicate that over 50% of children with ADHD are comorbid for other disorders. The rate of comorbidity is in the range of 30-50% for Conduct Disorder, 35-60% for Oppositional Defiant Disorder, 20-30% for Anxiety Disorders, 30% for Mood Disorders, and 20-25% for learning disabilities. Many of the studies reviewed attempted to screen for the presence of other comorbid disorders, whereas other studies did not. This high prevalence of other comorbid conditions has two implications for the research. The first is that treatment results can be confounded by the presence of these other disorders. Second, successful treatment with neurofeedback may also help to alleviate some of the negative behaviors associated with some of these other conditions. All of these factors should be considered while considering the research.

Review of the Literature

Kaiser & Othmer, 1997

Sample

The researchers obtained a pool of 408 children and adolescents (age 6-16 years, $\underline{M}$ = 10.7) and 122 adults (17-67 years, $\underline{M}$ = 37.2) to participate in this study. Ninety-two of the children and adolescents, and 58 of the adults were female. Subjects were obtained at nine clinical settings affiliated with EEG Spectrum, Inc., and were selected based on the availability of pre and post-training data for the TOVA. None of the subjects were on stimulant or antidepressant medications during the testing. Most suffered from ADHD and many also had comorbid conditions such as Tourette's syndrome, minor traumatic brain injury, epilepsy, anxiety disorders, and depression. The prevalence of so many comorbid disorders may be common for these clinical settings affiliated with EEG Spectrum, Inc., as they have been known in the last 10 to 15 years for treating these types of disorders with neurofeedback and are therefore most likely to attract populations accordingly. Subjects also included some who were referred for ADHD, but may not have met all criteria for a classical diagnosis.

The training protocol consisted of rewarding enhanced EEG amplitudes in the SMR band while simultaneously inhibiting excessive theta and high beta. Electrode placement always included one electrode site on the sensorimotor strip at either C3 or C4 and less commonly one electrode with either frontal or parietal placement. If training was done at C3 and C4 only, then a referential electrode was placed on the proximate ear. If training was done on frontal or parietal placement, the set up was bipolar with either C3-Fpz or C4-Pz. If the C3 placement was used, then the neurofeedback rewarded beta activity. If the C4 placement was used, then SMR activity was rewarded. Occasionally the two protocols were used in succession during a single training session with respective duration (10 minutes - SMR, 20 minutes - beta).

Training consisted of 30 minutes of visual and auditory feedback. Subjects were evaluated prior to and at completion of training which was set at a minimum of 20 sessions. Those subjects who were further treated were retested after approximately 40 sessions. Most subjects completed or discontinued training after 20 sessions. A Huynh -Feldt correction for degrees of freedom was applied to the task by measure interaction to counter potential nonsphericity of the four dependent measures. When an interaction of condition (treatment by dependent measure) was significant at the .01 level, planned comparison t-tests were used to evaluate differences for each dependent measure, applying the Bonferroni correction for multiple tests.

<u>Results</u>

Repeated measures analysis of variance (ANOVA's) were used to evaluate the effect of group membership for three factors: medication, gender, and age. Medication (MED) refers to whether subjects took medication for their ADHD symptoms or other comorbid conditions at any time during their EEG biofeedback training. Medication information was present only for 324 subjects, and the data from only these individuals were analyzed. No effects for medications (F [2,551] = 1.884 [non significant]), gender, (F [2,417] = 0.949 [non significant]), nor age (F [2,447] = 3.754, $p < .01$) were found on the TOVA measures. As no significant difference was found between groups, all groups were combined into a single group. Repeated measures ANOVA's were used to evaluate the effect of neurofeedback on the dependent variables of Inattention, Impulsivity, Response Time, and Response Variability. Low scores were truncated at four standard deviations below normal (i.e., 40 points). The following Table 1 is a list of pre and posttraining scores and the subsequent changes.

Table 1

Pre and Posttraining Scores

TOVA Factor	Pre-training	Post-training	Change
Inattention	83.4	91.7	+8.3
Impulsivity	85.5	98.9	+13.4
Response Time	89.9	88.4	-1.5
Response Variab.	79.7	86.6	+6.9

Note. From "Efficacy of SMR-Beta Neurofeedback for Attentional Processes," by D. Kaiser and S. Othmer, 1997. [On-line]. Available: www.eegspectrum.com/tova97/530tova.htm. Copyright 1997 by EEG Spectrum Inc. Adapted with permission of the author.

From an analysis of the results listed in Table 1, it can be determined that EEG biofeedback produced significant improvement in inattention scores, (F [1,323] = 38.678, p < .001); Impulsivity, (F [1,323] = 191.266, p < .001); Response Variability, (F [1,323] = 32.175, p < .001). Those with pretreatment impulsivity scores less than two standard deviations below the mean (i.e., scores of 70 and below) improved more than 25 points in measures of inattention, (F [1,92] = 97.414, p < .001). Sixty-two subjects underwent an additional period of training after 20 sessions were completed. These were individuals who had achieved only modest gains after 20 sessions of treatment. Impulsivity was found to improve from pretreatment levels after

20 sessions and then continued to improve after 40 sessions. Response variability, however, improved significantly only after 40 sessions.

The researchers state that the efficacy of SMR training for attentional deficiencies is clearly demonstrated. Significant improvement was found for measures of inattention, impulse control, and consistency of response after approximately 20 sessions or neurofeedback treatment. They also noted an intriguing trend in the data. It appeared that those with the most severe deficits in pretest scores of attention had the most significant improvements at posttest. It also appeared that more than 75% of all subjects with deficits improved on one or more measures, a response rate comparable with psychostimulant therapy. Impulse control improved from a borderline functioning level before training (score of 85.5) to the population norm (98.9). When only those individuals with severe pretreatment deficits in a measure were analyzed, significant improvement was seen in all measures. Inattention scores improved nearly two standard deviations in response to treatment. For individuals who chose to continue treatment until 40 sessions ($\underline{n}$ = 72), impulse control and response consistency continued to improve after 20 sessions.

In looking at the present study, there are a few limitations that can be noted. The results cannot explicitly confirm the validity of neurofeedback training since data was selected from a clinical population and not by random assignment. Subjects were often treated with more than one protocol which also may have affected the outcomes. Additionally, due to the presence of comorbid disorders such as Tourette's Syndrome, minor traumatic brain injury, Conduct disorder, and anxiety and depressive disorders, the sample may have additional confounding variables not detectable via the data and experiment methods used. For example, in several subjects tested, their performance on impulsivity measures actually declined. There was no determination as to why this happened. Again, these data may be the result of the complexities of the clinical sample. Some of the positive aspects of this study include the large number of subjects and the significance of the majority of the data despite the complexities of the sample population.

Additional questions regarding the author's approach of measuring only the changes in the amplitudes of theta may impact interpretation of the results. Typically, the ratio of theta to beta is used instead of the actual theta and beta levels because it controls for the gradual EEG differences between the younger and older ADHD subjects. In other words, as individuals become older, both their theta and beta amplitudes decrease, but their theta: beta ratio remains more consistent (Linden et al., 1996).

Kaiser, 1997

Sample

The researchers conducted a study with 142 adults (age 19-79, m = 40.8) with females comprising approximately 50% (n = 73). Subjects were obtained at 10 clinical settings affiliated with EEG Spectrum, Inc. and were selected based on the availability of pre and posttraining data for the TOVA. None of subjects were on stimulant or antidepressant medications during the test. Most suffered from ADHD, but, as in the previous study, many also had comorbid conditions such as Tourette's syndrome, minor traumatic brain injury, epilepsy, anxiety disorders, and depression. Subjects also included some who were referred for ADHD, but may not have met criteria for classical diagnosis.

The training protocol consisted of rewarding enhanced EEG amplitudes in the SMR band while simultaneously inhibiting excessive theta and high beta. Electrode placement was similar to the previous study (Kaiser & Othmer, 1997). Training consisted of 30 minutes of visual and auditory feedback. Subjects were evaluated prior to and at completion of the training which comprised a minimum of 20 sessions.

A Huynh -Feldt correction for degrees of freedom was applied to task by measure interaction to counter potential nonsphericity of the four dependent measures. Planned comparison t-tests were used to evaluate differences for each dependent measure, applying Bonferroni correction for multiple tests.

Results

Repeated measures analysis of variance (ANOVA's) were used to evaluate the effect of neurofeedback on the dependent variables, Inattention, Impulsivity, Response Time, and Response Variability. Low scores were truncated at four standard deviations below normal (i.e., 40 points). The following Table 2 shows the pre and post training data.

Table 2

Pre and Posttraining Data

TOVA Factors	Pre-training	Post-training	Change
Inattention	85.9	96.1	+10.2
Impulsivity	85.4	98.7	+13.2
Response Time	103.1	103.0	-0.1
Response Variability	86.7	95.7	+9.0

Note. From "Efficacy of Neurofeedback on Adults with Attentional Deficit and Related Disorders," [On-line]. Available: www.eegspectrum.com/tovadult/adults.htm. Copyright 1997 by EEG Spectrum, Inc. Adapted with the permission of the author.

A significant interaction of treatment and TOVA measures was found, [F (2,231) = 11.780, $p < .001$]. Neurofeedback produced significant improvement in inattention scores, (F [1,141] = 17.273, $p < .001$), impulsivity scores, (F [1, 141] = 85.760, $p < .001$), and variability of response time, (F [1,141] = 26.570, $p < .001$). No effect for response time was found. As in the previous study (Kaiser & Othmer, 1997), a trend was noted where the most significant improvements occurred in the area of inattention when the pretest scores were in the most severe deficit range (e.g., pretreatment scores below 70). Only a handful of subjects demonstrated marginal declines in impulsivity scores whereas the majority improved greatly in proportion to pre-treatment values. Those subjects with pretreatment impulsivity scores greater than two standard deviations below the mean (i.e., scores of 70 and below) on average improved more than 27.2 points. Response variability improved 25.9 points and inattention scores improved by 40.4 points for those with pre-training scores of 70 or below.

It appears that neurofeedback produced clinically significant improvement in 83% of all the subjects, superior to the rate of psychostimulants, which stands at approximately 70% (Cantwell (1994) and Barkley (1990), as cited in Kaiser, 1997). Many of the patients had already undergone numerous prior treatments including treatment with stimulant medication with little or no success in a variety of settings. Some of the adults had suffered from attentional and cognitive disorders for 20 to 30 years.

The results of this study may be even more impressive than the previous study since so many of the previous subjects had undergone numerous other treatments for their condition with little or no success. Additionally, they received treatment from a variety of settings and with a variety of clinicians, so that results due to the consistent quality of the treatment if they had all received treatment at one facility can most likely be alleviated. The high rate of success of neurofeedback in treating attentional problems in the present and in earlier studies seems to imply that profound effects on neurobiological mechanisms may be responsible for the results (Sterman (1996) and Othmer (1998), as cited in Kaiser, 1997).

This study contains many of the limitations mentioned in the Kaiser & Othmer study (1997). Data were selected from a clinical population and not by random assignment. Subjects were often treated with more than one protocol which also may have affected the outcomes. Additionally, due to the presence of many comorbid disorders, the sample may have additional confounding variables not detectable via the data and experimentation methods used. Some of the positive aspects of this study include the large number of subjects and the significance of the majority of the data despite the complexities of the sample population. Additionally, this study targeted strictly adults, whereas many of the other studies in this field had previously studied only children and adolescents.

<u>Lubar, Swartwood, Swartwood, & O'Donnell, 1995</u>

Lubar, Swartwood, Swartwood, & O'Donnell (1995) conducted a three-part study in which they attempted to assess the effectiveness of neurofeedback treatment for Attention Deficit/Hyperactivity Disorder.

<u>Part I: Effect of neurofeedback on a continuous performance task (TOVA)</u>

<u>Sample.</u> The subjects studied consisted of 23 children and adolescents ranging in age from 8 to 19 years in age who participated in a 2 to 3 month

summer program of intensive neurofeedback training. Nineteen subjects participated in part one of the study to assess the effect of neurofeedback on a continuous performance task, the TOVA. All subjects were neurofeedback clients in treatment for Attention Deficit/Hyperactivity Disorder. Participants were selected based on the availability of pre and posttraining data for the TOVA. All subjects in this part of the study were trained under identical treatment protocols. None of the subjects were on any stimulant or anti-depressant medication during this part of the study. The participants included 3 females and 15 males ranging in age from 8 to 19 years of age. All were Caucasian from middle income families. All clients met the following criteria in order to undergo neurofeedback treatment: (1) behavior symptomatology consistent with DSM-III-R criteria for the diagnosis of Attention Deficit Disorder, (2) no specific sensory defects or any other comorbid functional or physical illnesses, (3) power spectral analysis of the EEG displaying a pattern consistent with the diagnosis of ADHD (Mann et al., 1991).

All of the subjects participated in a program during the summer months of 1992 designed to provided intensive neurofeedback training consisting of daily 1-hour training sessions. Sessions were conducted Monday through Friday for as much as 8 to 10 weeks. The goal was to provide as close to 40 sessions as possible. Assessments were conducted using standard neurofeedback equipment and software. Subjects were randomly assigned to one of seven therapists. All seven therapists had at least 1 year of extensive experience in providing neurofeedback training for ADHD, and had at least bachelor's or master's degrees in heath care or education fields. EEG recordings were obtained from a bi-polar electrode situated on the midline halfway between Cz and Pz and halfway between Fz and Cz. A reference electrode was placed on the left earlobe. Therapists monitored beta activity above threshold levels that occurred while theta was suppressed.

The study used two treatment paradigms. The first paradigm was where theta thresholds were set a little lower than average microvolt theta activity and beta thresholds were set at average microvolt beta activity levels. In the second paradigm, beta thresholds were set a little higher than average microvolt beta activity and theta was set at the average of the theta activity for the individual child. Both paradigms were geared toward decreasing theta by inhibiting theta activity or rewarding beta activity. Training sessions were subdivided into a 2-minute baseline period, two 5-minute feedback conditions, a 5-minute reading condition with feedback, and a 5-minute listening condition with feedback. During the reading conditions, subjects read grade or age appropriate materials. Similar materials were read to the subjects by the therapist during the listening condition in the session. The TOVA was administered as part of the intake and upon completion of treatment.

<u>Results.</u> EEG data were analyzed using Spearman Rank Order Correlations. EEG changes were defined as a significant negative correlation of microvolts of theta across sessions ($\underline{p} < .05$). EEG changes were not defined according to beta levels because both training paradigms were encouraging a decrease in theta and an increase in the percentage of time their beta was above a set threshold. Because of this arrangement, no changes in actual microvolts of beta were expected, but rather only changes in the percentage of beta above the threshold levels.

Spearman Rank Order Correlation indicated that 12 subjects showed significant decreases in theta activity across sessions (known by the name EEG Change group), whereas 7 of the subjects did not reflect any decreases in theta (No EEG Change group). A Spearman Rank Order Correlation of total number of sessions by microvolt levels revealed a significant negative correlation ($r = -.88$, $p < .01$, two-tailed). The correlation for the No EEG Change group was not significant. All 19 subjects completed at least 30 sessions, 9 of 12 of the EEG Change group completed 40 sessions, and all 7 of the No Change group completed 40 sessions. There was a significant negative correlation for session by microvolt levels of theta for those subjects in the EEG Change group over 30 sessions ($r = -.872$, $p < .05$) and no significant correlation for the No EEG Change group over the same 30. Baseline microvolt theta levels were not significantly different between the EEG Change group ($M = 13.9$. $SD = 5.3$) and the No EEG Change group ($M = 13.2$, $SD = 3.6$) (t [17] = .33, $p < .75$). Additionally, no significant differences in microvolt theta activity were found between subjects trained in Paradigm 1 or Paradigm 2.

A statistical analysis of the percentage of theta and beta activity above the threshold levels was not possible due to periodic changes in threshold levels. Thresholds were changed periodically to maintain reward levels between 14 and 25 per minute. The variability in the threshold levels made it inappropriate to examine the percentage scores across sessions because percentage scores vary depending on the threshold level.

Changes on the TOVA were assessed by determining the number of TOVA scales out of 4 in which improvement occurred for each child. Independent t-tests were used to assess significant effects of EEG change on

TOVA performance. Straight differences between pre and posttest administrations were not used because such scores can be misleading when comparing changes made by older children relative to younger children and can exaggerate changes made by younger children relative to older children. Therefore, each child was given a score from 1 to 4 based on the number of scales in which they improved. Improvement on a scale was defined as a change in the raw score in the expected direction. None of the subjects trained were worse on the posttest. The group of children who showed significant EEG changes ($N = 12$) improved on an average of three TOVA scales, while the group with No EEG Change ($N = 7$) improved on an average of 1.5 TOVA scales (t [17] = 2.99, $p < .01$, two-tailed).

This study provided reasonably objective assessment of the efficacy of neurofeedback treatment for ADHD. Greenberg (1987, as cited in Lubar, Swartwood, Swartwood, & O'Donnell, 1995) indicated that the TOVA has been shown to reflect the improved performance following standard drug intervention. The subsequent implication is that the TOVA would also be a good measure of improved performance with neurofeedback treatment as well. Successful neurofeedback seems to have an effect similar to that of the improvements noted in pharmacological intervention on attentional processes. The difference between traditional drug treatment of ADHD (such as Ritalin) and neurofeedback is that the performance improvements with drug treatment are only noticeable while blood levels of the medication are at a therapeutic dose (Brown, Borden, Wynne, & Schleser, 1986, as cited in Lubar et al., 1995).

Some of the critiques of the previous study include the lack of a control group and the subsequent lack of randomness in assignment to the treatment group. All of the participants were clinic clients and therefore were motivated for treatment and had some expectations that treatment would work. The selection was based instead on the availability of pre and post treatment TOVA. The participants therefore only included subjects that actually completed treatment with neurofeedback. There may have been a large population of children involved in the neurofeedback treatment who actually dropped out due to a lack of improvement in their ADHD symptomology and therefore the results of the study may be biased. However, the overall posttreatment gains for the treated subjects offer at least some support for the efficacy of neurofeedback for ADHD clients.

Part II: Effect of neurofeedback on behavior ratings

Sample. The subjects in this part of the study were 2 females and 11 males. Criteria for participation in this part of the study were the same as before (the availability of pre and posttest data). Neurofeedback treatment was conducted in the same way as in Part I of this experiment with the same two training paradigms. In order to assess behavioral changes as rated by parents, the McCarney Attention Deficit Disorders Evaluation Scale (ADDES) was completed by parents pre and post neurofeedback training (McCarney, 1989, as cited in Lubar, et. al., 1995). The subscales measured by the ADDES are inattention, impulsivity, and hyperactivity. Forty-six items are included on the scale, and parents were instructed to rate the child's behavior in the home environment on a scale of 0 to 4 (0 = does not engage in the behavior, 4 = one to several times per hour). Raw scores on each of the subscales were converted into standard scores.

Results. Differences in ADDES standard scores before and after treatment were assessed by paired t-tests. Behavioral reports by parents on the

ADDES indicate significant behavioral improvement following neurofeedback training in each of the three subscales; inattention (t [12] = -4.474, $p < .001$), impulsivity (t [12] = -6.596, $p < .001$), and hyperactivity (t [12] = -4.60, $p < .0001$). A re-analysis of the data according to the direction of the changes made after neurofeedback was also performed. The results showed no significant differences in behavior ratings between those subjects who made EEG changes and those who did not. In other words, the behavior ratings were similar for both the EEG Change group and the No EEG Change group.

One of the major critiques of this part of the study is the use of subjective rating scales. The parents in this study, and in others, may tend to emphasize the positive gains based on their expectations or desires for treatment results. One facet of the results presented seemed unclear. The authors mentioned that there were no significant differences in behavior ratings between those subjects who made EEG changes and those who did not (i.e., the behavior ratings were similar for both groups). It was unclear as to what exactly the authors meant by this statement. Was the interrater reliability the same between the two groups of parent behavioral ratings, or did the EEG Change group have similar amounts of behavioral change overall in comparison to the No EEG Change group? Did both groups of parents see the same behavioral improvements, even though there were no EEG treatment effects noted for the EEG Change group? Again, the study is unclear on this point. This finding would seem to point again to the difficulty in using subjective ratings scales as they can be heavily influenced by the expectations from the raters.

An additional finding for this participant pool was that there were no significant differences between groups based on the decreased amplitude of theta over sessions. In other words, both groups had some decreased theta, but not enough to be significant. This finding could be interpreted as a placebo effect of their participation in an intervention. A long-term follow-up study over a period of years of the patients who did and did not show changes in EEG readings might reveal differences between groups. One additional consideration given by the researchers themselves is the possibility that some other measure of EEG change may have differentiated better between those individuals showing the greatest behavioral rating scale changes and those showing the least. These measures may include the percent of theta activity over sessions, percent of beta activity over sessions, or microvolt levels of beta or perhaps even the ratio of theta to beta activity. Due to the variability in the threshold levels, however, it was impossible to evaluate all of these measures in this study. Since Part II of this study had some results that would seem contradictory to the results of Part I, (i.e., the lack of a decrease of theta in both groups and no differences in parental behavior ratings), it is possible that there may be some other confounding variables for this treatment group. Some of the possibilities include the placebo effect, parental bias in ratings, comorbid disorders that may have complicated the treatment, or simple chance. This discrepancy might be eliminated with further replication of the research using behavioral ratings as compared to EEG changes and successful attentional deficit remediation.

<u>Part III: Effect of Neurofeedback on IQ Scores.</u>

<u>Sample</u>. Nine males and one female were included in this study. Subjects were all Caucasian and all in middle income families. The subjects

were a subset of the original participant pool that had available IQ scores. Criteria for inclusion were the same as in Parts I and II. Subjects in the study were administered the WISC-R approximately 2 years prior to the beginning of neurofeedback treatment by either their school psychologists or independent practitioners as part of their initial assessments. Upon completion of neurofeedback treatment, subjects were reassessed using the WISC-R by an independent neuropsychologist. This assessment arrangement was considered ideal because there could be a test-retest practice effect if two administrations occur less than 6 months apart.

Results. All subjects in this portion of the study made significant EEG changes. Significant differences were found between pre and posttreatment IQ scores: Verbal (t [10] = -3.65, $p < .005$), Performance (t [10] = -2.18, $p < .05$), Full scale (t [10] = -3.68, $p < .005$). The following Table 3 reveals the pre and posttest scores.

Table 3

Pre and Posttest Scores

IQ Score	Pretest Mean	Pretest Standard Deviation	Posttest Mean	Posttest Standard Deviation
Verbal	113.3	15.9	123.4	12.2
Performance	109.6	17.4	116.1	17.6
Full Scale	112.4	17.8	122.1	16.0

Note. From "Evaluation of the Effectiveness of EEG Neurofeedback Training for ADHD in a Clinical Setting as Measure by Changes in T.O.V.A. Scores, Behavioral Ratings, and WISC-R Performance," by J. Lubar, M. Swartwood, J. Swartwood, and P. O'Donnell, 1995, Biofeedback and Self-Regulation, 20 (1), p. 83. Copyright 1995 by the journal of Biofeedback and Self -Regulation. Adapted with permission.

The mean pretest scores for the whole group are as follows: Verbal (M = 113.3, SD = 15.9), Performance (M = 109.6, SD = 17.4), Full scale (M = 112.4, SD = 17.8). The posttest scores are as follows: Verbal (M = 123.4, SD = 12.2), Performance (M = 116.1, SD = 17.6), Full scale (M = 122.1, SD = 16.0). The 3 subjects with the greatest gains in order of highest to lowest with an increase in Verbal, Performance, and Full Scale IQ's, respectively, were the following: (1) 25, 23, 26 points, (2) 18, 12, 17 points, and (3) 17, 8, 17 points.

The results of this three-part study appear to be significant. There was an interrelationship between several variables, the TOVA, the changes in EEG activity, and changes in WISC-R scores, all associated with neurofeedback training. The subjective behavioral measure did not differentiate between the groups of children that showed EEG changes and those that did not. There were several advantages to this study. First, the treatment was accomplished in relatively controlled conditions. Second, the subjects were seen intensely over a short period of time and engaged in neurofeedback training in which as few changes as possible were made in threshold settings. Third, other forms of treatment interventions were held as constant as possible. However, because they could not exclude the influence of these other treatment interventions entirely, the fact that they may have had some influence on the results cannot be ruled out.

Some of the important findings include the fact that for children, particularly below the age of 14, reduction of theta activity appears to be the key factor associated with improvement in Attention Deficit Disorder. In order to differentiate which variables are more important relative to improvement as a result of intervention with children with ADHD, research designs such as one with matched groups, a control group which receives pre and post measurements without any intervention, and finally a group that is administered only medications with no other intervention would probably offer the best approach. Some of the other limitations of this study include typical maturational effects. Some of the improved IQ scores may have been a result of normal maturation, especially since some of the pre and posttests were 2 years apart. Some of the gains would seem to be in excess of a normal maturational gain in IQ, though maturation cannot be ruled out at this point.

Othmer, Othmer, & Marks, 1991

Sample

The authors conducted a study to attempt to determine the efficacy of EEG biofeedback to remediate attentional deficits and specific learning disabilities. Fifteen school-age children, ages 6 to 16, were accepted into the study if they were referred for academic problems, attentional deficits, hyperactivity, or conduct problems. Eighteen children in all were accepted into the study. Three of these received only six training sessions and terminated training for personal reasons not related to the experiment.

The training protocol employed beta enhancement training with concomitant inhibition of theta and high beta amplitudes. Electrode placement was bipolar, at the sensorimotor cortex, at C1-C5, C2-C6 sites. An ear ground electrode on the same side being trained was also used. Training was performed on the dominant hemisphere unless there were evident hemispheric differences in the EEG, in which case, the hemisphere with the larger EEG readings was trained. Protocols were adjusted in response to verbal reporting from the client, family, and teachers.

The training proceeded in 30-minute sessions on the instrument. An initial intake was conducted prior to training where history was taken, baseline EEG readings were obtained for both hemispheres, and a training session was conducted. The academic testing was accomplished in a 2 to 3 hour session on another day. Academic and cognitive skills were tested with the full WISC-R, the PPVT, the WRAT, Benton VRT, and the Tapping Sub test of the Harris Tests of Lateral Dominance.

Subjects had the following characteristics: Fourteen had been diagnosed as having attention deficit disorder. Of these, 7 had prominent symptoms of hyperactivity, and of those, 2 were on medication for the condition. Seven subjects were identified as having specific learning disabilities; of these, 4 were identified with dyslexia. Six of the subjects were characterized by oppositional/defiant disorder, and two by conduct disorder. Five of the children reported chronic headaches, and 13 of the group reported various sleep disorders, including two cases of an inability to fall asleep in one's own bed or room; four cases were reported of sleep walking and sleep talking, and three cases of nocturnal enuresis. Mood disorders were common as well, with three cases of chronic anxiety, and four of childhood depression or dysthymia. One subject exhibited obvious motor tics. Training was conducted for an average of 35 sessions, at a rate of 2 to 3 sessions per week. One subject was in ongoing educational therapy, and two were in ongoing psychotherapy.

WISC-R Results

The pretest scores on the WISC-R for the study group were noted to be largely above age-corrected norms (mean score = 10) which demonstrates the above average mental capabilities of the study participants overall. However, it was interesting to note that in the subtests usually associated with attentional deficits (Arithmetic, Coding, Information, and Digit Span, the

'ACID' test), the average of the data were all at a score of '10' or below. It was found that the largest improvements occurred in those areas where there were the most significant deficits. In all the data where subjects scored less than 10 on an individual subtest, the average changes were an increase of four points or greater for all subtests except for Mazes and Block Design. The ACID test categories are tightly distributed with gains ranging from 4 to 5 units. The average gain for the subtests that had an initial pretest score below 10 was 5.1 units. The authors considered the possibility that normally, if the individual subject were to retake the subtest without practice effects, they would most likely replicate the score on the subtest within 1.5 points. With this finding in mind, then, a gain of 3 points could be considered significant with 97% confidence. If a subtest was reproduced and there was variability within 2 points, a three-point gain would still be considered significant with an 80% confidence level. The following Table 4 is a list of the average increases in WISC-R subtest scores for all subjects.

Table 4

Average Increases in WISC-R Scores

Subtest	Increase	Subtest	Increase
Picture Completion	5 points	Information	2 points
Comprehension	5 points	Coding	2 points
Arithmetic	4 points	Mazes	2 points
Similarities	4 points	Vocabulary	2 points
Picture Arrangement	3 points	Object Assembly	2 points
Digit Span	3 points	Block Design	2 points

Note. From "EEG Biofeedback Training for Attention Deficit Disorder, Specific Learning Disabilities, and Associated Conduct Problems," by S. Othmer, S. Othmer, and C. Marks, 1991, [On-line]. Available: www.eegspectrum.com/adhd91/adhd91.htm. Copyright 1991 by EEG Spectrum, Inc. Adapted with permission of the author.

The following Table 5 is a list of the average increase in WISC-R subtest scores for all subjects with pretest scores below 10.

Table 5

Increase in WISC-R Scores for Pretest Scores Below '10'

Subtest	Increase	Subtest	Increase
Information	4 points	Picture Completion	7 points
Similarities	8 points	Picture Arrangement	7 points
Arithmetic	6 points	Block Design	1.5 points
Vocabulary	4 points	Object Assembly	4 points
Comprehension	7 points	Coding	4 points
Digit Span	5 points	Mazes	3.5 points

Note. From "EEG Biofeedback Training for Attention Deficit Disorder, Specific Learning Disabilities, and Associated Conduct Problems," by S. Othmer, S. Othmer, and C. Marks, 1991, [On-line]. Available: www.eegspectrum.com/adhd91/adhd91.htm. Copyright 1991 by EEG Spectrum, Inc. Adapted with permission of the author.

The increase in verbal and performance IQ scores was presented on a graph, but the data were not easily accessible for comparison. The following Table 6 is a list of the Full-Scale WISC-R IQ changes.

Table 6

<u>Full Scale WISC-R Changes</u>

Initial Full Scale IQ	Posttest Increase in IQ
90	+37
91	+33
96	+34
99	+29
103	+35
105	+29
106	+27
111	+24
118	+24
123	+5
126	+22
128	+14
130	+14
139	+14
143	+7
Average: 114	+23

<u>Note.</u> From "EEG Biofeedback Training for Attention Deficit Disorder, Specific Learning Disabilities, and Associated Conduct Problems," by S.

Othmer, S. Othmer, and C. Marks, 1991, [On-line]. Available: www.eegspectrum.com/adhd91/adhd91.htm. Copyright 1991 by EEG Spectrum, Inc. Adapted with permission of the author.

The Peabody Picture Vocabulary Test (PPVT) was used to supplement the WISC-R in the authors' study. They stated that it would be helpful "since vocabulary is perhaps the best single predictor of IQ as it evaluates verbal performance without involving word recall." The comparison of the PPVT with the WISC-R were presented in graph form. They indicated that the results were "hampered by the age limitations of the two tests, namely 18 in the case of the PPVT and 16.8 in the case of the WISC-R." The PPVT scores were consistent in some cases, but in other cases, the results actually show decreases in PPVT scores in the posttest. The authors did not have any explanation for the discrepancy and suggested more investigation.

The authors also used the Wide Range Achievement Test. Ten of the subjects were also given the reading and arithmetic subtests of the WRAT, again with mixed results. Six subjects showed major gains in reading performance, but five of these were reading above grade level at the outset. Of the three who had a significant deficit in reading, only one showed gains well in excess of chronological age. The arithmetic results were mixed as well. Improvements of more than two grade levels were shown by 4 of the 10 subjects tested. All of these subjects had been lower than grade level at the outset of training. In contrast, two subjects actually showed significant decreases in score and one had previously registered a deficit. The subject had evidently been in a home-schooling situation where the authors speculated that the student's arithmetic skills may not have been cultivated.

The authors also used the Bender Visual Retention Test (VRT). In this test, simple geometric figures are drawn from memory after a brief exposure. The number of errors made is shown, along with the number of correct representations. Six of the 14 subjects improved from a rating of average or below to superior. Six showed lesser gains, and two were rated superior in the pretest with no significant changes. The authors conclude from these results that the EEG training can improve short-term visual memory.

The Harris Tests of Lateral Dominance - Tapping Subtest was used to determine shifts in handedness, and as a test of changes in eye-hand coordination. The test compared right and left-hand performance in a timed challenge in which pencil dots must be placed in rows of boxes. Dominance was defined as right or left if the scores differed by 20% or more. Seven of the 15 subjects significantly improved their score, 3 by more than 100%. The authors present the results based on a theory that right handedness is the standard and that left handedness may be a result of injury such as birth trauma which leads to compensation and subsequent left handedness (Hepper, 1990, as cited in Othmer, Othmer, & Marks, 1991). The authors indicate that any trauma results in a shift toward left handedness. As this "deficit" in cortical organization is remediated, the "native" right handedness may be restored.

Follow-up was conducted with parents more than one year after the initiation of EEG training. Questions were asked with respect to a number of categories and results were scored +1 in case of significant improvement; a score of +2 was given for "major" improvement and a negative score of 1 was given for residual problem areas. Sometimes both positive and negative scores were given where the researchers thought it was appropriate. The subjects were divided into two groups, the first where significant benefit was seen or few residual problems remained, and the second group, where major problems still remained.

The first category included areas in which improvement was expected, such as hyperactivity, concentration, and sleep disorders. Ranked first was self-esteem. The authors claimed that children benefited in terms of their self-esteem due to the fact that the EEG biofeedback training was something they did for themselves. Dominant influence on self-esteem was that they were more functional, their sibling and peer relationships were improved, and interactions with authority figures, parents and teachers were better. The school grade category was affected in that four of the subjects were in academic environments where grades were not given. Grades remained a problem with only one child. The three cases of nocturnal enuresis responded to the training, as did the single case of obvious motor tics.

The second categories rated were behavioral categories and academic performance. Overall, there seemed to be a lasting impact on behavioral disorders. However, there were significant problems that remained. The authors ascribed this to four factors: (1) unlikely that typical 30-40 session training sessions are sufficient to deal with behavioral disorders, although this number appears sufficient to remediate cognitive deficits, (2) a higher standard is applied by parents (i.e. they agree their children are reading better, but for behavioral problems, parents see success as a complete elimination of the problem instead of a 70% improvement in frequency or intensity), (3) Parental expectations may increase with improvements in child's behavior, and (4) behavioral disorders are usually complicated by psychological factors which take time, and possibly other modalities to resolve. In academics, the authors indicate that it is likely that more time must elapse before children show the full benefit academically of their new cognitive skills.

The authors indicate that this study demonstrates a significant benefit effect of beta training on attentional deficits, specific learning disabilities, sleep disorders, headache syndromes, and on certain adverse behavior. With the WISC-R, it was shown that for initial values less than the norm, improvements were generally well outside the range of test uncertainty.

The authors indicate that the testing of the WISC-R demonstrated gains in alertness, attentiveness, and perseverance that were greater in the retest. Impulsivity was better, and test anxiety reduced. The improvements were attributed to behavioral and cognitive factors and therefore they stated that the improvements appear to be directly attributable to EEG training, rather than being simply incidental.

The study is one in which significant EEG, academic, and behavioral changes were noted in participants in treatment. The study corroborates the results of other studies that display the efficacy of neurofeedback in the treatment of ADHD symptoms and also demonstrates some remedial effects on other disorders commonly associated with ADHD.

Some of the critiques of the study concern the use of the instruments and the subsequent conclusions the authors reach using those instruments. The first test they discuss is the WISC-R. One positive facet of this study was the fact that the authors tried to eliminate the possibility of practice effects on the WISC-R by insisting on an interval of at least 9 months before retest. Should there actually be practice effects, the authors present an interesting argument for the fact that practice effects, if they existed, would be negligible. First, in one sample of retest error with a sample of 300, after only a 1-month interval, only a 7-point IQ change was observed (Wechsler, 1974, as cited in Othmer, Othmer, & Marks, 1991). After some 6 to 9 months, more extinction would naturally be expected. Second, the concern about retest error diminished if one is observing significant change in the WISC-R. For example, in a number of the WISC subtests, the child is asked to stop after a certain number of errors, or by reaching the end of a time limit. On the retest, therefore, the child is exploring new ground if he is in fact doing significantly better than before. One alternative to their speculation is that the child, due to practice effects, could have sped through sections of the test that he had already successfully completed and therefore now, for the first time, actually had an opportunity to get to questions he did not get to before.

The authors indicated that significant gains were observed in areas where long-term memory cannot have been an issue, such as Digit Span. However, the possibility exists that a child or adolescent, during the first administration of the test, actually learns how to listen more carefully and organize the numbers in a way that is easier to recall. This cognitive strategy would be indicative of practice effects, not of the ability to remember the actual numbers used in the subtest. One reasonable argument that would contradict the last hypothetical statement is that the gains were in fact least where a practice effect might be expected, such as Block Design and Object Assembly. Block Design and Object Assembly tend to tap visual organizational and performance skills. In the Block Design subtest, for example, once a subject has completed the Block Design subtest, it is fairly easy to cognitively figure out a more structured approach to replicating the design presented, and therefore the typical subject would be more adept at the task upon the second administration of the Block Design subtest.

In the Object Assembly subtest, a subject may remember the failed attempts to create the object and therefore will not repeat these same mistakes. Instead, they may try new combinations and permutations, with the possibility of successfully completing the object where previously they had failed. Additionally, it would seem likely that a subject would remember the successful completion of objects from the previous administration and therefore put these objects together more quickly, therefore also improving their score. Since, however, these subtests seemed to demonstrate the least amount of improvement, it seems to provide support that the gains seen are in actuality not a result of practice effects.

The authors also used the Wide Range Achievement Test (WRAT) as a measure of improvement for the EEG training. They indicated that they received mixed results in the scores of the WRAT. First of all, the authors did not indicate which version of the WRAT they used. Since the study was done in 1991, it can be inferred that it was an earlier version than the current WRAT-III. Additionally, the WRAT is a test of achievement, not of IQ, and so improvements would be very grade dependent. A student would not likely be able to complete questions beyond grade level if they have not yet been taught these things in their academic setting. Even if the attentional processes improved, they would not necessarily show up as improvement on the WRAT. One other comment involves their rationale for the instruments they chose. They did not indicate their reasoning for their choice of instruments. The study is also unclear as to why they used the WRAT and to whom they administered it. Was it administered to all the subjects, or just to the subjects who would not take the WISC-R?

They also reported mixed results on the PPVT. Again, there is no clarification as to which version of the PPVT was used. The original version was constructed in 1959 and updated in 1981. Revised version scores may be more comparable. Also, according to Sattler (1992), the PPVT scores are not interchangeable with WISC-R scores and in some cases, the PPVT yields considerably lower scores than does the WISC-R. Although the PPVT measures vocabulary which can be a good indicator of general verbal intelligence, the test measures both recognition and visual comprehension because of the use of pictures together with words. The Wechsler intelligence tests involve retrieval of information to a greater extent than does the PPVT-R. Receptive vocabulary is related to general intelligence, but Sattler states that the practice of using the PPVT to estimate general intelligence does not appear to be justified, as it is too limited in its scope, measuring only one facet of a child's ability repertoire (Sattler, 1992). Sattler specifically states that the PPVT is useful in measuring extensiveness of receptive vocabulary. It should not be used as a screening device for measuring intellectual level of functioning. Scores on the PPVT are not substitutes for IQs obtained on Wechsler batteries, and therefore, the authors' use of the PPVT as another measure of general intelligence comparable to WISC-R scores would seem to be inappropriate. This test idiosyncracy would account for the mixed results and actual declines in some IQ scores on the PPVT.

Linden, Habib, Radojevic, 1996

Sample

Eighteen subjects were randomly assigned from community referrals to an outpatient clinic, Mission Psychological Consultants. The subjects were children aged 5 to 15 with a primary diagnosis of ADHD (N = 12) and some also with learning disabilities (N = 6). All subjects were diagnosed using DSM-III-R criteria collected from the following sources: (1) family history, (2) teacher behavior rating scales, (3) parent behavior rating scales, (4) family interview, (5) developmental history, and (6) psychoeducational testing including intelligence and achievement tests. Children who had mental retardation, depression, and anxiety disorders were excluded.

The 18 subjects were randomly assigned to one of two groups: an experimental group, which underwent 40 sessions of EEG feedback treatment over six months (N = 9), or a waiting list control group, which underwent no EEG biofeedback treatment during the same period of time (N = 9). Equal number of ADHD (N = 6) and ADHD with Learning Disabilities (LD) (N = 3) subjects were represented in each treatment group, and statistical analysis indicated that the two groups were equivalent on diagnostic representation.

A waiting list control group was utilized because the option of performing placebo EEG biofeedback for a 6-month time period was decided to be unethical by both the human subjects committee and the biofeedback manufacturer consultants to the study. All subjects in the study were not prescribed or taking any medication for ADHD or involved in other treatments for their disorders during the 6-month duration of their participation in this study. The waiting list control subjects were offered the experimental treatment after completion of the 6-month waiting period as an incentive to remain in the research study without starting any other treatments. The dependent measures of intelligence and parent behavior rating scales were collected prior to and after six months of treatment. The IQ examiners and research assistants that scored the rating scales were blind to the subject's group assignment. The principal investigator randomly assigned the subjects into the two groups.

EEG sessions were 45 minutes in length and consisted of electrode attachment and 3, 10-minute EEG biofeedback segments: (1) standard training (biofeedback with eyes open while attending to visual and auditory feedback, (2) a reading task (biofeedback during reading age-appropriate books), (3) an auditory listening task (biofeedback while an assistant read age appropriate material to them). During the reading and listening sessions, if subjects stopped receiving feedback rewards (points or tones) the task was temporarily stopped and the subject was instructed to concentrate until the rewards began, and then continued reading or listening. At the conclusion of each training day, the subjects were given small rewards, (i.e., baseball cards or stickers) which were provided based on their levels of cooperation, effort, and performance.

Subjects attended two sessions per week either after school or on weekends. The first author trained all the EEG neurotherapists who conducted individual sessions for each subject. The neurotherapists, who were constantly in the room sitting next to the subject, instructed the children in learning the feedback process, recorded the subject EEG data after each task, and monitored their EEG recordings to ensure accurate feedback. The children were encouraged to become aware of their brainwave activity and develop their own strategies to obtain the highest amount of reinforcement; however neurotherapists were available to assist the subjects in developing and recalling strategies when necessary.

Visual and auditory feedback was provided via color VGA monitors and audio speakers within the computer. Protocols intended to decrease theta and increase the beta bands of the EEG were used. Audio tones or beeps and visual (graphs, game movement, or points) feedback were attained by the subjects when three conditions were met simultaneously: (1) beta amplitude was above its threshold, (2) theta amplitude was below its threshold, and (3) the EMG muscle artifact was below its threshold. The EEG brainwaves were trained to decrease the theta: beta ratio relative to the subject's performance by gradually decreasing the thresholds for theta and increasing the thresholds for beta as the training sessions progressed. The technique was performed in a similar manner for each child throughout the 40 sessions, regardless of the age of the child or diagnosis.

Electrode placements were attached to scalp at bipolar placements of Cz and Pz and grounded at the right ear. The ratio of theta:beta was used to assess changes in the EEG over time as a basis to modify the training procedures, by guiding the beta threshold settings higher and the theta settings lower, and to assess improvement. This ratio was used instead of the actual theta and beta levels because it controls for the gradual EEG differences between the younger and older ADD subjects (i.e., as individuals become older, both their theta and beta amplitudes decrease, but their theta:beta ration remains more consistent). Unfortunately, software restrictions and revisions of Biocomp and Autogenics equipment, EEG data and threshold settings were inconsistent. Therefore, EEG data were not submitted to statistical analysis.

Measures

Intelligence was measured using the composite score on the Kaufman Brief Intelligence Test (K-BIT). A description of the test and the reliabilities and validity coefficients was presented earlier in the section on methodological considerations and will not be repeated here.

The K-BIT was selected because of its use for repeated measures (test-retest) is better than the longer Wechsler IQ tests because of it brevity. IQ was measured in order to compare the results of the current study to previous studies of EEG biofeedback with ADHD children. The behavioral ratings dependent measure was composed of three scales from two common behavior rating scales. The parent IOWA-Conners behavior rating scale was used for measures of inattentive and overactive (I/O or ADHD) behavior seen in ADHD, and aggressive and defiant (A/D) behaviors seen in Oppositional Defiant Disordered patients (ODD). In addition, the parent behavior rating scale index for inattentive behaviors by Swanson, Nolen, and Pelham (SNAP) was used to assess the presence of ADD behavior without hyperactivity. These behavior rating scales were selected for their ability to differentiate subgroups of ADHD children, and most importantly their ability to be used for repeated measures.

The IOWA-Conners Behavior Rating Scale is a 10-item scale designed to provide a standard measure of attention deficit/hyperactivity and aggression in children. There are two subscales, each consisting of 5 items: the Inattention/Overactivity scale and the Aggressive scale. The items contained on the two rating subscales were derived from the Conners Teacher Rating Scale, the most commonly used rating scale for research and treatment of hyperactivity and related disorders (Atkins & Milich, 1987, as cited in Linden, Habib, & Radojevic, 1996). Items are scored by a child's classroom teacher or parent as occurring on a continuum, 0 = not at all, 1 = just a little, 2 = pretty much, or 3 = very much. The test-retest reliability for the IOWA-Connors is $\underline{r}$ = .89 for the inattentive/overreactivity subscale (I/O) and $\underline{r}$ = .86 for the aggressive subscale (A/D). Internal stability coefficients are $\underline{r}$ = .80 (I/O) and $\underline{r}$ = .87 (A/D). Validity of the IOWA-Connors has been established with comparison to other behavioral rating scales and methods. Significant correlations were reported for the I/O scale and the Hyperactivity factor of the Conners Teacher rating Scale, and for the A/D scale with the Conduct Problem factors of the Connors Teacher rating scale. Convergent and discriminant validity for these scales was evidenced with classroom observations of clinic referred boys (Milich & Fitzgerald, 1985, as cited in Linden, Habib, & Radojevic, 1996) and playroom observation data (Milich, Loney, & Landau, 1982, as cited in Linden, Habib, & Radojevic, 1996).

The SNAP Questionnaire was developed by Swanson, Nolan, and Pelham in 1981 (as cited in Linden, Habib, & Radojevic, 1996). It consists of 46 items taken from the DSM-III symptoms of ADHD, the DSM-III-R symptoms of ADHD and Oppositional Defiant Disorder (ODD) and the Carson/Lahey items for ADD without hyperactivity or undifferentiated ADD (sometimes referred to as ADD in comparison to ADHD). The Inattention subscale contains 5 items. The items are scored in the same manner as the above IOWA-Conners Rating scale. The reliability and validity of the Inattention subscale of the SNAP are similar to the IOWA-Conners.

Results

Multivariate analyses of variance (MANOVA) were conducted on the pretreatment dependent measures of IQ, inattention, overactivity (hyperactivity) and aggressive-defiant (ODD) behavior. The two conditions did not significantly vary on any of these measures. Mean age for each group was identical, 9 years and 2 months, and so no analysis was necessary for age effects. A 2 (Experimental versus Control) x 2 (pre versus post) multiple analysis of variance (MANOVA) for the IQ and behavioral rating variables did not demonstrate significant main or interaction effects. However, a trend emerged approaching significance for the main effect of time. Since specific predictions were made that the experimental group would outperform the control group, follow-up ANOVAs were employed to test the trials effect further. The variable of IQ was significantly enhanced at posttreatment for the EEG Biofeedback group (F [1,16] = 6.41, p = .02). The experimental group had an average increase in IQ of 9 points greater than the Waiting List Control Group. The Inattentive behaviors were significantly reduced at posttreatment for the EEG Biofeedback group, (F [1,16] = 5.27, p = .04). However the two groups did not significantly differ on Aggressive/Defiant behaviors at posttreatment. Although there was no statistical difference in hyperactive behaviors, the EEG Biofeedback group's hyperactive diagnosis decreased below the cutoff score that is typically used for a positive finding of hyperactivity, documenting the clinical significance of this improvement.

The authors also evaluated the sample size by calculating a power analysis for the four dependent measures. At the .05 alpha level and a difference of 0.5 standard deviation, the power coefficients were as follows: IQ > .99, Hyperactivity = .68, Inattention > .99, and Aggressive/Defiant > .99. All but Hyperactivity exceeded the de facto standard for adequate power, .80.

The results of this study are consistent with previous research conducted by Lubar and associates (1976, 1984, 1985, 1991, as cited in Linden, Habib, and Radojevic, 1996), and Tansey (1983, 1984, 1985, 1990, as cited in Linden, Habib, and Radojevic, 1996). The present study included a larger sample size with adequate power to detect significant differences in IQ and most of the behavioral ratings. With respect to previous research, the current study also utilized improved methodology. It had a control group which received no treatment of any kind; the same type and amount of EEG biofeedback was used for all treated subjects (beta enhancement & theta suppression), and similar dependent measures used in previous research for comparison purposes. The researchers indicated they had difficulties with software and hardware and therefore did not actually have recorded EEG data. However, they did observe enhanced beta amplitudes and decreased theta amplitudes and subsequently changed thresholds accordingly.

Some of the increases in IQ may be due to EEG biofeedback and an increased ability to attend and concentrate, but the increases may also have been affected by reinforcement of these behaviors over 40 hours of focused concentration irrespective of the neurofeedback. If the authors had conducted QEEG assessments pre and posttreatment, they might have been able to distinguish between the two causal factors a little more accurately.

Additionally, the results may have been different if the authors had used more sensitive WISC-R or WISC-III measures of IQ. This study also used EEG training to increase beta. Other studies have focused on the reinforcement of SMR either alone or in conjunction with increases in beta and inhibition of theta. Subjects here received 40 sessions, whereas most children in previous research and clinical treatment received a range of between 40 and 70 sessions. Certain children in the study may not have had the optimal number of sessions necessary to acquire the benefits of EEG training. Individualizing EEG protocols based on each child's ADHD symptoms and brainwave activity may be important in future studies

Some other study limitations include the fact that parent ratings were not completed blind to treatment group. However, parents were not given information about previous rating scores and according to their reports, memory deficits for pretreatment ratings usually occurred. But ratings may have been affected by parents' expectations for improvement.

Rossiter & La Vaque, 1995

Sample

The purpose of this study was to examine the efficacy of 20 sessions of EEG biofeedback in reducing ADHD symptoms and to compare the results with those obtained with psychostimulant medication. The participants were 46 patients seen at two outpatient mental health clinics on a fee for service basis. Subjects were referred by their parents, physician, school, or were self referred. Patients were evaluated by the first author and received a primary DSM-III-R diagnosis of ADHD or Undifferentiated Attention deficit disorder. The study included patients between 8 and 21 years of age, with IQs between 80 and 120. All were administered TOVA pre and posttreatment.

Two treatment groups of 23 patients each were formed. The first group included all patients who received EEG biofeedback (EEG) as part of treatment. The second group included patients who were treated with psychostimulants and did not receive EEG biofeedback (MED). The MED group was drawn from a larger pool of patients (N = 39) ages 5 to 45 and matched with the EEG group by age. Baseline evaluations were completed for both groups of patients before decisions regarding drug treatment were made. The option of EEG or trial on medications was discussed with all regardless of their history of prior treatment with medications or expressed desire to receive EEG. In some cases, the choice of treatment was dictated by the availability of insurance coverage for EEG biofeedback or whether the patient's schedule could accommodate the three treatment sessions per week considered optimal.

Instruments

Intelligence data were obtained using the Kaufman Brief Intelligence Test (K-BIT) or the age appropriate Wechsler Scale (WISC-R or III, WAIS-R). In some cases, results obtained during a school evaluation during the previous year were used. The Behavior Assessment System for Children (BASC) was used to evaluate children and adolescents from 4 to 18 years of age. The BASC provides teacher, parent, and self reports plus direct classroom observations and a structured developmental history. Parent and teacher questionnaires are parallel forms and permit direct comparisons on a number of scales including anxiety, aggression, attention problems, atypicality, conduct problems, depression, hyperactivity, social skills, somatization, depression and withdrawal. Although a combination of the BASC instruments were used clinically, only the 6 to 11 (138 items) and 12 to 18 (126 items) year old Parent Rating Scales completed by mothers were included in the study. Parents rate items on a 4-point scale indicating whether it never, sometimes, often, or almost always occurs. In addition to the clinical scales noted above, the BASC also utilizes three validity scales. The BASC provides separate scales for measuring hyperactivity and impulsivity.

Several broader composite scales were also used in the study. The Externalizing Problems composite is characterized by disruptive behavior problems such as aggression, hyperactivity, and delinquency. The Internalizing Problems composite includes scales that measure depression, anxiety, somatization and similar problems that are not marked by acting out behavior. The Behavior Symptoms Index provides a global measure of psychopathology derived from the other clinical scales.

The baseline evaluation for the EEG and MED subjects included the TOVA and intelligence testing if current IQ data were not available from another source. The BASC was administered for 14 of the EEG group, although the authors did not indicate why all of the EEG group was not given the BASC. The remaining 10 members of the EEG group were evaluated using the Personality Inventory for Children (PIC) or the Minnesota Multiphasic Personality Inventory - Second Edition (MMPI-2) with patients over 18 years of age.

A number of the subjects in both the EEG ($\underline{N}$ = 5) and the MED ($\underline{N}$ = 4) were being treated with psychostimulants at the time of the baseline evaluation. With the exception of two EEG patients being treated with Pemoline (Cylert), all of the patients were taking methylphenidate or dextroamphetimine. Medication was discontinued 2 days prior to baseline testing. This time period was considered sufficient to produce results not contaminated by medication effects. Methylphenidate and dextroamphetamine have half-lives and produce behavior effects for 12 hours or less (Barkley, 1990 as cited in Rossiter & La Vaque, 1995). Pemoline has a more variable half-life and may be effective for as long as 12 to 18 hours (Wender, 1987, as cited in Rossiter and La Vaque, 1995). Personality and behavioral assessment was completed at the same time as TOVA testing. After baseline testing, medications were reinstated for the five EEG patients being treated with psychostimulants and continued at maintenance levels through the 20 EEG sessions.

Post treatment administration of the TOVA for the EEG group was carried out after 20 EEG biofeedback sessions had been completed. This administration occurred from 4 to 7 weeks after biofeedback began. Among the EEG group, 5 of 23 patients were still being treated with psychostimulants. For those patients, medications were discontinued 2 days before posttreatment TOVA's were administered. The MED group was retested while medicated from 1 to 5 weeks after starting medication. The TOVA was re-administered 90 minutes after taking the short acting form of methylphenidate or dextroamphetamine or 2.5 hours after taking the long acting forms of the medications. At that point, the medications are at peak effectiveness (Greenberg & Dupuy, 1993, as cited in Rossiter & La Vaque, 1995).

Both authors provided neurofeedback. Treatment protocols varied and depended on the age, presenting symptoms, and the baseline test results obtained form each patient. EEG protocols were sometimes changed during the course of treatment as target behaviors for intervention changed.

Protocols were patterned after Lubar and Lubar (1984) and Othmer and Othmer (1992). Lubar protocols emphasize suppression activity in the theta range (4-8 Hz) with children and adolescents through the age of 14 increasing beta (16-20 Hz) or sensorimotor rhythm (SMR) output (12-15Hz) with adults 20 and older, and a combination of theta suppression and beta or SMR enhancement in the 14 to 20 age range. The Othmer protocol is to enhance beta (15-18 Hz) or SMR (12-15 Hz) production for all ages. Suppression of theta and high beta is of secondary importance (Rossiter & La Vaque, 1995).

With Lubar protocols, they used two bipolar electrodes, a forehead ground and linked ear reference electrode. With the Othmer protocol, they employed a single active electrode, a reference electrode on the left ear, and a ground electrode on the right ear. The active electrodes were placed at Cz, (Othmer protocol) another midway between Cz and Fz, and midway between Cz and Pz (Lubar protocol), depending on the individual patient's needs.

Patients were seen three to five times per week for 45 to 50 minute treatment sessions that included 30 minutes of EEG biofeedback. Sessions consisted of three 10-minute or two 15-minute segments. At least 10 minutes of the training time was spent in active focusing. The patient was seated in front of a computer monitor with eyes open receiving both visual and auditory feedback. The patient was instructed to increase output in the beta or SMR band while inhibiting theta activity. No other activity was being carried on at the same time. Some patients engaged in reading or another cognitive challenge during part of the 30-minute biofeedback session. Neurofeedback continued through 20 sessions over a period of 4 to 7 weeks.

Patients were re-evaluated using the TOVA in conjunction with parent and teacher questionnaires to determine if there was a positive response to treatment. The determination based primarily on the TOVA results where a change of 7.5 points (M = 100, SD = 15) in either direction is considered clinically significant (Greenberg & Dupuy, 1993, as cited in Rossiter & La Vaque, 1995). When there was evidence of improvement at the reevaluation, it was recommended that EEG biofeedback be continued, usually for an additional 20 sessions. This continuation of treatment was to allow the patient to make additional progress or to provide the opportunity to over learn the skills involved and increase the likelihood that they would continue over time. Otherwise the EEG biofeedback component of the treatment program was discontinued and alternatives considered.

Patients in the MED group were started or restarted on methylphenidate (N = 16) or dextroamphetamine (N = 7) prescribed by personal physicians following the baseline evaluation. After the patient had been on medication for a minimum of 3 days with no significant side effects, the TOVA was readministered. The response to medication was determined by retesting the patient 90 minutes after taking the medication and comparing the results with the pretreatment TOVA.

Treatment was not limited to neurofeedback for the EEG patients or psychostimulants for the MED patients. Additional interventions were provided based on the needs of the individual patient. Additional treatments included school behavior modification programs aimed at improving the accuracy and consistency of behavior and/ or schoolwork. Teachers completed behavior and academic rating forms which were sent home daily or weekly and linked to four to six privileges dispensed by the parents. If patients were experiencing behavior problems at home, the parents were seen as needed to develop effective behavior management strategies. During the time period that the study was conducted, no patients were involved in individual psychotherapy or family therapy. No academic tutoring programs or special education placements were implemented or terminated.

Results

EEG and MED patients were initially matched by TOVA age group. Analysis of demographic and treatment variables indicated that age matching produced treatment groups that were equivalent in most responses. They did not differ in age, general distribution, intelligence, frequency of ADHD as a primary diagnosis, frequency of secondary /tertiary diagnosis, or frequency of LD or Emotionally disturbed diagnoses. The EEG and MED groups were not significantly different on baseline TOVA measures of attentiveness, impulsivity, processing speed or variability in attention. However, more of the EEG ($\underline{N}$ = 17) than MED patients ($\underline{N}$ = 10) had previously been treated with psychostimulants .

The EEG and MED groups did not differ in the frequency of parents receiving behavior management training. However, patients in the MED group were more likely than those in the EEG group to be involved in a school behavior modification program during treatment. The relatively low frequency of school behavior modification for the EEG group is due to the fact that many of the EEG patients were treated during the summer months when school was not in session.

The first purpose of the study was to demonstrate improvement in TOVA outcome variables following 20 sessions of the EEG program. TOVA data for the EEG group were analyzed using a one-tailed t-test for dependent measures. It was predicted beforehand that all four TOVA variables would demonstrate significant improvements following treatment. These predictions were confirmed. The EEG group showed increased attentiveness ($\underline{t}$ = 3.01, $\underline{p}$ = .003), reduced impulsivity ($\underline{t}$ = 2.47, $\underline{p}$ = .01), increased processing speed ($\underline{t}$ = 1.85, $\underline{p}$ = .04), and decreased variability in attention ($\underline{t}$ = 4.67, $\underline{p}$ = .0001). It was also predicted beforehand that the EEG group would show significant behavioral changes on the five BASC scales. The prediction was confirmed. A one-tailed t-test for dependent measures indicated significant reductions on the hyperactivity ($\underline{t}$ = 2.84, $\underline{p}$ = .007), Attention Problems

(t = 2.81, p = .007), Externalizing Problems (t = 2.84, p = .0005), Internalizing Problems (t = 5.01, p = .0001), and Behavior Symptoms Index (t = 4.41, p = .0004) scales.

The second purpose of the study was to compare the effectiveness of the EEG biofeedback program with that of a medication program in reducing the symptoms of ADHD. It was predicted beforehand that both treatment programs would result in significant improvement on TOVA outcome measures. This hypothesis was confirmed. The MED group showed improved attention (t = 2.50, p = .01), reduced impulsivity (t = 3.79, p = .0005), improved processing speed (t = 3.72, p = .0006), and reduced variability in attention (t = 4.08, p = .0003). It was further predicted that there would be no significant difference between the EEG and MED groups in the degree of improvement shown. The results supported this hypothesis (two-tailed t-test for independent measures). There were no significant differences between the EEG and MED groups on change scores (posttest minus pretest score) for errors of omission (t = 0.93, p = .36), errors of commission (t = 0.03, p = 0.98), average response time (t = 0.79, p = .043), standard deviation of response time (t = 0.39, p = .70), or the sum of the change scores on the four TOVA variables (t = 0.11, p = .91).

The study demonstrated that treatment with EEG biofeedback as a major component led to significant reduction in both cognitive and behavior symptoms of ADHD after 20 treatment sessions were completed over a period of 4 to 7 weeks. The EEG group manifested significant improvement in attention, impulse control, speed of information processing and consistency of attention on the TOVA. BASC questionnaires completed by mothers confirmed the reduction in ADHD symptoms and also indicated a decline in internalizing and externalizing psychopathology. In every case where parents or teachers reported significant improvement in behavior or school performance, corresponding improvement in the TOVA performance was observed. This finding confirms that improvement was not limited to TOVA test scores, but had generalized beyond the clinic and was observed as symptom reduction in their daily lives. The EEG biofeedback program led to improvements on all four TOVA outcome variables that was equivalent to that obtained with the medication program.

The study indicated that EEG is an effective treatment for ADHD and may be the treatment of choice in cases where medication is ineffective, only partially effective, has unacceptable side effects, or where medication compliance is low. Improvement was evident in far fewer than the 40 to 80 sessions sometimes cited as the expected course of treatment (Barkley, 1992, as cited in Rossiter & La Vaque, 1995). Additionally, the improvements seen in both treatment groups were considered comparable. This result is seen as encouraging since drug treatment is currently the treatment of choice. The implications for this study seem to indicate that drug treatment does not have to be the only treatment option for parents and children with ADHD.

This study was the first of its kind to actually compare the two different types of treatment. Some of the limitations of the study involved methodology. Because the study took place in a clinical fee for service setting, it was impossible to limit the participants to just the one type of treatment regimen. They continued to engage in other forms of treatment concomitant with the neurofeedback or drug treatment. This additional variable may have confounded some of the results as the effects of treatment could not be considered to be solely the result of either the neurofeedback alone or the drug therapy alone. The study used the BASC parent rating scale. The authors did not discuss the reliability or the validity of this instrument. None of the other studies using behavioral measures used this particular instrument, and therefore the possibility exists that more reliable or more commonly used instruments may have been available. The authors again did not discuss the reason for their choice.

Additionally, the measures used were not consistent across groups. The study indicated that some of the participants in the EEG group were not given the BASC measure, although the authors did not indicate the reason. Additionally, the remaining subjects were instead given the PIC-R or the MMPI-2. Again, the rationale for the adjustment in the study measures was not discussed and the substitution does not seem especially comparable. Both are either parent or self-report measures that discuss specific behaviors, but the purpose of the two tests is very different, and therefore the results could not be considered equivalent. The authors also failed to mention whether the PIC-R and the MMPI-2 were given pre and posttest or just administered one time during the study.

The potential effects of maturation were also not discussed. The MED group appeared to receive the posttest soon after the beginning of participation in the study. Although medication effects can usually be seen soon after drug treatment has begun, if the researchers had tested those participants at the same time as the EEG group, there may have been improved results, just as a result of simple maturation. This issue could be turned around, however, in that because they tested the MED group subjects sooner, there is less likelihood of contamination of the results via simple maturation.

Finally, the results of the study help support existing research, but they need to be confirmed by systematic follow-up studies with larger samples of patients. Additionally, there was no control group in the study which also limits the generalizability of the results.

Boyd & Campbell, 1998

Sample

Six middle school students from Wyoming diagnosed with attention deficit hyperactivity disorder were selected for sensorimotor rhythm (SMR) training with EEG biofeedback. The subjects were all males ranging in age from 13 to 15 years. Two subjects were in sixth grade; one was in the seventh grade; and three were in the eighth grade. The subjects were all diagnosed with ADHD and had been treated or were currently being treated with a psychostimulant medication such as Ritalin. Selection criteria included a diagnosis of ADHD and likely parental cooperation.

A complete quantitative EEG evaluation was conducted for each subject. Based on the resultant findings, the researchers decided to administer neurofeedback treatment focusing on increasing SMR brain wave activity. The measures used included the WISC-III Digit Span Subtest and the TOVA. The subjects were evaluated following a 72-hour drug-free period. After the QEEG evaluations were completed, the subjects were administered the WISC-III Digit Span Subtest and the TOVA. The standard scores from the Digit Span Subtest, the Inattention Scale of the TOVA, and the Impulsivity Scale of the TOVA were added together and divided by three in order to obtain a combined standard score.

Electrodes were placed on the sensorimotor region of the brain at Cz. Five of the six subjects received twenty 30-minute sessions of EEG biofeedback training. The sixth subject received only nine sessions due to school absences and problems with motivation. The posttest evaluation took place after another 72- hour drug-free period. The subjects were again administered the WISC-III Digit Span Subtest and the TOVA. The standard scores from these tests were again averaged to obtain a combined standard score.

Results

Five of the 6 subjects improved from the pretest to the posttest in their combined standard scores. The actual difference between posttest and pretest combined standard scores was as follows: 13, 6.4, 4.3, 1.7, 1.6, and invalid ($p < .001$). The TOVA results for the sixth subject were invalid, but there was mild improvement in the Digit Span score. Since all six subjects completed the Digit Span Subtest, a comparison of pre and posttreatment standard scores was completed for all six subjects. The differences in pre and posttest scores were as follows: 5, 35, 20, 15, 5, 5 ($p < .01$). The authors maintain that the results of this study supported previous findings that neurofeedback can be used to treat ADHD problems. They indicated that five of the six subjects "clearly" benefited from the treatment. They cited Othmer's 1994 study as saying that neurofeedback can successfully treat approximately 30% of subjects with ADHD disorders, but indicated that this study demonstrated that positive gains were made in 80% of the subjects.

The first criticism of the study may be the authors' statement that the subjects "clearly benefited" from treatment. The subjects definitely made an improvement in their scores on the TOVA and their Digit Span scores. However, it appears that they may be generalizing the improvements on these few scores to an overall beneficial effect. They do not report any outside data regarding behavioral improvement via parental or child self-reports. Additionally, there is no time frame indicated in the study between pre and posttesting on the Digit Span subtest so if the interval between testing sessions was less than 6 months, there may be some resulting practice effects.

There was no discussion as to the rationale behind their choice of measures. They appeared to choose the Digit Span subtest of the WISC-III to be a measure of attention or impulsivity or both, perhaps based on the fact that Wechsler reports it as contributing to the factor called Freedom from Distractibility. However, according to Sattler (1992), this claim is unsupported. The possibility exists, then, that the Digit Span subtest is actually not an accurate test for assessing improvement in attention and impulsivity. The authors may have done better to choose a more reliable and appropriate instrument to assess for these changes.

This study does not appear to be a good study for cross evaluation or replication of previous findings. The study did not have a control group, the size was very small, and the treatment protocol was administered by less than qualified administrators. The overall purpose of the study was more to show that the EEG could be used effectively in the school setting. The authors admitted to difficulties with equipment and the need to alter the treatment location frequently which could also have affected the treatment to some degree. They also indicated that the staff changed frequently. This problem could have both a positive and a negative outcome on the results. The possibility exists that the quality of treatment may have been compromised based on the experience and training of the individual, but it would also help to rule out the possibility that the efficacy is related to the effect of a consistent relationship with the neurofeedback practitioner and not to the neurofeedback itself.

Graham, 1995

Graham's study attempted to answer the following questions. Is it possible to effect changes in ADHD behavior using 15 sessions of intensive Photic-Driven EEG neurotherapy? Is it possible to measure the EEG while engaged in tasks such as the TOVA? What changes in the EEG and test performance will indicate generalization from training?

Method

The author used a quasi-experimental design and used a randomized waiting control group with repeated measures. Subjects were randomly assigned to one of two groups. The first group received psychometric testing followed by a 4 to 6 week waiting period. At the conclusion of the waiting period the testing was repeated and the subjects were assigned to treatment with the protocol. Members of the second randomized group were assigned to treatment immediately following initial testing. Both groups were tested following treatment. The independent variable in the study was the treatment with photic-driven EEG training and an attempt was made to align the dependent measures with current DSM-IV diagnostic criteria of attention and impulsivity.

Attention was measured via the WISC-III freedom from distractibility scale, TOVA - errors of omission, Raven's Progressive Matrices (RPM), Achenbach Child behavior Checklist and Profiles (CBCL-P) attention profiles scale, and decreased theta and increased beta band EEG activity while doing the TOVA as well as in quantitative EEG brain maps. Graham also measured impulsivity using the WISC-III Processing Speed scale, TOVA errors of comission, CBCL-P attention problems profiles scale, decreased theta and increased beta activity while doing the TOVA as well as in the quantitative EEG changes. The final measure was the Wechsler Individual Achievement Test (WIAT).

Sample

A sample of 32 children from intact families was used. They were recruited from a developmental pediatrician's private practice, from personal referrals, and from the Children of Attention Deficit Disorder (CHADD) organization in Seattle, Washington. Following phone contact by the researcher, 25 families agreed to enter the study. The children were ages 8 to 14. All children had a physical exam and were diagnosed by the developmental pediatrician using DSM-III-R criteria. Exclusionary criteria included any history (personal or familial) of epilepsy, severe hyperactivity, mental retardation, or other co-morbid psychiatric disorders. An attempt was made to limit intake of ADHD medications for at least 8 hours prior to testing or treatment sessions and medication dosages were not changed throughout the study. A clinical and academic history was obtained and the author performed a brief neurological screening exam to identify any hearing or vision problems. Subjects also had EEG activity measured while engaged in doing the TOVA.

The photic-driven EEG training consisted of 15 sessions. The equipment consisted of a set of wrap-around photic stimulation sunglasses provided by Synthetic Systems, Inc. There was an EEG sensor in the glasses that was utilized to measure the EEG and control the frequency of the photic driving. The system worked by capturing and analyzing the subject's dominant EEG frequency. The energy is then converted into pulses of light by the use of a regular personal computer. The light pulses are presented via the wrap-around sunglasses. The sunglasses have eight light emitting diodes (LED) that have four per side and produce two candle power at maximum intensity. The intensity was controlled by the researcher so that no subject received more than 25% of the maximum light intensity.

The goal of the training sessions was to increase the SMR activity and decrease the theta activity. Subjects were instructed to keep eyes closed during the procedure. The light pulses emitted produced patterns on the subject's closed eyelids. The subjects were assisted to identify and attempt to reproduce the pattern associated with the SMR frequency. This goal was accomplished by using the software program to set the frequency of the lights at the SMR frequency and then the subjects were told to watch and describe the resulting pattern. Then they were told to "watch" for that pattern and learn to make this pattern occur more frequently. Then the pattern was paired with a sound tone when the frequency was in the SMR frequency range and the tone stopped when the theta threshold was exceeded. Over the last few sessions, the photic stimulation was gradually withdrawn. The subjects were instructed to elicit the sound tones without the benefit of the lights. The goal was accomplished gradually over a total of 15 daily sessions. The total treatment session length averaged 40 to 50 minutes. Each treatment session consisted of photic-driven training intervals that typically lasted 2 to 4 minutes as well as frequent rest periods of up to 4 minutes to prevent fatigue.

The EEG testing procedures consisted of an initial interview followed by a 1 to 2 hour testing session. A representative sample of five was additionally tested to obtain quantitative EEG's and dynamic brain wave activity maps. Subjects also had EEG measured while doing the TOVA. Electrodes were placed using monopolar placement at Cz and were linked to both ears for ground and reference.

Results

There were 8 girls and 17 boys, and 14 out of the 25 subjects were medicated. Twenty-five percent of the girls were medicated and 75% of the boys were medicated. One subject dropped out of the study due to an increase in aggressive behavior. Three subjects were removed from the database due to severe hyperactive behavior that inhibited valid interpretation of the data.

One of these subjects had prenatal exposure to cocaine, and the other two were poorly controlled on a combination of antidepressant and stimulant medications. The resulting numbers included a remaining 10 subjects in the control group. Overall, 21 subjects were included for analysis in the complete database. A significance level of .05 (two-tailed) was accepted for this study and only results that exceed the significance level were presented. Analyses were performed using split sample paired t-tests. Due to the fact that the data were not normally distributed, nonparametric Wilcoxon Matched-Pairs Signed-Ranks Tests were additionally performed (Hinkle, Wiersma, & Jurs, 1988, as cited in Graham, 1995).

The psychometric data indicated that all the subjects in the experimental group improved over the 15 sessions. None of the 10 control subjects showed significant changes on any measure. The experimental group made large changes in controlling impulsivity as noted most remarkably in the WISC-III Processing Speed scale sores (81% improved). TOVA errors of commission showed a 95% improvement, and the CBCL-P indicated a 69% improvement in parent ratings and 72% of children noted improvements. Significant gains were also made in the Freedom from Distractibility Scale on the WISC-III (81% improvement). The post treatment scores of the WIAT were statistically significant and, although only 11 of the 25 subjects agreed to retest at 3 months, all 11 improved. The RPM and the TOVA omission scores, however failed to show significant improvements.

The EEG mean amplitudes of theta, SMR, and beta bands failed to change significantly in the QEEG's or while doing the TOVA. Standard deviations of EEG bands were examined as indicators of variability around the sample means. When looking at this measure, the standard deviations of the subject's theta, SMR, and beta band activity increased significantly while engaged in the TOVA. There was a 67% increased variability in theta, 72% increased variability in beta, and 50% increase variability in SMR. The increase in variability in EEG band sample means may indicate some samples were much higher and some much lower. This finding could be due to the effect of training, however, the author indicated he was unclear as to whether the increases were in response to the cognitive task.

The author's original hypotheses included whether it is possible to effect changes in ADHD behavior using 15 sessions of intensive Photic-Driven EEG neurotherapy; if it is possible to measure the EEG while engaged in tasks such as the TOVA; and what changes in the EEG and test performance will indicate generalization from training? From the results, the author indicated that there were significant changes made in the Wechsler tests involving the Processing Speed score (Coding and Symbol Search subtests) and the Freedom from Distractibility score (Arithmetic and Digit Span subtests). However, these could potentially be the result of practice effects as the tests were re-administered within 3 months of the initial assessment, 3 months less than the recommended 6 month interval recommended by test developers to alleviate practice effects.

Additionally, according to Sattler (1992), the Freedom from Distractibility factor in the WISC-III is very weak and the subtests do not contribute enough statistically to the factor. In fact, Sattler recommends that users should disregard the Freedom from Distractibility score until there is further evidence to support its use. As such, this factor of the WISC-III may not be an appropriate measure to assess for improvement in ADHD symptoms. The Processing Speed score, on the other hand, has been empirically validated to reflect the ability to employ a high degree of concentration and attention in processing information and as such would seem appropriate for use as a measure in this study (Sattler, 1992). The TOVA would also seem to be an appropriate measure of improvements in attention and impulsivity related to training, but it appears that Graham used the measure only as an activity which the subject engaged in while recording quantitative EEG readings. Here, it may seem that a potentially useful instrument was not used at all for the purpose for which it was intended.

Graham indicated that he used the Child Behavior Checklist as a subjective rating instrument. One possible question is which version of the Checklist he used. Different versions of the test tap different ages. The study was not clear in this regard. For the adolescents, a better instrument may have been the Youth Self Report, which correlates highly with the Child Behavior

Checklist (Sattler, 1992). Graham also used the Raven's Progressive Matrices (RPM) to measure potential changes in attentional processes. The RPM is a nonverbal test of reasoning ability based on figural test stimuli. Sattler (1992) indicates that reliability and validity coefficients are satisfactory, although it is not apparent whether the RPM would be an efficient indicator of change in attentional processes.

Another speculative hypothesis for the results includes the EEG readings during the TOVA. If the EEG was only measured during the execution of the TOVA testing, it may not accurately reflect the effects of the EEG training. Although the test itself is a measure of attentional processes and impulsivity, the actual brain activity used to take the test may not be an accurate reflection of normal attentional processes as the test itself is very monotonous and non-stimulating. Other studies have employed cognitive tests where a subject reads a book or is read to by the therapist. Here the cognitive activity may be more indicative of normal attentional processes as it also engages the reader in attributing meaning to the stimulus as well as requiring concentration.

Another possible reason for the lack of significant changes in EEG readings is that the author used the mean amplitude of theta and beta as an indicator of training efficacy. This measurement may not have taken into effect the gradual effects of maturation in children of different ages. A better indicator that actually takes maturation into account is the ratio of theta:beta.

Two other limitations of the study may involve the treatment protocol and the brevity of treatment. There is very little literature involving the use of photic-driven EEG neurotherapy. Most of the major researchers in the field do not mention this type of EEG treatment and the reliability of this type of intervention may seem questionable. Two positive features of this study are that the author used a control group and also attempted to exclude other comorbid psychiatric disorders. These features would seem to be helpful in alleviating the potential complications in determining the efficacy of treatment as compared to a more heterogeneously disordered group.

Alhambra, Fowler, & Alhambra, 1995

Sample

Questionnaires were sent to patients who had completed at least 30 sessions of EEG biofeedback as a treatment for ADHD. A total of 43 questionnaires were sent. Thirty-two were male, and 11 were female. Forty of the 43 patients fell between the ages of 7 and 15, and the remaining three were 17-years, 16-years, and 1-year. Patients were diagnosed with ADHD based on the following: observations made by parents and teachers, QEEGs, and TOVA scores. Questionnaires asked the parents or guardians of the patient to describe the child's symptoms, medication history, academic performance, school conduct, and social behavior before, during and after neurofeedback treatment.

The TOVA, QEEGs and brain mapping results were analyzed before and after 20 sessions of treatment. EEG monitoring was done by monopolar electrode placement at Cz with two ear electrodes providing a reference and a ground. Each session lasted 30 to 45 minutes with the goal of inhibiting theta while increasing SMR or beta waves. Sessions were conducted by a certified neurotherapist under the supervision of a pediatric neurologist in a private setting.

Results

Of the 43 questionnaires sent, there were 36 responses. Twenty-six responses were for male children (72%) and the remaining 10 were for females (28%). The ages of these 36 patients ranged from 6 to 17 years. Thirty-one of the 36 (86%) showed some overall improvement in their ADHD condition upon completion of EEG biofeedback treatment. Improvement was judged to be significant in 30 patients, and slight in the remaining patient. Three of 36 showed no improvement after treatment. The remaining two indicated uncertainty as to whether or not there was any improvement.

All 36 patients had an initial TOVA test before starting neurofeedback. Thirty-three were abnormal, and three were normal. Thirty-one of these patients with abnormal TOVAs had repeat TOVA tests after 20 sessions. Twenty-three (74%) of these showed significant improvement of scores and 8 (26%) did not. All of those with increased TOVA scores improved clinically.

Among the eight patients without TOVA improvement, four (50%) showed clinical improvement and four did not. Four of the five patients who did not have clinical improvement also did not show improvement on the TOVA test. None was observed to be symptomatically worse after the sessions.

All patients in the study had QEEG before the start of EEG biofeedback sessions. Only 10, however, were repeated at the end of the sessions and 9 of these improved clinically. Seven out of nine also showed improvement in their QEEG parameters. QEEG changes included the following: decreased relative and absolute power of theta activities, less hemispheric asymmetry, better posterior and anterior hemisphere coherence, and increased relative power of beta waves.

Twenty-four of the 36 patients who responded (66%) were on medication for their ADHD condition. Of this 24, five were able to be removed completely from their medication after treatment. Eleven of the 24 showed a decreased dependence on their medication in the form of a reduced dosage. The remaining eight initially on medication showed no change. Four of the eight showed overall improvement, possibly implying that this same dosage of drug was more effective. Twelve of the 36 were not on medication before undergoing neurofeedback and 11 of these 12 remained free from medications after treatment.

Effect on comorbid conditions associated with ADHD

Four of the 36 were suffering from seizures before treatment. After treatment, two were no longer having seizures; one was having fewer seizures; and one remained unchanged. Five of 36 reported headaches and abdominal pain before treatment. After EEG, all five improved, with two of five no longer suffering from the condition. Two of the 36 patients suffered from nightmares before treatment, but not afterwards. There were two reports of bruxism (teeth grinding) and the condition disappeared in one patient and improved in the other. Similarly, there were also two reports of bedwetting where one case was resolved and the other evidently improved after treatment. There were two reports of mood swings with both experiencing signs of improvement after EEG treatment. Two reports of depression both improved after the experiment; three reports of motor tics where two of the three noting improvements after treatment. Clinical outcomes were conducted 0 to 12 months after completion of EEG neurofeedback. The long term effects or sustained benefits could not be evaluated.

One of the difficulties with the methodology in this study is the use of self-report questionnaires. The self-reports are subjective and therefore subject to bias. Parents or guardians of children who completed treatment may have emphasized only the positive aspects of treatment because of their own expectations or even fears of disappointing the researchers. The difficulty also arises in interrater reliabilities. Whereas one parent may view one outburst per week as "successful," another may view one per week as a failure. The authors did not indicate whether they used standardized instruments in their questionnaires or ones they had created themselves, and therefore it is difficult to evaluate the effectiveness or reliability of their questionnaires.

Additionally, there was no discussion in the results about the differing lengths of treatment times. All the assessments were conducted at the 20 session point, however the authors indicated that all completed 30 sessions of treatment, and some even had up to 60 sessions of treatment. They did not distinguish which of the subjects that improved had received more than 20 sessions of treatment. There was also no discussion of the statistics used to compute their significant findings and therefore the appropriateness of the statistics could not be determined.

Some of the positive features of the study include the clinical reports of improvement by parents due to treatment with neurofeedback. This finding supports other studies in which neurofeedback was claimed to be a successful component of ADHD treatment. Additionally, there were a number of clinically significant improvements in a variety of other comorbid disorders. These improvements may provide hope and support for finding other non-pharmacological treatments for a host of other disorders typically viewed as more difficult to treat.

Thompson & Thompson, 1998

Sample

This study was conducted to provide additional research regarding the efficacy of neurofeedback in the treatment of children with ADHD. The participants in the sample consisted of a selected chart review of clients seen consecutively at a learning center that specializes in using neurofeedback plus coaching in metacognitive strategies to improve concentration and attention. The sample consisted of 111 persons, 98 children between the ages of 5 and 16 years, 13 adults, 17 to 63 years. Age distribution was as follows: four children 5 to 6 years old, twenty-six 7 to 8 year olds, thirty-six 9 to 11 year olds, twenty-five 12 to 14 year olds, seven 15 to 16 year olds. Of the adult group there were seven 17 to 18 years old and the other six were over age 28. Participants were mixed in racial backgrounds, countries of origin and socio-economic status. The ratio of males to females was approximately three to one. All subjects met DSM-IV criteria for ADHD based on clinical interviews and questionnaires (SNAP version of the DSM-IV, Connors - Abbreviated Symptom Questionnaire for Parents (ASQ), and Conners ASQ for Teachers). They also demonstrated an EEG power spectrum consistent with the diagnosis of ADHD. All participants who were taking stimulant medication (29 children at intake and 6 at posttest) were off their mediation for at least 20 hrs prior to testing. Ritalin was the prescribed medication in all cases.

Various factors led to only 55 clients (9 adults and 46 children) having pretest and posttest results on all of the measures. There were no drop-outs, but data was incomplete for many subjects. Factors contributing to incomplete test results included the following: (a) Pretest scores from psychological testing done elsewhere were sometimes incomplete or had used different measures. Since IQ testing was not repeated at intake if testing had been done within the previous 24 months, this reason was the most frequent cause for missing data on the Wechsler test, (b) time constraints at posttest sometimes meant certain tests or subtests were dropped from the battery (for example, with some clients, only the 'ACID' subtests were administered), (c) a few children were unstable on some measures at pretest due to extreme restlessness, frustration, or young age. These difficulties were true especially during the second half of the TOVA when the target stimuli are frequent and errors increase. All clients were able to sit for the 22.5 minute administration of the TOVA at posttest.

Testing was done by the first author both at intake and after the completion of 40 to 50 minute session, which combined neurofeedback with coaching in learning strategies. All charts were included where pretesting and posttesting results were available for one or more of the following: TOVA, Wechsler Intelligence Scales, WRAT-3, and the EEG assessment protocol which provides, among other measures, a ratio comparing theta to beta activity. Paired t-tests of the difference between means for all subjects with available data were carried out and levels of significance computed.

Instruments

Eight trainers had bachelor's, master's, or doctoral level degrees in health care, teaching, or psychological fields. Clinicians were chosen for their ability to relate to and coach students. At this particular center, students typically work with a number of different trainers over the course of their training, including persons of different backgrounds, ages, and personalities. Because of the variety of trainers with which the subjects interacted, the training effects should be dependent on the neurofeedback and the strategies taught and not on the relationship with a particular trainer.

Electrode placement was typically referential to the left ear lobe. Occasionally a bipolar placement was used FCz-Cpz as suggested by Lubar (1991). This placement was done mainly with hyperactive children so that common mode rejection would eliminate some of the movement and muscle artifact. For most students the electrode was placed at Cz. Left side placement at C3 was sometimes used if the functions that predominantly involved the left hemisphere, such as language, needed to be strengthened.

The goal of the training protocol was to decrease theta. Some students had excessive alpha activity so individuals were trained to lower alpha during cognitive tasks. Most students with problems of hyperactivity were trained to increase SMR at Cz or C3. More recently the protocol is training at

C4. In a few children who displayed reading difficulties and were impulsive, sessions would include both reinforcement of beta activity in the 15 to 18 range for that part of the session while they practiced reading strategies, and SMR activity in the 13 to 15 range for the remainder of the session.

Children earned tokens for effort and good performance, and the child had a bank account and could exchange tokens to purchase rewards from a 'store' in the learning center. Prizes ranged from pens, bookmarks, and action figures to books, board games, and gift certificates for a local music shop. Points were given by the machine for each 0.5 seconds of activity during which the slow-wave activity was maintained below threshold at the same time as fast wave activity was maintained above threshold. Thresholds were initially set by the first author who did all of the intake assessments based on levels of slow wave and fast wave activity observed at that time.

The results of each few minutes (or section) of training were reviewed with the student on a statistics screen after each section of training. Trainers were instructed to emphasize the neurofeedback, with the student watching the screen for two 3 to 6 minutes periods initially. The third section of training would last from 3-minutes for very young students to as much as 10-minutes for older students. During this section, academic challenges and metacognitive strategies were introduced appropriate to the needs of the student as determined by the director after initial academic and intellectual testing. During this section the feedback is auditory. This process of alternating pure feedback with feedback combined with cognitive activities was continued for the remainder of the session. The idea behind this approach is that once the student is relaxed, alert and focused, this is a useful moment to discuss learning strategies. To practice maintaining a particular EEG pattern while engaged in academic tasks may also help in the transfer of skills from the training center to the classroom.

Clients also were trained to regulate some of the Electrodermal responses (EDR) while doing neurofeedback to lessen anxiety. Data on the EDR and temperature were not systematically reported or collected. Learning to regulate these physiological measures seemed easier than learning self-regulation of brain wave activity because it took fewer sessions. This success encouraged students that they would also learn to regulate their brain waves.

Metacognition refers to thinking skills that go beyond basic perception, learning and memory. It consists of executive functions that consciously monitor our learning and planning. Metacognitive strategies increase awareness of thinking processes. Strategies were taught during part of each session to all students while they were simultaneously receiving feedback. The strategies consisted of coaching the students in thinking skills that let them monitor their learning. The strategies outlined below were taught for approximately one third of each session while the student was also receiving auditory feedback. The kinds of strategies taught include the following: word analysis skills for decoding; active reading strategies; listening skills;

organizational skills for making a presentation; writing a paragraph or writing an essay; answering exam questions; tricks for times tables; solving word problems in math; organizing study time; creating mnemonic devices,; and preparing study notes. Adult clients typically wanted to work on time management, efficient reading strategies, and in three cases, basic math skills for everyday life such as fractions, interest rates, budgeting. Techniques emphasized (a) remaining alert while listening or studying, and (b) organizing and synthesizing material to aid recall. The goal was to teach students to be active learners. This goal seems essential for people with ADHD as they are not naturally reflective about the learning process and tend to get bored easily.

Before entering the program, 29 of the 98 children (30%) were taking stimulant medications. The drug used was methylphenidate in all cases. Of these students, 23 came off medication during the course of their training. Thus 79% of those who were taking the stimulant drug when they started training, stopped its use. In five students, the dose of medication was lowered as training proceeded. Just one student remained on Ritalin at the original dose level by the end of training. No students began taking medications during or after the training.

Results. Part I results on a continuous performance task (TOVA)

The TOVA was administered as part of the initial interview and again after 40 training sessions. Results on the TOVA were available for 76 students

(11 adults and 65 children). TOVA changes for each of the four variables were assessed by the use of the t-test for matched pairs. No participant was worse on posttesting. Results revealed consistent improvements, particularly in terms of less variability in reaction time. Significance levels were $p < .001$ for variability, which is the most sensitive scale for indicating an ADHD problem. For children, inattention and impulsivity also showed significant improvements ($p < .001$), whereas in the smaller adult group the mean for inattention improved significantly ($p < .01$) but the change in impulsivity, through increasing from low average to mid average, did not reach significance.

Mean reaction time in children did not increase as much or as consistently as the other three variables because there was a subgroup of children who had slower reaction times on retest. The average increase was six standard score points from 82 to 98 ($p < .02$). There were 26 students who demonstrated a fast, impulsive style on intake whose reaction times became slower. Their impulsivity scores and variability scores, however, markedly improved. A non parametric sign test for two correlated samples showed that the relationship between slower reaction time and decreased impulsivity was significant ($z = 4.4$, $p < .001$) Although a slower reaction time is not the direction that is usually considered to be improvement on the TOVA, it represented an improvement clinically in the subset of 26 as these students were too fast initially (sacrificing accuracy for speed) and were responding more slowly and carefully after training. In the other 50 students, the initially slow reaction times got faster as accuracy scores improved.

Part II. Results on Academic Measures (WRAT-3)

A screening instrument for academic performance, the Wide Range Achievement Test (WRAT-3) was administered as part of the initial test battery and again after 40 training sessions. This instrument measures word recognition, spelling, and arithmetic calculations and provides standard scores, percentile ranks, and grade equivalents. Alternate forms (Blue and Tan) were used for the two testings to reduce any practice effect.

Results on the WRAT -3 were available for 99 students (11 adults and 88 children) The improvements were significant ($p < .001$) for the children. The small adult group showed significant gains only in their arithmetic scores. Of the 11 adults, the three youngest showed academic gains. In addition to improvements in arithmetic and word recognition, their spelling scores rose by 10, 12, and 20 standard score points, respectively.

Of the 88 children, 20 children did not make gains in spelling, 18 did not make gains in word recognition, and 16 did not make gains in math. Among children who did not improve in all three areas, improvements were nonetheless made in areas that were most important to them. Some children, for example, had above average reading to begin with and needed to improve only in arithmetic. Others were nonreaders who mainly needed decoding strategies and received minimal coaching in math strategies.

There were four children who did not increase their WRAT-3 standard scores between pre and posttesting. These included twin girls who had received intensive tutoring and had high pretest scores. Their initial scores represented over achievement when compared with their low average intelligence levels. Both had been diagnosed with absence seizures just before entering training and had been placed on medication to control the seizures. Their retesting was also done on their 8th birthday so they were at a disadvantage with respect to norms and possibly also excitement about their upcoming birthday party. A third child also tested a few days after his birthday and had lower standard scores due to the older comparison group. The fourth child, who had fetal alcohol syndrome, was having problems in the family at the time of retesting. No subjects were eliminated from the study because of extenuating circumstances. If test scores were available, they were included.

Gains made by children who were nonreaders or extremely poor readers on entry to the program had the greatest improvement. Among the most improved in reading were two learning disabled children. One eventually rose from early second grade levels to sixth grade levels in reading and arithmetic, but he did not show large changes until between the 44th and 50th session. He required about 85 sessions to catch up to his sixth grade level. These cases serve to show that one should not stop after 40 sessions if some progress is being made. The second child rose by more than two grade levels after only 40 sessions and was able to leave his contained special education class. A number of children who did not show much gain after 40 sessions demonstrated good improvement on their testing after 60 sessions. This review examined test results after 40 sessions so these additional improvements are not reflected in the results.

In the adult group there was some instruction in math skills for three of the clients who initially were very weak in arithmetic skills and virtually math phobic. This instruction contributed directly to the significant arithmetic gains for this group. For all ages, decreased impulsivity could be posited as a factor in reducing careless errors on arithmetic calculations. Gains were not expected in spelling or decoding skills for adults as they were not deficient to begin with and no coaching in strategies for these skills was provided. In the case of adults, active reading strategies were being coached. A measure of reading comprehension, rather than oral reading of words in isolation, would thus be a better way to measure gains.

Part III: ACID Pattern Results

The ACID pattern is for four of the tests on Wechsler Intelligence Scales. Significant improvements were observed in these ACID pattern scales (n = 68, 13 adults and 55 children). The pre and post average for the 68 subjects demonstrated an average gain from 35.9 to 42.2 scaled score points. This gain was significant at the $p < .0001$ level. This level of significance held for each of the subgroups [Children tested on the WISC-R (n = 28), Children tested on the WISC-III (n = 27) and adults tested on the WAIS-R (n = 13)]. The WISC-R scores were from earliest clients and from those where the school psychologist had used that version of the test. Whatever form was used at pretest was repeated at posttest. The findings paralleled the results of a smaller number of subjects for whom the full IQ tests were carried out. The ACID subtests were still the lowest at posttest for the group who had the full IQ testing done, indicating that there were improvements across the board and not just in these four areas.

Somewhat greater gains were observed in the WISC-R group compared to the WISC-III group. Factors affecting the greater gains in the WISC-R group as compared to the WISC-III changes might include those earlier clients having multiple problems, with 18 of 28 clients testing using the WISC-R showing learning disabilities and social problems in addition to ADHD. These clients started at a lower level and had a greater potential range for improvement and for regression toward the mean. Of these 18 clients with severe learning disabilities plus ADHD, 12 completed the full WISC-R. Their WISC-R scores went from a mean Full Scale Score of 82 to 97, a slightly larger gain than for the whole group noted below.

Part IV - Results on Wechsler Intelligence Scales

All of subtests of the Wechsler Intelligence Scales (WAIS-R, WISC-III, WISC-R) were available for 55 students, 9 adults, and 46 children. The pre and post test interval varied from 6 months to 2.5 years because IQ testing was not initially repeated if it had been done within 2 years of intake. If Wechsler scores were not available, testing was done prior to the student commencing training. The posttests were all done at the ADHD center.

The findings demonstrated that all subjects made increases in their IQ scores and significant increases ($p < .0001$) were achieved in the full-scale scores of the Wechsler Intelligence Scales with IQ equivalent standard scores averaging a 12 point gain. In a detailed look at the results, it was found that in full scale IQ, two-thirds (38/55) of the sample made more than a 10 point gain in IQ ($4 \geq 20$ points, $17 \geq 15$ points, $17 \geq 10$ points). Six children made less than a 7-point gain. These six children all continued in the program after the progress testing. They required more than 40 sessions of training to get optimal results. Overall, more than 90% of the students made a greater than or equal to a 5-point gain in full scale IQ with 40 sessions of training.

The test retest improvement due to practice effect reported in the WISC-III manual is 7 points for the full-scale score. The retest interval in the manual was only 3 weeks. In the interest of further rigor, additional t-tests were performed using scores corrected by 7 points for practice effects. The changes were still significant. The significance level with the correction factor changed to $p < .02$ for the smaller WAIS-R group. Significance was maintained at $p < .0001$ for the larger WISC-III group ($n = 30$) and for the total group.

Subjects in this study were also tested before and after training using the EEG assessment program designed by Lubar. Lubar et al., (1995) referred to the work of other researchers who reported that multichannel EEG brain mapping demonstrates stability in the EEG over time (Etevenon (1986); Fein et. al., (1983) as cited in Lubar et al., 1995). Changes in the EEG readings observed after training are therefore considered to be due to a training effect.

There are several possible hypotheses for the positive results in this study. Part of the positive effects of the training could be due to a more positive attitude and increased desire to please in children who have been through the training program. It could be that they became less impulsive and more reflective, which led to better test taking ability or that they developed more confidence in their own ability to succeed.

The results in this study were found to be similar to previously published findings (Lubar, 1997, Linden et al., 1996). In the current study, all participants had decreased theta/beta ratios with the exception of one child, though the amount of change varied widely. The authors indicated that there is no normative data about what constitutes a significant decrease in the ratio overall.

This study is helpful for several reasons. First, it provides evidence that a training program in neurofeedback combined with training in metacognitive strategies produces positive clinical outcomes. The study also further replicates the previous findings of improved IQ scores as a result of training and improved school performance beyond what could be considered simply the result of maturation or practice effects.

An additional positive outcome of this study involves a subgroup of children that the authors indicated had severe comorbid social difficulties and learning disabilities. Major social gains were observed in the subgroup of 18 children. Two of the children had been previously diagnosed as autistic and others demonstrated symptoms similar to that of Aspberger's syndrome. None of these children had been able to maintain age-appropriate friendships. The training had been requested to improve their attention span, decrease impulsivity, and hopefully to increase self-esteem. Parents were cautioned not to expect much change as their conditions were severe. However, by the end of the training, all of them were socializing, having friends call on them and even inviting them to events. They could not be considered entirely normal, but they were now being accepted by their peer groups. These clinical findings also give support for the clinical and behavioral improvements experienced in other clinics and studies that encountered more severe comorbid disorders. This result may give hope to the overall clinical profile for improved quality of life in these more severe disorders.

Some of the limitations of the study include the fact that it was not a controlled scientific study and therefore no definitive conclusions can be drawn as to exactly which components of the treatment were efficacious. Significant changes were measured on standardized tests, but it cannot be determined what produced the changes because there were no control groups.

Additionally, there is always the possibility that improvements in IQ, EEG readings, academic performance, and social behavior may be the result of participation in an extended intervention with one-on-one interaction with a caring adult or simply the results of maturation. However, it does appear that the effects are significant for most of the participants and it would be difficult to surmise that all the positive gains were simply the result of maturation. If this were the case, then most would mature outside of treatment eventually and the prevalence rates would not be so high. It would seem, then, that most should "outgrow" their ADHD symptoms by adolescence and certainly experience remediation by adulthood. Clinically, however, this is not the case, which further supports the idea that these positive gains are a result of the neurofeedback training.

Studies involving Instantaneous Neuronal Activation Procedure (INAP)

The following study involves two individual case studies which are of interest and relevance to the treatment of ADHD. Although most of the studies reviewed here are empirical studies, these two case studies are significant clinically and merit attention as they may contribute greatly to the future of neurofeedback treatment of ADHD. The first case study involved a young boy treated with neurofeedback treatment alone. The second case study involved neurofeedback treatment and adjunct therapy with Instantaneous Neuronal Activation Procedure (INAP), a form of active alert hypnosis. The authors cited many studies where there is universal agreement that hypnosis involves the subject's attentional processes (Barabasz & Barabasz, 2000).

Some of the research indicated the use of hypnosis to facilitate the more general and specific attentional processes. Attentional shifts are also possible using hypnosis and have been causally linked to specific EEG changes which can vary depending on the specific hypnotic instructions given to the client (Hilgard, 1965, 1979, as cited in Barabasz & Barabasz, 1996). INAP is an experimental clinical procedure intended to enhance vigilance performance for either focused attention or optimal situational awareness depending on the specific hypnotic instructions given. The form of hypnosis involved here is an active alert eyes open hypnosis and increases frontal EEG beta activity independent of neurofeedback (Barabasz & Barabasz, 1993, as cited in Barabasz & Barabasz, 1996).

<u>Barabasz, Barabasz, 1996</u>

<u>Case study #1, neurofeedback alone</u>

The first case study involved an 8-year-old boy who was referred for treatment from a licensed psychologist. He had been on Ritalin since he was 6.5 years of age after diagnosis with ADHD. The boy's parents were Caucasian, middle income college students who had already pursued drug and behavior modification treatment for their son. The boy had extensive accommodations at school to provide more structure, rewards, and individual attention for his learning, but he still ended up repeating second grade because of failing grades and impulsive behaviors. The child met DSM-III-R criteria and later DSM-IV criteria for attention deficit hyperactivity disorder. His Wechsler Intelligence Scale for Children (WISC-III) revealed a verbal IQ of 92 and a performance IQ of 78. His Bender Motor Gestalt Test performance was consistent with that of a 5-year old. His testing behavior was excellent. Except for a 5-minute break at the approximate midpoint of the session, the child was determined to stay on task. He handled the frustrations of failed items commensurate with the reactions of a typical 8-year-old male.

Quantitative EEG analyses were completed during recording of each of the following attentional conditions: (a) eyes closed, (b) listening to a story, (c) reading a story selected by the child and his parents, (d) finding a letter A in a series of word lists, (e) drawing a picture, (f) completing simple arithmetic. The results indicated that the boy showed brain wave patterns typically characteristic of someone with attention deficit disorder in response to five of the six attentional task conditions. Compared to the normal responding, the child demonstrated excessive theta and deficient beta activity in the right frontal lobe. His SMR readings were also low in comparison to his level of theta.

During the first 25 sessions, the boy gradually learned to engage with the computer feedback task. Initially he could stay engaged for only 3 minutes at a time, but increased this engagement to 20 minutes at a time. He learned to produce fewer and fewer muscle artifacts and was beginning to inhibit theta while producing more beta. Parent reports using the ADDES scale showed only slight behavioral improvement, but little if any improvement was noted in school.

By session 45, there was significant improvement in both his grades and in teacher reports regarding the boy's behavior. EEG readings confirmed that he had made significant improvements in the ability to enhance frontal beta. The subject began to take medication vacations of increasing length, from 1 day per week, to not taking it for 4 days per week. Neurofeedback continued for 22 additional sessions (67 total). His neurometric assessment at the end of treatment could not be distinguished from a person who would have had normal EEG readings. His school grades had gone from failing to C's in math, B's in reading and spelling, and A's in science and industrial arts. Parent and teacher forms of the ADDES revealed dramatic improvements in all areas. His WISC-III verbal score increased 11 points to 103, while the performance IQ increased 17 points to 94. Drug therapy with Ritalin had been terminated completely during his last 2 months of treatment. The boy's self-esteem had greatly increased to one of great self-confidence and pride. Additionally, the family reported increased cooperation and improved relationships with all members of the family. Follow-up assessments at 7 and 12 months after the termination of treatment were conducted and showed no apparent reversals in normal EEG responding. The academic and behavioral improvements had also been maintained.

Case study #2 - neurofeedback with INAP hypnosis.

The subject was a 9-year-old male diagnosed as having ADHD by a school psychologist, school counselor, and classroom teacher 2 years earlier. The boy was on Ritalin treatment for the previous 20 months. Failing grades and impulsive and aggressive behaviors resulted in repeating the third grade. The child was in a resource program where his Special Education teacher implemented a token economy behavior modification program.

The child met the DSM-III-R and DSM-IV criteria for ADHD. His WISC-III Verbal IQ was 84, and his Performance IQ was 80. His Bender Motor Gestalt Test was consistent with a significantly younger child. The parent report from the ADDES was consistent with ADHD and showed much more severe symptomatology than in Case 1. Neurofeedback treatment was carried out using the identical procedures described in Case 1. Quantitative EEG evaluations of the responses to the attentional tasks revealed brain wave patterns which where characteristic of attention deficit disorder. EEG beta activity was significantly greater during the eyes closed resting condition than on any of the other five tasks requiring focused attention. The child showed excessive theta and deficient beta activity when required to attend to the various tasks, particularly at the frontal sites.

This successful treatment was complete after only 32 neurofeedback sessions which included INAP hypnosis as an adjunct to neurotherapy. The subject was engaged in the active alert eyes open hypnotic exercise. Once subjective signs of hypnosis were observed, the client was asked to raise a finger upon perception of the suggested alertness responses. Upon observation of the patient's signal, suggestions specific to attentional process were administered. For example, "in this special state of alertness, you will be able to focus your attention anyway you like, you can concentrate as completely as you desire." With an adult, the suggestion may sound like, "in this special state of alertness, you will be calm and confident - finding it easier to concentrate completely - reading faster than ever and retaining what you read."

Compared to the first case study, little progress was made during the first session, most likely due to training the child in INAP and practicing the technique. In sessions 3 through 12, however, INAP was used before the EEG neurofeedback training, and the child's progress was twice that of the first case study. Despite the apparent greater severity of the ADHD symptoms, the second child doubled the first child's times on tasks in session by session comparisons and began to show measurable EEG changes in a positive direction by sessions 11 and 12. The next three sessions did not include the INAP procedure during which the child's progress stagnated. INAP was reintroduced in session 16. The child responded by immediately increasing his average time on tasks by nearly 50%.

During sessions 18 to 20, the child's mother noted the best report card she had ever seen and that the child was back in the regular classroom on a trial basis. At session 21, the researchers began the final phase of INAP where INAP is self-induced by the patient and practiced in the office. By the end of the session, the child was using the procedure before each task without being instructed or assisted to do so. A medication free neurometric assessment conducted two days later revealed significant improvements toward beta/theta levels that would be indicative of normal on all attentional tasks.

Assessment results after session 32 also showed essentially normal EEG responding. Ritalin was terminated on a trial basis at session 26, but was never resumed because the responsiveness to neurotherapy increased dramatically. Parent and teacher forms of the ADDES showed dramatic improvements in all areas. Subjective teacher reports regarding his behavior improved as well. His WISC-III verbal score increased 9 points to 93 whereas his performance score rose 21 points to 101. The child was placed back into the regular classroom which in turn increased his self-confidence and self-esteem. The subject's grades improved from all failing to average in all subjects. Follow-up neurometric assessment at 6 and 12 months after termination of treatment showed continued improvements in grades, behavioral reports, and social relationships. Both case studies involved treatment initiation while on Ritalin. Both children came from intact families and have histories of active parental participation in behavior modification programs over a 2-year period with little, if any positive effects. The only major difference is the child in case study 2 was Latino and also had more severe symptomology.

One interesting finding in these two studies was the dramatic increase in the effectiveness of the treatment of the ADHD with the addition of the INAP. In this study, it proved to be the key component to produce the same lasting effects in half the time of the first case. This finding was substantiated by the withdrawal of the additional INAP during three sessions mid-treatment which seemed to produce a stagnation in the child's progress.

The merits of this study appear to be obvious. Both studies had successful treatment with neurotherapy, but the second child, with the addition of INAP seemed to accelerate the treatment progress. One of the difficulties of using this case study to draw conclusions regarding the efficacy of treatment is the fact that a single case study (or two) is very limited in its scope and its results are not generalizable to other populations without repeating the research with better designed studies.

Anderson, Barabasz, Barabasz, & Warner, 2000.

Sample

Sixteen children's records were independently and randomly drawn from a pool of patients treated with neurotherapy from the practice of Arreed Barabasz. All patients treated in Dr. Barabasz' practice agreed that their treatment data could be used for research and education purposes as part of a signed pretreatment disclosure. This agreement actually helped the sampling as it alleviated the potential bias that may arise from the difference between subjects that volunteer versus those who ordinarily would not volunteer for a study. Thirteen of the participants were male and three were female. All of the participants met DSM-IV criteria for ADHD. All had a history of 4-10 years ($\underline{M}$ = 6.3 years) of psychostimulant drug use and behavior modification treatment prior to beginning neurotherapy with instant alert hypnosis treatment. All of the children were moderately to highly hypnotizable on the basis of the Stanford Hypnotic Clinical Scale: Child Form (Morgan & Hilgard, 1978, as cited in Anderson, Barabasz, Barabasz, & Warner, 2000).

Neurofeedback electrode sites common to all 16 participants included Fp1, Fp2, Fz, Cz, Pz. First, each participant completed five feedback trials per site to assure familiarity with neurofeedback and to allow participants adequate experience in the management of movement artifact. Then the following neurofeedback sessions were divided between the neurofeedback plus alert hypnosis condition and the neurofeedback only conditions and were used to provide data for the present study. Data provided by the equipment consisted of average microvolts per trial for EEG beta and theta frequencies. For each site, all neurofeedback plus alert hypnosis trials and neurofeedback only trials were averaged and then converted into beta/theta ratio data for statistical analysis.

Results

A two-factor analysis of variance (ANOVA) with repeated measures on both factors was chosen for data analysis. Treatment (neurofeedback + hypnosis, or neurofeedback only) was one factor and the electrode sites (Fp1, Fp2, Fz, Cz, Pz) was the other factor, thereby creating a 2 x 5 factorial design. The ANOVA revealed a significant effect for treatment, (F [1,15] = 59.56, $p < .001$). Neurotherapy with INAP produced significantly higher beta to theta ratios than neurotherapy only. The means and standard deviations for site and treatment are in the following Table 7.

Table 7

Treatment Means by Site

Site	Treatment	Mean	SD
Fp1	Neurofeedback only	1.49	.83
Fp1	Neurofeedback and INAP	3.31	2.34
Fp2	Neurofeedback only	1.17	0.40
Fp2	Neurofeedback and INAP	2.50	1.14
Fz	Neurofeedback only	1.06	0.52
Fz	Neurofeedback and INAP	2.17	0.84
Cz	Neurofeedback only	1.10	0.88
Cz	Neurofeedback and INAP	2.76	2.03
Pz	Neurofeedback only	1.59	1.03
Pz	Neurofeedback and INAP	2.86	.98
All 5 sites	Neurofeedback only	1.28	.52
All 5 Sites	Neurofeedback + INAP	2.72	1.46

Note. From "Efficacy of Barabasz's Instant Alert Hypnosis in the Treatment of ADHD with Neurotherapy," by K. Anderson, M. Barabasz, A. Barabasz, and D. Warner, 2000, Child Study Journal, 30, p. 51. Copyright 2000 by the Child Study Journal. Adapted with permission.

No significant differences were found among electrode placement sites, (F [4,15] = 2.26, p = .065). The interaction between treatment and sites was also not significant, (F [4,15] = .051, p = .727). The results seemed to support the hypothesis that INAP could be an adjunct to neurotherapy for ADHD. The study also confirms findings of earlier case studies involving INAP and neurofeedback. A more significant finding was that the beta:theta ratios were significantly higher when alert hypnosis was used as an adjunct to neurotherapy than with neurofeedback alone. When combined with results of other studies involving active alert hypnosis, the results show that Barabasz' INAP technique increased beta production while inhibiting theta which resulted in the decreased symptomatology associated with ADHD. Additionally, the findings support the hypothesis that neurofeedback increases beta over theta ratios, but alert hypnosis trials significantly increase the same ratios, but by almost twice as much as neurofeedback alone.

This study is one of only a few that is attempting to replicate the finding of earlier case studies by Barabasz and Barabasz. An attempt was made to obtain a larger sample of subjects to test out the new adjunct to neurofeedback. The results seemed to support the earlier findings. Some of the positive outcomes of this study seem to be that this adjunct to neurofeedback could decrease overall treatment time for many patients. Earlier case studies seemed to indicate that the same treatment effect could be obtained in almost half the time of standard neurofeedback treatment alone. Lubar (1997) indicates the average number of sessions with neurofeedback alone to be anywhere from 40 to 80 sessions. This acceleration of treatment would be beneficial to the patients in that it would be less time consuming and more cost effective. Additionally, if the treatment were more effective overall, it may also decrease the need for additional behavior modification and pharmacological programs.

Some of the limitations of this study include the fact that all of the patients were treated by the same therapist. As yet, no other clinicians have attempted to treat patients in a study using neurofeedback and INA,P and therefore there is no guarantee that another therapist will be successful with the technique. There was also some confusion in the methodology,. The study did not indicate whether the experiment was conducted with one treatment group or two. The results seemed to indicate that there was both a group treated with neurofeedback only and one with neurofeedback and INAP, but again, it was unclear. Additionally, the authors made conclusions about the fact that neurofeedback in conjunction with active alert hypnosis can decrease treatment time, but they never discussed the actual number of sessions each patient underwent, so there is no way to substantiate that neurofeedback with INAP can successfully treat ADHD in fewer sessions.

The authors also used only the measure of the beta to theta ratio to determine the effectiveness of the treatment. Firstly, in the majority of the literature, the ratio is referred to as the theta to beta ratio, so this deviation from the norm could be confusing at first. Secondly, the study did not use any other measures to determine effectiveness of treatment such as TOVA scores, behavioral ratings, or academic performance. There was not even any indication that the treatment of the children upon which the study is based was successful. It would be highly doubtful that the researchers would use failed treatment records, but it is unclear. The authors indicate that 16 records were chosen randomly, but no clarification as to whether all received both treatments (neurofeedback and INAP) or only one, and no indication that any of the children's records indicated resistance to treatment. Again, the only result the study addressed was the beta to theta ratios, not the actual treatment efficacy for the individual patients.

One other possible drawback to the use of active alert hypnosis as an adjunct to neurotherapy is that the authors fail to discuss the issue of hypnotizability. They did address the fact that the subjects' records indicated that they were hypnotizable, but the question remains whether or not this adjunct procedure may work for many of the population who are not as hypnotizable. Since the procedure is "eyes open," it would seem that hypnotizability may not be as much of an issue, but as the study is presented, it is remains unclear. Overall, INAP sounds very promising, but there is a need for more controlled studies to establish the generalizability and potential of INAP as an adjunct to neurotherapy.

Warner, Barabasz, & Barabasz, 2000

This study was conducted in an attempt to replicate in a more controlled study the findings of previous case studies involving the treatment of ADHD with neurofeedback in conjunction with a the previously discussed technique known as INAP.

Sample

The sample consisted of 18 children and 1 young adult who met DSM-IV criteria for ADHD and were treated using Barabasz' alert hypnosis instantaneous neuronal activation procedure (INAP) as an adjunct to neurotherapy. Fifteen were male; four were female. All met DSM-IV criteria for ADHD and had a history of 4 to 10 years of psychostimulant drug use and behavior modification treatment prior to beginning the alert hypnosis INAP treatment. Pre and posttest means on each subscale (Inattentive, Impulsive and Hyperactive) of the Attention Deficit Disorders Evaluation Scale - Home Version (ADDES) were compared using a t-test for dependent samples. For each subscale, the mean posttest score was significantly lower than the mean pretest score ($p < .001$), indicating parents reported fewer incidents of inattentive, impulsive, and hyperactive behaviors in their children following treatment. Ratings provided to the therapist also suggested improvement in the self-monitoring behaviors of the majority of clients with five of the children no longer meeting the DSM-IV criteria for ADHD.

Prior to beginning INAP treatment, parents of participants were asked to complete the ADDES, Home Version. If both parents were living with the child, they were to decide who would fill it out. Of the 19 participants, 18 were assessed by the mother and 1 by the father.

INAP treatment followed the protocol outline by Barabasz and Barabasz (1995, 2000) and was reported by Anderson. Each participant was treated individually. Therapy included the visual and auditory presentation of the client's EEG in real time on a computer screen and stereo speakers, analyzed for characteristics of frequency, amplitude and artifact. Participants were instructed to increase their beta waves and decrease their theta waves, with feedback provided on an ongoing basis via the computer.

Treatment typically occurred in biweekly sessions, with the duration of treatment in this study ranging from 4 to 14 weeks. Following treatment, (a) each participating parent completed the ADDES on his/her child and (b)the therapist rated the degree to which he believed each participant had improved. Therapist ratings were made on the following scale: 1 = recovered (cured), 2 = much improved, 3 = improved, 4 = no response to treatment. Positive and substantial clinical changes were obtained in an average of 23.2 sessions (3-14 weeks of treatment), a number well below the usual 40 to 80 sessions for neurotherapy alone. Treatment outcomes were achieved despite the fact that all of the patients had long histories of previous treatment with traditional stimulant medications and behavior modification without effects.

Instruments

The edition of the Attention Deficit Disorders Evaluation Scale - Home Version (ADDES) used in this study is a 46-item rating scale designed to be completed by the parent or guardian of a child with ADHD. Items deal with behaviors exhibited in the home setting (e.g., easily distracted, does not listen to others, does not follow directions, will not wait for his or her turn at activity, is easily angered, cannot remain seated).

Results

The researchers initially planned to use a multiple analysis of variance (MANOVA), but the data did not meet the criteria for nonsphericity and had a high intercorrelation between subscales. The authors then decided to examine the differences between pre and posttest means for each sub-scale using paired t-tests. A family -wise alpha level .05 was set for testing differences and the Bonferroni adjustment technique was employed to control for Type I statistical errors. Because three comparisons were made between pairs of means, only those resulting in a $p < .017$ were accepted as statistically significant.

Results of the t-tests for paired samples indicated that the mean of posttest scores was significantly lower than the mean of pretest scores on each of the subscales: $t\ (18) = 6.645$, $p < .001$ for the Inattentive Scale; $t\ (18) = 5.125$, $p < .001$ for the Impulsive Scale; $t\ (18) = 4.641$, $p < .001$ for the Hyperactive scale. Because lower posttest scores are indicative of decreased inattentive, impulsive, and hyperactive behaviors, results provide evidence that, on average, parents viewed their children's undesirable behaviors as less prevalent after treatment than before treatment.

Examination of the ratings given by psychologists at the conclusion of treatment revealed that they viewed five clients as having recovered (as no longer meeting DSM-IV criteria), eight clients as having made substantial improvement, five clients as having made some improvement, and one client as having not profited from the treatment. The correlations between therapist rating and ADDES scores assigned by parents at posttest indicated substantial agreement, $r = .764$, $p < .001$, between therapist ratings and posttest Inattentive scores; $r = .716$, $p < .001$, between therapist ratings and posttest Impulsive scores, $r = .709$, $p < .001$, and between therapist ratings and posttest hyperactive scores. These findings suggest that the therapist and the parents were in general agreement about the degree of improvement in the children's behavior.

Finally, correctional analysis indicated that the age of the client was not systematically related to the ADDES-Home Version's scores of the therapist's ratings at posttest. Correlations ranged from .218 to -.349, but no coefficient differed significantly from zero at or beyond the .05 level.

Outcome measures suggest that clients with ADHD who received alert hypnosis instantaneous neuronal activation procedure (INAP) as part of neurotherapy decreased behaviors that were judged by parents to be inattentive, impulsive, and hyperactive. Therapist ratings also suggest that the majority of clients in the study (18 of 19) decreased behavior associated with attention deficit hyperactivity disorder. Combined with results reported by Anderson et al., (2000), it appears that alert hypnosis in combination with neurofeedback results in (a) increased beta-theta ratios in ADHD clients, (b) decreased incidence of inattentive, impulsive, and hyperactive behavior, as judged by parents, and (c) a decrease in symptoms associated with the criteria for ADHD. The following Table 8 displays the numerical results of the study.

Table 8

TOVA Factors Pre and Posttest Results

Subscale/Administration	Mean	Standard Deviation	t Ratio	p value
Inattentive				
Pretest	52.4	13.54	6.645	$p < .001$
Posttest	28.9	15.04		
Impulsive				
Pretest	30.7	15.09	5.125	$p < .001$
Posttest	19.5	14.82		
Hyperactive				
Pretest	23.4	13.95	4.641	$p < .001$
Posttest	9.6	9.83		

Note. From "The Efficacy of Barabasz's Alert Hypnosis and Neurotherapy on Attentiveness, Impulsivity and Hyperactivity in Children with ADHD," by D. Warner, A. Barabasz, and M. Barabasz, 2000, Child Study Journal, 30, p.43. Copyright 2000 by Child Study Journal. Adapted with permission.

Several threats to internal validity are noted as a result of not having a comparison group, and outcomes cannot be generalized beyond the specific therapist providing the intervention in this study. Nevertheless, the findings are sufficiently impressive to suggest the need for further investigations into the efficacy of the alert hypnosis procedure. Data was collected from a clinical treatment program where the focus was on direct service. Therefore, there was no control group of untreated ADHD children. The lack of a control group results in a number of threats to internal validity. Although it is reasonable to believe that changes in ADDES Home Version scores are a function of the intervention, at least two rival explanations are also plausible. First, the changes may be the result of other factors that influenced the clients between the time of the pretest and posttest. Second, it may be that parents simply expected their children to improve as a result of the intervention and therefore they provided ADDES ratings consistent with expectations. Likewise, ratings by the therapist can be attributed logically to an expectation for improvement. Another limitation of the study is that all clients were treated by the same therapist. Therefore, there is no certainty as to the degree to which other therapists may be successful in applying the techniques used here.

Conclusions and Implications for Future Research

All of the studies mentioned previously have profound implications for the treatment of attention deficit hyperactivity disorder. Whereas these studies did not prove conclusively that neurofeedback is guaranteed to remediate all of a child or adults' attentional symptoms, they definitely demonstrated a large degree of success as an alternative to the more traditional treatments.

The studies generally seemed to indicate that neurofeedback significantly improves attention and impulsivity in most patients. The majority of the studies reported substantial gains in attention and impulsivity which usually generalized to academic performance, and frequently to behavioral performance as well. The most consistent finding related to neurofeedback's ability to help remediate attentional difficulties involved those patients with the most severe deficits. In many of the studies previously discussed, the researchers noted the intriguing trend that those with the most severe deficits seemed to experience the most substantial gains.

Another clinically significant finding involved the efficacy of neurofeedback as a treatment for attentional difficulties equal to traditional treatment with medications. This finding clearly offers an effective alternative to drug treatment without the typical side effects associated with the use of stimulants. Additionally, it seems that many patients who undergo neurofeedback treatment concomitantly with drug treatment, often reduce the amount of medication needed or are able to stop drug treatment altogether. Recently, there has been an additional study conducted in Germany (not yet translated into English) replicating the finding that neurofeedback treatment is as equally efficacious to traditional medication treatment as measured by Intelligence testing, behavioral ratings, and performance on the TOVA (Fuchs, 2000).

One of the other potential gains from using neurofeedback treatment instead of simple behavior modification or drug therapy is the potential for long-term cost effectiveness. Drug therapy must be continued indefinitely or until the patient may happen to "grow out of it." The cost of drug therapy over the course of many years can become quite expensive as well as annoying. Neurofeedback, on the other hand, may be more cost intensive on the front end of the treatment, but will most likely result in long-term gains and no further need for additional treatment, ultimately defraying the cost. Additionally, neurofeedback is less complicated to implement than other treatments. Some behavior modification plans and drug therapy treatments require the cooperation and participation of several teachers, administrators, nurses, doctors, and parents in the constant monitoring and administration of the reward system.

Another substantive finding in the literature is that neurofeedback is an effective treatment for children, adolescents, and adults. The efficacy is apparently not limited by the age of the client. This finding may provide a significant degree of hope for many adults who have struggled with attentional deficits, often for 20 to 30 years. This treatment may also offer hope for children and adolescents who suffer socially due to poor academic performance associated with attentional problems.

Another definitive result of neurofeedback treatment of patients with ADHD symptomology is the significant improvement in their scores on a continuous performance test such as the TOVA. In all but one of the studies surveyed that used the TOVA, neurofeedback treatment was found to significantly improve performance on the variables measured by the TOVA. This result would seem to have the potential for generalizability of improvement to other areas requiring continuous performance, such as reading, test taking, auditory learning in a lecture situation, and even something so basic as driving. However, more research is needed before claims like this one can be made.

Another key finding of the literature strongly supports the idea that effective treatment of attentional difficulties with neurofeedback involves facilitating a decrease in the amount of theta present in a patient's brain wave patterns. Past literature indicated that ADHD symptoms are typically associated with an excess of theta activity. The previously reviewed studies strongly corroborate this finding and reported that most of the improvements in attention are correlated with a noted decrease in the measured amounts of theta activity.

The studies also indicated that neurofeedback actually has the potential to help remediate some or most of the deficits in attention and behavior with the potential for permanent gains. In all of the studies that conducted pre and post treatment intelligence testing, there were significant gains in the IQ scores, most of which were significant above and beyond what could be attributed to possible practice effects and maturation. Results showed that a majority of the subjects actually increased their IQ as a result of the treatment and that the gains seemed to continue even after the termination of treatment. Additional follow-up studies are needed to clearly establish the long-term gains as permanent, but some of the studies thus far have conducted follow-up evaluations of up to ten years posttreatment with no loss in original gains from neurofeedback (Tansey, 1993).

One of the newer arenas in neurofeedback treatment of ADHD involves the use of INAP as an adjunct to neurotherapy. The three studies conducted so far seem promising. They indicate that this adjunctive technique can actually increase both the efficacy and the time efficiency of neurofeedback, which would further reduce the cost factor involved in the treatment. This idea is still a relatively new one; however, the results of the studies merit further exploration and research.

Although the three studies report substantial gains in efficacy, it is still unclear what the actual mechanism is responsible for the change. It is still unknown what the mechanism is involved in the hypnotic procedure that facilitates the acceleration of the gains typically seen in neurofeedback, and whether or not this mechanism is related specifically to hypnosis or can be replicated in a variety of other adjunctive procedures to neurofeedback.

Although there are some significant findings related to neurofeedback treatment of ADHD, there are also some areas that could be problematic and therefore merit additional research and replication. It appears that neurofeedback is efficacious beyond what could reasonably be considered to be the result of normal maturation. If the efficacy of neurofeedback were simply the result of maturation, then the clinical prevalence of ADHD symptomology would most likely decrease with age. Most children or adolescents would "grow out of" the disorder and its accompanying symptomology. However, the prevalence rates for ADHD in adulthood would seem to contradict this possibility. Although maturation can be a significant factor that contributes to improved functioning in most individuals, the extent to which maturation plays a part in the treatment of ADHD is unclear. One possible explanation may be that simple maturation may be enhanced by the treatment. However, even if this explanation were the case, it would seem that neurofeedback could still be considered effective because it mobilizes the mind's own ability to learn and develop the skills necessary for improved functioning.

The studies reviewed also noted an interesting potential to effect change in some of the other disorders often found to be comorbid with ADHD. Several of the studies indicated that treatment with neurofeedback frequently resulted in a decrease in symptomology in comorbid disorders such as autism, anxiety disorders, learning disabilities, sleep disorders, motor tics, enuresis, and mood disorders. This finding may provide insight into the possible etiology and mechanisms for treating these difficult disorders that frequently have a poorer prognosis in treatment. The findings are not definitive, however, and therefore more research in this area is needed.

The literature also suggested that neurofeedback can be effective even when using a variety of treatment protocols involving differing electrode placements and rewarding different brain wave frequencies. For example, one study treated all the subjects with an identical treatment protocol, whereas other studies varied the electrode placement and treatment protocol based on the patient's response to treatment and input from parents and significant others. Additional studies attempted to consistently vary the electrode placement. In all the studies, however, neurofeedback still resulted in positive gains in attention and impulsivity reduction regardless of which electrode placement was used. This finding would seem to support the clinical efficacy of neurofeedback treatment in general and that efficacy may not be as dependent upon a specific treatment protocol involving a specific brain site.

The possibility still exists, however, that neurofeedback treatment may be more effective if one electrode placement is used over another. Additional research where treatment protocols were more stringently regulated may help to discern if the variance in electrode placement plays a significant role in the efficacy of treatment. One variant of this factor is the use of monopolar placements over bi-polar electrode placements. The literature is not clear whether and to what extent one type of placement is more effective than another.

A similar question exists regarding which brain wave frequency to reward or enhance during neurofeedback training. Several of the studies specifically encouraged the decrease of theta activity while increasing beta. Others encouraged an increase of SMR frequencies while inhibiting theta. Some employed a combination of the two protocols. Further research in this area might help to delineate whether one protocol is more effective than another in the treatment of ADHD symptoms or whether this restriction is not a necessary component of the treatment. Perhaps all of the variations have a similar end result and therefore may be roughly equally effective in remediating attentional difficulties.

A related finding was the use of the theta:beta ratio. Most of the studies indicated that the efficacy of neurofeedback treatment could be determined by monitoring the theta:beta ratio. This measure seemed to be a more accurate measure of treatment effects than simply measuring the decrease in theta or increase in beta alone as these measures vary by age. One difficulty noted in the literature, however, was the fact that there were no normative data for this ratio according to age. The ratio is supposed to compensate for maturation effects that would contaminate the measuring of theta and beta alone. The literature seems to imply that this ratio is stable over time, but again there is no database of normative data to substantiate this claim.

One potentially problematic issue in the literature is the equipment used in treatment. Although the researchers seemed to trust the software and equipment used in the studies, there were several studies that experienced some serious difficulties with either the software or hardware that compromised their ability to record EEG measurements accurately. At this point, it would seem possible that the choice of equipment may very well affect the results of the study and it remains unknown as to what degree the results may be altered. Since neurofeedback is a relatively new field of treatment and relies heavily on technology, the potential is always there to have faulty equipment. However, as seen in the medical field, the demand in clinical settings usually facilitates an improvement in the reliability and efficiency of the equipment in question, and therefore the development of more reliable equipment and software will most likely follow in the near future. Creative solutions to these difficulties need to be developed.

Some of the less cohesive aspects of the studies reviewed involve methodology and several other factors. The first is the fact that all of the studies collected data from clinical populations. As mentioned previously, this facet has the potential to limit the generalizability of the results to the normal population who may have ADHD and do not seek treatment. The possibility exists that if the studies were conducted with participants from the general population, the results may significantly differ.

In all the studies reported, the participants were those who completed treatment. There may have been, however, a large number of people who initiated treatment, but dropped out because treatment did not work for them. It would be interesting to initiate a study even in a clinical setting that included those that did not complete treatment instead of starting by studying clients who had already completed treatment. Additionally, there are only a few studies that have a control group. Part of this difficulty may stem from the problems inherent in attempting to run a study over the course of several months with placebo treatment and up to 80 hours of clinical time. Many studies in other disciplines or clinical trials involving control or placebo treatment groups are not as time intensive. It seems that it would be difficult to motivate someone to participate in 40 to 80 hours of treatment when the possibility exists that they may be receiving a placebo treatment. Even if they are promised the actual experimental treatment afterward (40-80 more sessions), it still involves a huge time commitment and therefore may be less appealing to potential participants.

The use of behavioral ratings in the assessment of the efficacy of neurofeedback treatment poses some methodological problems. In one of the studies, there was no reported difference between the behavior ratings of those who improved their EEG performance and those who did not. This finding seems contradictory to the expected outcomes. Several other studies, however, did find behavior ratings to be commensurate with positive treatment outcomes. Although only one study had this difficulty, it still casts doubt on the reliability of the results that are assessed via behavior ratings. Additional replications of the study that did not produce significant differences between the experimental and control groups would seem to be warranted to make sure that the data in the other studies are not more profoundly influenced by rater expectations than was previously thought.

Most of the studies reviewed worked with middle income families. The potential effect of socio-economic status (SES) on treatment cannot be ignored. There were no extant studies involving populations of lower SES. Populations in this SES may have a significantly different clinical distribution. Additionally, neurofeedback at this point can be fairly expensive and therefore may not be as accessible to a population with a lower SES.

Related to the accessibility of treatment is the idea of the length of treatment. The general consensus by some of the major neurofeedback researchers was that successful treatment usually took a minimum of 30 sessions to effect a noticeable change. However, several studies reported significant changes in attention and IQ scores after only 15 to 20 sessions. Others reported it was necessary to continue for up to as many as 40 to 80 sessions for maximum treatment efficacy. In this respect, there appeared to be some contradictory information regarding how many sessions would produce a reduction in ADHD symptoms. Compounding this idea is the introduction of INAP into the treatment with neurofeedback that appears to greatly accelerate the gains and decrease the time needed for treatment. This contradiction would seem to imply that there are still many unknown variables that have the potential to influence the efficacy and efficiency of treatment.

Other contradictory results noted in the literature involved one study where 1/3 of the experimental subjects actually did not see any improvements in their TOVA scores. This finding seems to contradict the overall trend of predictable improvement in TOVA performance after neurofeedback. The study did not have an explanation for the discrepancy.

Many of the studies reported their data in terms of the difference between pre and posttest scores on the TOVA. However, simply reporting raw data changes may inflate or distort the results as there are significant differences between scores noted in older children in comparison to younger children. If all the scores were compared with each other irrespective of the age difference, the gains can be greatly exaggerated.

One last difficulty observed in the literature is attempting to identify the actual mechanism responsible for the improvement in attention after neurofeedback. Are the treatment successes a result of the actual neurofeedback, or simply the result of 40 sessions of intense one-on-one interaction and instruction on improving attention? Could one of the confounding variables also be the long-term relationship with the neurotherapist? The studies involving INAP seem to imply greatly enhanced treatment efficacy with the introduction of a hypnotic procedure. Would the same result be seen if the client were instructed in deep breathing or relaxation exercises before engaging in neurofeedback treatment? Another alternative may simply be the encouragement of the patient's competence to learn and attend more effectively. All of these factors could possibly be responsible for the change seen in both neurofeedback and in the treatment with the INAP procedure. Additional clinical research is necessary to distinguish what aspects of the treatment are actually responsible for the changes in ADHD symptoms.

Additional research can also be conducted using more advanced research designs using controls and various experimental groups. One example of a more complex research design may be a four group design involving not only a non-treatment control group and a neurofeedback group, but also two alternate treatment groups, perhaps one receiving medication and one receiving a behavioral treatment, such as social skills training, attention training, cognitive strategies, relaxation training, or hypnosis. Further replication and exploration of INAP treatment is necessary before it can be established as an effective component of ADHD treatment. However, as the previous studies have demonstrated, neurofeedback appears to indeed be an effective treatment for at least 80% of the population with ADHD and has the additional potential to help remediate or reduce the symptoms from many other complex disorders that occur comorbidly as well.

ADHD was once an incurable disorder thought to be treatable only with medication which, unfortunately, was only effective with continued use of the drug. Upon cessation of the drug, the ADHD symptoms would return. Now, there seems to be hope for a non-pharmacological treatment that may have a more long-term remedial affect. Neurofeedback may provide the field of psychology with a previously unknown window into understanding and remediating attentional difficulties and perhaps even some of the more difficult behavioral disorders.

REFERENCES

Alhambra, M., Fowler, T., & Alhambra, A. (1995). EEG biofeedback: A new treatment option for ADD/ADHD. Journal of Neurotherapy, 1 (2), 39-43.

American Psychiatric Association. (1987). Diagnostic and statistical manual of mental disorders (3rd ed., rev.). Washington, DC.

American Psychiatric Association. (1994). Diagnostic and statistical manual of mental disorders (4th ed.). Washington, DC.

Anderson, K., Barabasz, M., Barabasz, A., & Warner, D. (2000). Efficacy of Barabasz's instant alert hypnosis in the treatment of ADHD with neurotherapy. Child Study Journal, 30 (1),51-62.

Barabasz, A., & Barabasz, M. (2000). Treating ADHD with hypnosis and neurotherapy. Child Study Journal, 30 (1), 25-42.

Barabasz, M., & Barabasz, A. (1996). Attention deficit disorder: Diagnosis, etiology and treatment. Child Study Journal, 26 (1), 1-37.

Boyd, W., & Campbell, S. (1998). EEG biofeedback in the schools. The use of EEG biofeedback to treat ADHD in a school setting. Journal of Neurotherapy, 2 (4), 65-71.

Clarke, A., Barry, R., McCarthy, R., & Selikowitz, M. (1998). EEG analysis in attention-deficit/hyperactivity disorder: A comparative study of two subtypes. Psychiatry Research, 81, 19-29.

Evans, J., & Abarbanel, A. (1999). Introduction to quantitative EEG and neurofeedback. San Diego: Academic Press.

Fuchs, T. (Trans.) (2000). Aufmerksamkeit und neurofeedback [Abstract]. [On-line]. Available: www.eegspectrum.com/german/fuchs.htm.

Graham, J. (1996). Improved neuronal regulation in ADHD: An application of fifteen sessions of photic-driven EEG neurotherapy. Journal of Neurotherapy, 1 (4), 27-36.

Ingersoll, B., & Goldstein, S. (1993). Attention deficit disorder and learning disabilities. New York: Doubleday.

Kaiser, D. (1997). Efficacy of neurofeedback on adults with attentional deficit and related disorders. [On-line]. Available: www.eegspectrum.com/tovadult/adults.htm.

Kaiser, D., & Othmer, S. (1997). Efficacy of SMR-beta neurofeedback for attentional processes. [On-line]. Available: www.eegspectrum.com/tova97/530tova.htm.

Linden, M., Habib, T., & Radojevic, V. (1996). A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. Biofeedback and Self-Regulation, 21(1), 35-50.

Lubar, J. (1991). Discourse on the development of EEG diagnostics and biofeedback for attention-deficit/hyperactivity disorders. Biofeedback and Self-Regulation, 16 (3), 201-225.

Lubar, J. (1997). Neocortical dynamics: Implications for understanding the role of neurofeedback and related techniques for the enhancement of attention. Applied Psychophysiology and Biofeedback, 22, 111-126.

Lubar, J. F., & Lubar, J. O. (1999). Neurofeedback assessment and treatment for attention deficit/hyperactivity disorders. In James Evans & Andrew Abarbanel (Eds.), Introduction to quantitative EEG and neurofeedback (pp. 103-143). San Diego: Academic Press.

Lubar, J. O. & Lubar, J.F. (1984). Electroencephalographic biofeedback of SMR and beta for treatment of attention deficit disorders in a clinical setting. Biofeedback and Self Regulation, 9 (1), 1-23.

Lubar, J., Swartwood, M., Swartwood, J., & O'Donnell, P. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measure by changes in T.O.V.A. scores, behavioral ratings, and WISC-R performance. Biofeedback and Self-Regulation, 20 (1), 83-99.

Mann, C., Lubar, J., Zimmerman, A., Miller, C., & Muenchen, R. (1991). Quantitative analysis of EEG in boys with attention-deficit hyperactivity disorder: Controlled study with clinical implications. Pediatric Neurology, 8, 30-36.

McCarney, S. (1989a). Manual for the attention deficit disorders scale - home version. Columbia, MO: Hawthorne.

McCarney, S. (1989b). Manual for the attention deficit disorders scale - school version. Columbia, MO: Hawthorne.

Othmer, S. (1999). EEG biofeedback training: The old and the new. [On-line]. Available: www.eegspectrum.com/articles/oldnew.htm.

Othmer, S., & Othmer, S. (1992). EEG biofeedback for attention deficit hyperactivity disorder. [On-line]. Available: www.eegspectrum.com/adhd/adhd.htm.

Othmer, S., Othmer, S., & Kaiser, D. (1999). EEG biofeedback: A generalized approach to neuroregulation. [On-line]. Available: www.eegspectrum.com/articles/kall.htm.

Othmer, S., Othmer, S., & Marks, C. (1991). EEG biofeedback training for attention deficit disorder, specific learning disabilities, and associated conduct problems. [On-line]. Available: www.eegspectrum.com/adhd91/adhd91.htm.

Plude, D. (1996). New technology: A biological understanding of attention deficit hyperactivity disorder and its treatment. The Journal of Neurotherapy, 1(3), 10-14.

Robbins, J. (2000). A symphony in the brain. New York: Atlantic Monthly Press.

Rossiter T., & La Vaque, T. (1995). A comparison of EEG neurofeedback and psychostimulants in treatment attention deficit/hyperactivity disorders. Journal of Neurotherapy, 1 (1), 48-59.

Sattler, J. (1992). Assessment of children. (Rev., 3rd ed.). San Diego: Jerome M. Sattler Publishing, Inc.

Tansey, M. (1993). Ten year stability of EEG biofeedback results for a 10 year old hyperactive boy who failed fourth grade in a class for the perceptually impaired. Biofeedback and Self-Regulation, 18, 33-44.

Thompson, L., & Thompson, M. (1998). Neurofeedback combined with training in metacognitive strategies: Effectiveness in students with ADD. Applied Psychophysiology and Biofeedback, 23 (4), 243-263.

Warner, D., Barabasz, A., & Barabasz, M. (2000). The efficacy of Barabasz's alert hypnosis and neurotherapy on attentiveness, impulsivity and hyperactivity in children with ADHD. Child Study Journal, 30 (1), 43-47.

Zametkin, A., Nordahl, T., Gross, M., King, A., Semple, W., Rumsey, J., Hamburger, S., & Cohen, R. (1990, November 15). Cerebral glucose metabolism in adults with hyperactivity of childhood onset. The New England Journal of Medicine, 323 (20), 1361-1366.

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