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Evaluation of the effectiveness of an attention enhancement program for children diagnosed with ADHD administered in the school setting.

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EVALUATION OF THE EFFECTIVENESS OF AN ATTENTION ENHANCEMENT PROGRAM FOR CHILDREN DIAGNOSED WITH ADHD ADMINISTERED IN THE SCHOOL SETTING

A Dissertation Presented by WILLIAM R. GRISANZIO

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY September 2000 Counseling Psychology Program
EVALUATION OF THE EFFECTIVENESS OF AN
ATTENTION ENHANCEMENT PROGRAM
FOR CHILDREN DIAGNOSED WITH ADHD
ADMINISTERED IN THE SCHOOL SETTING

A Dissertation Presented

by

WILLIAM R. GRISANZIO

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ABSTRACT
EVALUATION OF THE EFFECTIVENESS OF AN
ATTENTION ENHANCEMENT PROGRAM
FOR CHILDREN DIAGNOSED ADHD
ADMINISTERED IN THE SCHOOL SETTING
SEPTEMBER 2000
WILLIAM R. GRISANZIO, B.S., MAINE MARITIME ACADEMY
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Directed by: Professor William J. Matthews

Attention-Deficit Hyperactivity disorder (ADHD), a persistent pattern of inattention and or hyperactivity-impulsivity, is a growing concern in many school districts because it is estimated to affect as much as 3 percent to 5 percent of the school age population (APA, 1994). The problem is that regardless of the currently accepted methods of treatment such as parent training, family therapy, classroom management, social skills training, and medication therapy, the symptoms of ADHD persist into adolescence at an alarming rate. Children with disorders of behavior exhibit excessive theta brainwave activity compared to normal children (Lubar, 1991). The present study administered a changing criterion treatment protocol, which integrated components of neurofeedback, meditation, and control theory, in order to decrease theta brainwave activity. The purpose of the present study was to explore whether a school system could identify specific
profiles of attention with a computerized continuous performance test (CPT), administer an attention enhancement program, and remedy those deficits identified by the CPT. The subjects were 5 male children between the ages of 8 and 10 years who were diagnosed ADHD by their family physicians. Subjects were selected according to their performance on the Test of Variables of Attention (T.O.V.A.), a computerized continuous performance test. Subjects received between 18 and 26 attention enhancement sessions over a four month period during their regular school day. Although the T.O.V.A. showed moderate ability to identify specific profiles of attention, as supported by moderate Pearson correlations between T.O.V.A. impulsivity and ADHDT impulsivity ($r = -.58, P<.05$) and T.O.V.A. inattention and ADHDT inattention ($r = -.63, P<.05$), T.O.V.A. performance did not consistently improve after attention training. Although the attention enhancement program was completed within the school, there were many unforeseen difficulties and impediments to its successful administration. Secondary dependent measures included the Stroop Color and Word Test, Attention-Deficit Hyperactivity Disorder Test (ADHDT), EEG measures, Parenting Stress Index, and Behavior Rating Profile. The results of these measures were equivocal.
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DEFINITION OF TERMS

Alpha - brainwaves measured in the 8-13 Hertz range.

Amplitude - a mathematically defined measure of the size of the electrical signal.

Artifact - any electrical signal measured by the EEG which does not originate in or directly reflect the activity of the brainwaves. Examples of artifact include signals from surrounding electrical components, such as lamps and wall sockets or signals from other muscle activity not being monitored.

Bandpass - a frequency range of electrical activity to be sampled.

Beta - brainwaves measured in the 16-22 hertz range.

Biofeedback - an instrumental procedure that senses, records, and provides the subject with information about those physiological functions in relation to which there is usually no awareness or voluntary control (Campbell, 1989).

EEG Inhibit - frequency of brainwaves that the subject trains to inhibit (theta, 4-8 hertz).

Electroencephalograph - instrumentation that measures the frequency and amplitudes of brain electrical activity.

EMG - electromyograph, muscle electrical activity.

Frequency - the number of cycles per second or hertz.

Electrode Impedance - resistance between the sensor and the contact site on the skin. The better the contact, the lower the resistance, and the lower the noise.

Monopolar Electrode Configuration - use one active electrode on the scalp and two ground electrodes on each ear lobe.

Neurofeedback - brainwave biofeedback.

Sampling Rate - the rate at which the electroencephalograph measures brainwave electrical activity. Set at either 128 or 256 samples per second.

Theta - brainwaves measured in the 4-8 hertz range.

Threshold - an arbitrary point at which feedback is either begun or suspended.
CHAPTER I
INTRODUCTION

Statement of the Problem

Attention-Deficit Hyperactivity Disorder (ADHD), a persistent pattern of inattention and or hyperactivity-impulsivity, is a growing concern in many school districts because it is estimated to affect as much as 3 percent to 5 percent of the school age population (APA, 1994). The symptoms of this disorder are believed to emerge in school age children due to the academic and social demands of the school environment (McGee, Williams, & Feehan, 1992). The fourth grade, specifically, has been identified as a point of difficulty for ADHD children because the academic focus shifts from the memorization of information to the application of basic principles (Barkley, 1990).

The problem is that regardless of the currently accepted methods of treatment such as parent training, family therapy, classroom management, social skills training, and medication therapy, the symptoms of ADHD persist into adolescence at an alarming rate, with 68 percent of children diagnosed with ADHD showing signs of psychopathology after the age of thirteen (Gittelman, 1985), 43 percent continuing to be hyperactive (Lambert, 1987), 71 percent to 84 percent continuing to manifest ADHD symptomatology (Mendelson, Johnson, & Stewart, 1971), and over 80 percent continuing to have the disorder (Barkley, 1990).

Statement of Purpose

The purpose of this study was to explore whether a school system could identify specific profiles of attention with a computerized continuous performance test, administer
an attention enhancement program, and remedy those deficits identified. The primary question was whether performance on the continuous performance test would improve. Of secondary interest were the ancillary effects that might accompany an improvement in the students attention profile. Would behavior change at school as rated by the classroom, art, and music teachers? Would behavior change at home as rated by parents? If the behavior at home did change would it effect a parents subjective level of parenting stress? Another point of interest was how an improvement in attention and behavior might affect the student's social ranking among peers.

Since the attention training program utilized brainwave biofeedback, or more recently termed neurofeedback, the subjects brain waves were also examined over time.

Rationale and significance of Study

Interest in non-traditional treatments for children and adolescents with ADHD has increased over the past several years. Some non-traditional treatments are eye movement desensitization and reprocessing, deep pressure/touch therapies, stress-challenge treatments, confrontational scare treatments, and electroencephalographic (EEG) biofeedback (Arnold, 1995). Arnold cautioned that new treatments should not be embraced uncritically or rejected without fair examination.

Neurofeedback represents the cutting edge of psychophysiological research in the treatment of ADHD. The basic foundation of neurofeedback training can be understood by considering the definitions of feedback and control theory. Feedback is defined as the return to the input of a part of the output of a machine, system, or process to either improve performance or provide self corrective action (Webster, 1981). Control theory
maintains that a variable can be controlled when information about that variable is made available to the controller (Anchor, Beck, Sieveking & Adkins, 1982). If a variable within the physiological system of a person is made available to that person and a degree of control is developed, improvements or self-corrections may become possible within that system.

The variable of main concern in this study is brain waves, specifically theta brain waves. In a recent cross national EEG study using subjects from Japan, China, and Korea, ADHD children were identified as having more delta and theta activity along with less alpha activity than those found in the control groups (Matsuura, Okubo, Toru, Kojima, He, Shen, & Lee, 1993). This finding of increased theta activity has been consistently found since Jasper and his colleagues (1938) first examined the differences in brain waves of normal children to those with behavior disorders. At least twelve studies conducted between 1950 and 1960, three during the period of 1970-1980, and five since 1990 support the finding of increased theta activity.

Considered the founder and developer of neurofeedback in the treatment of ADHD, Lubar (1991) found that subjects, when supplied with the proper shaping protocol, could learn to decrease their theta activity while concurrently increasing beta activity. In a recent study Lubar and his colleagues (Lubar, Swartwood, Swartwood, & O'Donnell, 1995) documented successful reductions in theta waves in 12 out of 19 subjects. The rationale for changing this brain wave pattern lies in the fact that beta brain wave activity is considered by most psychophysicologists to reflect active mental processing and delta and theta activity to reflect decreased arousal (Andreassi, 1989).
This method of treatment has been criticized by traditional leaders in ADHD treatment and research, who cited poor research methodology (Barkley, 1990, 1992). However, Barkley did acknowledge the results revealed a "general tendency" to a type of under-reactivity to stimulation in some hyperactive children (1990) and that the possibility of neurofeedback ultimately proving to be effective for some types of ADHD could not be ruled out (1992).

The results of the present study may be of interest to schools, neurofeedback researchers, and traditional researchers involved in the study of ADHD. Schools appear to be "between a rock and a hard place," faced with a growing number of children diagnosed with ADHD. On the one hand the school is expected to provide accommodation to the student's problem in learning. On the other hand, they come under fire for the increasing use of psychostimulants at school. Schools' interest in the available non-traditional treatments may increase as the debate concerning the diagnosis and treatment of ADHD increases in intensity. Educational institutions will look to the research literature for evidence of treatment efficacy.

Specific aspects of this study are likely to be of interest to both nontraditional and traditional researchers. Unlike most published neurofeedback studies, the present study was conducted at school, and the treatment sessions were integrated within the subjects daily school routine. This afforded a preliminary examination of the affect, if any, the school environment had on the subjects ability to accomplish the neurofeedback task. The intent was to address apply the treatment in the natural context in which the subjects were experiencing the most difficulty. In addition, it was not known whether the school
environment would hinder or complement treatment. The second unique aspect of this study was the manner in which the continuous performance test was utilized. Not only was it utilized to measure attention, but it was also the means to establish subject homogeneity. At the same time the use of continuous performance tests is on the increase among biofeedback researchers, its ecological validity, or its ability to provide information regarding how subjects might behave in the real world, continues to be questioned (Dupaul, Anastopolous, Shelton, Guevrement, and Metevia, 1992).

Finally, the manner in which the present study utilized neurofeedback may be of particular interest. Neurofeedback was used to guide the subjects in a particular form of meditation with the hope of accomplishing the neurofeedback task quicker.
CHAPTER 2

REVIEW OF THE LITERATURE

Traditional treatments for ADHD

The traditional treatments for ADHD include medication therapy, psychosocial treatments, parent training, cognitive behavioral therapy, family therapy, and combined treatments.

Medication Therapy

Psychostimulant medication is the most common and most effective treatment for children with Attention-deficit Hyperactivity Disorder (Dupaul & Barkley, 1990; Pelham, 1993). Even though stimulants have been found to be quite safe for hyperactive children (Safer, 1992), not all hyperactive children use them because between 23% and 27% of children are non-responders—that is, their symptoms are not reduced by the administration of stimulants (Dupaul & Barkley, 1990). Even among drug responders, stimulant therapy is rarely sufficient to bring the academic and social functioning of hyperactive children into the normal range (Pelham, 1993).

The current issue concerning stimulants is whether their effects on behavior and school performance are short-term or long-term. Short-term effects are typically those observed or measured within a one to three hour period (Carlson & Bunner, 1993) after ingestion of the stimulant. Extended treatments are those that typically last for three months, and long-term treatments last a minimum of 9 to 12 months (Schachar & Tannock, 1993). Most evidence suggests that the beneficial effects are short-term (Pelham, 1993). Evidence supporting long-term effectiveness is lacking. The theory behind
long-term effectiveness assumes generalization of the short-term benefits. If a child receiving stimulant medication attempts more math and reading tasks (Elia, Welsh, Gullotta, & Rapoport, 1993), attends to task more and is academically more efficient (Dupaul & Rapport, 1993), and is better behaved, more compliant, academically more productive, and less aggressive toward peers (Pelham, 1993), it seems only logical that these benefits would generalize and the child would learn more. This, however, is not the case.

Several recent literature reviews of extended and long-term treatments concur in their findings: support for long-term effectiveness is lacking (Pelham, 1993; Schachar and Tannock, 1993; Swanson et. al., 1993; and Carlson & Bunner, 1993). Schachar and Tannock (1993) reviewed eighteen extended treatment studies of psychostimulants and support the notion that methodological flaws such as nonrandomized designs, diagnostic heterogeneity, lack of treatment controls, narrow range of outcome measures, and small sample sizes may have limited the ability to obtain significant results. Thus, if medication were titrated to the optimum effective dosage with a randomly assigned homogeneous subject population, significant effects may be found among certain subgroups of the ADHD population. To address these concerns and those of comorbidity, it has been recommended to move away from single diagnoses and toward the use of profiles as a means to establish subject homogeneity (Kendall & Panichelli-Mindel, 1995).

Because the evidence of these effects translating into long-term improvement is lacking, these authors as well as others (DuPaul & Rapport, 1993) recommend combined stimulant and psychoeducational interventions.
Psychosocial Treatments

Several approaches to the treatment of ADHD that have been found to be at least partially effective are parent counseling and training, family therapy, school-based behavioral management (Barkley, 1990), social skills training, and cognitive-behavioral therapy (Anastopoulos, DuPaul, & Barkley, 1991). The most common treatments used in the classroom are behavior modification and stimulant treatment (Pelham et. al., 1993; Coker & Thyer, 1990).

Parent Training/Counseling

In their review of parent training for families of children with ADHD, Newby, Fischer, and Roman (1991) reviewed three of the most common parent training programs—those of Barkley (1987), Patterson (1976), and Forehand (1981). In their review, four observations were offered. First, the approaches to changing behavior were varied—from social reinforcement to token economies. Second, the treatment formats varied across all three programs. Third, all three programs used time-out as the primary method of disciplining, and fourth, all programs emphasized assessment prior to training. Although the authors acknowledged that there was a substantial body of research to support the efficacy of parent training in altering children's noncompliant behavior, they stressed that variables such as good therapeutic rapport, flexibility, pacing in delivering the intervention, warmth, and empathy were equally important. Patterson (1982) remarked that both therapeutic skill and knowledge of behavior therapy were necessary in order to affect behavior change.
Even though ADHD parent training programs have yet to receive comprehensive empirical support for their efficacy (Anastopoulos et. al., 1991), and many methodological inconsistencies and shortcomings have been identified (Barkley, 1990), the available studies are considered sufficient to recommend and utilize parent training with the ADHD population. Anastopoulos, Shelton, DuPaul, and Guevremont (1993) examined the effect parent training had on parent self-esteem and stress, and found that parents had learned to manage their child's ADHD behavior better. This improvement in coping appeared to facilitate an improvement in the parents' perception of their child, which was believed to have resulted in a reduction in reported severity of the child's symptoms. However, depending on which dependent measure was examined, from 5% to 43% of treatment subjects either regressed or did not improve as a result of treatment.

**Cognitive behavioral Therapy**

Cognitive-Behavioral Therapy (CBT) has been indicated in the treatment of ADHD because many of the problems of ADHD involve deficits in cognitive functioning (Kendall & Panichelli-Mindel, 1995). Thus, the focus of CBT is how children respond to their thoughts rather than their situation and how their thoughts and behaviors might be related. In his review of the Cognitive-training therapies, in which the focus is the development of self-control skills and reflective problem-solving strategies (Abikoff, 1991), 21 controlled studies were examined. The evidence to support the effectiveness of self-regulation skills in curtailing ADHD behavior was lacking. A major weakness of these studies was the use of nonclinical subjects which limits the ability to generalize to the ADHD population. Available research does not support the effectiveness of cognitive
therapy in the treatment of ADHD other than in the treatment of impulsivity (Kendall & Braswell, 1993).

**Family Therapy**

A recent study evaluated three family therapy models in the treatment of ADHD adolescents (Barkley, Guevremont, Anastopoulos, & Fletcher, 1992). Barkley and his colleagues evaluated behavioral management training (n=20), structural family therapy (n=20), and communication training (n=21) at pretest and posttest as well as a three-month follow up. All three models produced significant reductions in negative communication, conflicts, and subsequent anger as well as improvements in school adjustment. However, only 5-30% of subjects reliably improved from treatment and only 5-20% recovered following treatment. An interesting finding was that the group that received communication training in which the focus was on family conflicts and negative attributions appeared to have worsened parental ratings concerning their adolescents behavior. Whether this observation is due to a decrement in behavior or an increase in awareness of their attributions is not clear.

**Combined Treatments**

The support for combined treatments is inconsistent. In an earlier review, Pelham and Murphy (1986) identified and reviewed 19 studies involving a total of only 167 subjects. Besides low subject numbers, three major methodological weaknesses were identified as hindrances to effective interpretation of the results. They were failure to include separate manipulations of behavioral intervention and medication, wide variety of
behavioral interventions, and inconsistent evaluation of individual differences on treatment response. In their most recent investigation, Pelham and his colleagues (Pelham, Carlson, Sams, Vallano, Dixon, & Hoza, 1993) addressed these methodological weaknesses in their examination of the separate and combined effects of behavior modification and two doses of methylphenidate compared with no behavior modification and a placebo on the classroom behavior and academic performance of 31 ADHD boys attending a summer treatment program. Behavior modification and methylphenidate both significantly improved classroom behavior, while only methylphenidate improved academic performance. Combined treatment was more effective than behavior modification alone but not methylphenidate alone.

Horn, Ialongo, Pascoe, Greenberg, Packard, Lopez, Wagner, & Puttler (1991) utilized a double blind, placebo design in their examination of a high and low dose of methylphenidate alone and in combination with behavioral training plus child self-control training with 96 children diagnosed with ADHD. They found no evidence for the superiority of combined treatments relative to medication alone.

Firestone, Crowe, Goodman, and McGrath (1986) examined the effects of parent training and titrated doses of methylphenidate on 73 children with ADHD. Over a three-to-four-week period the children were administered methylphenidate in 5-mg increments. After the optimal dosage was determined, with the aide of parent and teacher reports, group comparisons were made. They examined reaction time, impulsive responses, school performance, hyperactivity, and conduct. Stimulant medication alone was responsible for improved attention and behavior. Parent training was found to add little improvement.
In those studies on combined effectiveness which designated medication as the baseline, the addition of behavior modification (Pelham et al., 1993); parent training (Firestone et al., 1986); and parent training plus child self control (Horn et al., 1991) failed to enhance treatment results. However, when the psychological intervention was considered to be the baseline, combined effectiveness was claimed (Pelham et. al., 1993).

One study (Carlson, Pelham, Milich, & Dixon, 1992) provided evidence that combined methylphenidate (MPH) and behavior modification therapy was not only superior to either treatment alone, but that the total dosage of medication used by ADHD children may be reduced with concurrent behavior modification. Consistent with the short term studies of methylphenidate and academic performance, 0.3 and 0.6 mg/kg MPH dosages were found to be more effective than placebo in facilitating more attempts at math problems and increased success at reading problems. Behavior modification, which had no effect on academic performance, was found to reduce disruptive behavior and facilitate on-task behavior as compared to the no treatment group. The most significant results of this study were the interactions between behavior modification and MPH. In the regular classroom condition, .6 mg/kg of MPH was found to have significantly more impact on behavior than .3 mg/kg of MPH. However, in the behavior modification condition, no differences were found between these two dosages.

There are numerous other studies that examined combined effectiveness, such as a series of three case studies of three mothers with hyperactive boys (Pollard, Ward, & Barkley 1983). Examined were the effects of parent training alone and combined with methylphenidate on parent-child social interactions. The combined treatments failed to
produce superior results than either treatment alone. However, because they were looking at the parent and not just the child, they found that parent training was more effective in eliciting positive parental attention.

Electroencephalography

In a lecture delivered to the International Congress of Electroencephalography and Clinical Neurophysiology in 1993, Pierre Gloor (1994) spoke about how the neuropsychiatrist Hans Berger (1877-1941) committed his life to understanding man as a psychophysiological being. Gloor talked not only of the accomplishments of Berger, but of his many frustrations and failures and how they were actually precursors to the cutting edge of psychophysiological monitoring today: PET and MRI scans. Berger's early research explored the connection between mental activity and cerebral blood flow and temperature. Due to the lack of adequate instrumentation available, Berger abandoned this line of research for the EEG and is credited with obtaining the first reported human EEG in 1929, in which he recorded 10Hz alpha waves (Grass, 1984). Berger first began studying electrical activity in animals but soon realized he could put needles near the cortex of persons with skull defects and get potentials large enough to record.

It is great advances in technology that mark the history of our knowledge of physiology and human functioning. These advances at times collide with existing paradigms. Berger came face to face with dualism or Wundt's psychophysical parallelism (Gloor, 1994). The demonstration of the alpha rhythm and beta waves was met with utter disbelief by fellow neurophysiologists and those pioneers who believed in its significance were met with scorn and derision (Neidermeyer, 1975).
In his discourse on the heritage of the electroencephalograph, Grass (1984) describes the 50 years prior to Berger, 25 years after Berger, and then the next 25 years as distinct periods due to developmental advances in electronic instrumentation. Along with advances in physics came advances in technology, which permitted the measurement and localization of physiological processes that were previously not possible (Gloor, 1994). EEG technology was based on electromagnetic theory in the 50 year period prior to Berger, electron theory and the electron tube in the following 25 year period, and the transistor in the 25 year period after that. Current advances with microprocessors and digital processing continue to shape the availability, capability, quality, and utilization of the EEG.

Early evidence for brainwave Differences (1950's & 1960's)

Albert Grass, the developer of the first clinical EEG, offered the following remark regarding the early time period in electroencephalography, "Most of us were thirty-five years old with boundless energy and curiosity. EEGers from all over the country were on a first name or nickname basis so close had our common interests brought us together."

Unfortunately, along with the boundless energy and enthusiasm of the early pioneers came flawed research designs in their exhaustive attempts to learn the relationships between brain waves and illness. Klass and Daly (1979) found that the basic early design was to search for brain wave differences in a group of subjects, establish a group of subjects with similar patterns, develop a symptom profile with those subjects, and then attribute those brain waves to the predominant symptom. Although much of the early research was compromised by fundamental flaws in research design, the sheer number of studies
suggested that the brain waves of children with behavior disorders were different than those of children without behavior disorders.

Differences between the EEGs of normal children and those with behavior disorders have been documented as early as 1938 when Jasper and his colleagues (Jasper, Solomon, & Bradley, 1938) compared the EEGs of 71 behavior-disordered children with those of 40 normal children matched by age. They discovered a pattern that became common among not only behavior disordered children, but brain pathology in general—that of pronounced theta and slow-wave activity.

No longer content with the identification of differences, several investigators focused their efforts on the comparison of behavior-disordered children's brain wave profiles with those of younger normal children. The focus on age marked the birth of one of the most prominent theories regarding slow-wave activity—delayed central nervous system maturation (Kennard, 1969; Bosaeus, Matousek, & Peterson, 1977; Matousek & Peterson, 1971). These studies suggested that the EEGs of behavior-disordered children appeared similar to those of younger normal children. Providing further support for maturation, the frontal theta and posterior slow wave activity appeared to decrease with increasing age.

Klass and Daly (1979) examined brainwaves from a somewhat different perspective. They surmised the possibility of a circular relationship between brainwaves and the environment. The family environment of behavior-disordered children were believed to be especially vulnerable to increased stress as a result of parental efforts at child behavior management. Increased stress could heighten emotional arousal, which
corresponded to increased frontal theta activity (Cohn & Nardini, 1958; Mundy-Castle, 1958; Klass and Daly, 1979). The behavior of the child and the family environment may actually be mutual reinforcers either exasperating or maintaining the dysfunctional equilibrium. Disturbed parent-child relationship was found to be the strongest predisposing factor in differentiating between behavior-disordered children and normal controls (Stevens, Sachdev, & Milstein, 1968). This finding supports the utilization of parent training and counseling (Barkley, 1990)—the primary method of treatment for ADHD today.

Over a period of several years, Cohn & Nardini (1958) observed that aggressive individuals appeared to present with a consistent brain wave pattern: slow occipital activity. They presented ten case studies examining the relationship between brain profiles and developmental history. It was their contention that the observed profile was a continuous development of the abnormal bi-occipital activity found in children. Their hypothesis was basically one of delayed maturation. With increasing age, paroxysmal activity decreases in the occipital region of the brain and becomes more dominant in the frontal areas of the brain. Their subjects were quite heterogeneous, presenting with seizure disorder, head injury, impulsive and aggressive behavior, personality disorder, and alcoholism. These observations lend further support to the familiar response of the brain to insult: slowing.

Klinkerfuss, Lange, Weinberg, & O'Leary (1964) examined the EEGs of hyperkinetic children and also found predominantly slow wave activity. Out of 782 children referred to a hospital hyperkinetic clinic over an 18 month period, 277 were
excluding due to major illness, 87 were excluded due to young age (less than 4), 65 had no EEG record, resulting in a hyperkinetic group (n=353) for examination. This group was divided into two groups for comparison. The first group consisted of those subjects for which there was evidence of both hyperkinesis and seizure activity or neurological findings. The second group consisted of subjects with hyperkinesis and minimal evidence of neurological impairment. Further distinctions were made within these groups according to age. The EEGs were rated as mild, moderate, and marked according to the degree of paroxysmal activity observed. The most consistent evidence was abnormal slow frequencies in the hyperkinetic group. Even though the data did not support a relationship between age and the presence of slow wave activity, the authors attributed their findings to delayed maturation, brain damage, or genetics.

Stevens, Sachdev, & Milstein (1968) examined the neurological and behavioral correlates of EEG deviations. Behavior-disordered children (n=97) referred from a hospital pediatric clinic, private practitioners, and mental health clinics were compared to normal children (n=88) referred from the same pediatric hospital and the local public school. The selection criterion for normal controls was agreement on a behavior rating scale by both parents and teachers. Nearly half of the children referred from the pediatric hospital were rated less favorably by the teachers and nearly half of the children referred from the local school were rated less favorably by the parents. This resulted in two distinct control groups, one in which there was agreement among parents and teachers (n=57) and one in which there was not (n=31). They found that the general designation abnormal EEG failed to predict significant differences between children. However, specific EEG
characteristics were found to predict relationships between certain behavioral traits, predisposing factors, and specific EEG abnormalities. Among many other clinical items, they found significant positive correlations between EEG spike activity and disturbed attention, paroxysmal activity and impulsivity, and delta activity (slowing) and hyperactivity. Their data suggested that both heredity and family environment were heavily involved with hyperactivity. The authors hypothesized that heredity may be involved in both the abnormal EEG and the disturbed family relations. However, an argument can be made for a circular mechanism in that the disturbed family relations may have interfered with the child's normal social adaptation and the development of normal physiological cerebral electrical patterns.

Later evidence for brainwave Differences (1970's & 1980's)

Since the early studies by Jasper (1948) and his colleagues, many studies have suggested that the brainwaves of behavior-disordered children vary from those of normal children. Wikler, Dixon, & Parker (1970) examined the psychometric, neurological, and EEG characteristics that differentiate children with scholastic-behavioral disorders from control children matched for sex, race, age, intelligence, and sociometric class. By establishing a hyperactive and nonhyperactive group from the behavior disordered children, they were also the first to examine the differences between these groups. A total of 25 children between the ages of five and fifteen years were referred to an outpatient clinic. Twenty-two were referred by teachers and three were referred by physicians. Excluded were those children showing signs of organic neurological disease based upon a screening examination, those with seizure disorder, and those with IQS below 86. A local
school system provided the matched control group. Both groups were administered psychometric tests, a neurological examination, and an EEG examination. Children in the patient group were classified hyperactive, nonhyperactive, or uncertain according to a behavior checklist administered during the intake interview. Eleven children were classified as hyperactive and nine nonhyperactive. The mean age of the hyperactive group was 2.8 years less than that of the nonhyperactive group.

The results revealed significant increases of slow alpha and theta rhythms in the patient group as compared to controls. When compared on mean age and mean total slow activity, the nonhyperactive group (mean age 136 months) revealed more slow wave activity than the hyperactive group (mean age 102 months). The control groups revealed significant age effects with the younger group (mean age 100 months) having more slow wave activity than the older group (mean age 134 months). The data suggested that some factor other than age differentiated the patient and control groups, thus not supporting the delayed maturation theory.

Recent evidence for brainwave Differences (1990s)

Due to increases in EEG technology, current researchers have been able to perform much more accurate, informative, and controlled studies. The objective has moved from making distinctions between very broad heterogeneous groups to revealing specific differences, under specific conditions, within specific brain regions of homogeneous groups. In addition, researchers have moved from identifying differences to predicting group membership (diagnosis) according to the EEG profile.
Mann, Lubar, Zimmerman, Miller, & Muenchen (1992) conducted a well controlled study of a group of boys diagnosed with attention deficit disorder without hyperactivity, learning disability, or conduct disorder, in order to determine the predictability of averaged power spectral analyses in ADHD. These authors acknowledged one of the well known facts of ADHD children: they have difficulty focusing their attention and concentrating for extended periods of time on academic tasks. An important and somewhat exciting component of their study was an examination of the impact that academic tasks such as reading and drawing had on the ability to discriminate ADHD from controls. They reported the most consistent and significant findings as increased theta activity and a lack of beta activation among boys with ADHD during these academic tasks. Most significant is that these differences were not observed during baseline conditions when the children were at rest performing a visual fixation task. EEG changes from baseline to drawing task were greatest with the ADHD group. They were able to predict group membership for the ADHD boys 80 percent of the time and 74 percent for controls. Increased theta in boys with ADHD was responsible for far more significant differences than any other frequency in both absolute and relative amplitude and during all three cognitive tasks; however, beta deficiencies were responsible for the larger percentage of changes between groups.

The authors concluded that deficient desynchronization and persistent slow activity at a time when one would expect significant desynchronized fast activity and attenuation of slow activity is a reflection of decreased cortical arousal from subcortical regions. These findings support the delayed maturation theory in that the EEG profiles of the
ADHD resembled EEG profiles of younger children. Thus, quantitative analysis of EEG may provide an objective, physiologically based, method to identify ADHD. Dykman, Holcomb, Oglesby, & Ackerman (1982) found similarly that the power band 16-20 Hz provided the best separation between groups of hyperactive, learning disabled without hyperactivity, mixed hyperactivity/LD, and no disability children.

Matsuura, Okubo, Toru, Kojima, He, Hou, Shen, & Lee (1993) tested the immaturity theory by examining EEG differences in children with normal and deviant behavior, both from the general population, and with attention deficit disorder with hyperactivity, who had been referred to psychiatric clinics in Japan, China, and Korea. All pupils from six schools in Tokyo, six schools in Beijing, and from four schools in Korea were administered the Rutter Child questionnaire to differentiate deviant (Japan, n=27, mean age 8.2, China, n=39, mean age 8.3, Korea, n=87, mean age 8.1) and normal behavior children (Japan, n=30, mean age 8.1, China, n=27, mean age 8.7, Korea, n=26, mean age 8.2). Subjects were then randomly selected and those who agreed to undergo routine EEG examination were selected for the study. Hyperactive subjects (ADD-H) were selected from those who were referred to psychiatric clinics in each country. Those subjects with stable baseline recordings (eyes-closed) who were not on medication were included in the study (Japan, n=21, mean age 8.5, China, n=41, mean age 8.6, Korea, n=29, mean age 8.0). Group differences were found on the large number of slow waves and smaller number of alpha waves in the ADD-H group. The ADD-H group had higher amplitude delta and theta, and lower percentage time of alpha and beta than normal and deviant behavior groups.
Ackerman, Dykman, Oglesby, & Newton (1994) were interested in whether garden-variety poor readers differ from dyslexic poor readers. The authors hypothesized that both groups of poor readers would exhibit greater theta power and less beta power while viewing lists of letters and first-grade-level words. This study allows us to gain an interesting perspective of the ADHD child—as a control group. The authors believed that ADHD children were appropriate controls due to the inability to recruit poor readers who did not exhibit problems with attention. Three groups dyslexic (n=42), slow learning (n=21), and normal reading ADD controls (n=56) referred for psychoeducational evaluation were matched on attention and hyperactivity. Any differences found could then be attributed to the reading variable. The normal reading group, with higher Verbal IQS, exhibited higher beta power and lower theta power than controls.

The most recent study of brainwave differences was conducted by Janzen, Graap, Stephanson, Marshall, and Fitsimmons (1995). The investigation examined the EEG differences between two diagnostically distinct groups, ADD (n=8) and normal controls (n=8), while performing cognitive tasks. They found increased theta activity and decreased beta activity with the ADD group during the cognitive tasks, and no differences between the groups during baseline. Compared to beta, theta differences accounted for far more differences between the groups, which suggests that criterion-based training protocols utilize theta inhibition rather than beta augmentation in the treatment of ADHD.

**Biofeedback**

Feedback and control theory are the two most important concepts in biofeedback research and are attributed to the field of engineering (Anchor, Beck, Sieveking, &
Adkins, 1982). Feedback is defined as the return to the input of a part of the output of a machine, system, or process (as for producing changes in an electrical circuit that improve performance or in an automatic control device that provide self-corrective action) (Webster, 1981). Control theory maintains that a variable can be controlled when information about that variable is made available to the controller (Anchor et. al, 1982). The basic foundation of biofeedback training can be understood by considering these two definitions. If a variable within the physiological system is made available to the person and a certain degree of control is developed, improvements or self corrections may be possible within that system.

Even though Jacobson's progressive relaxation techniques were found to teach individuals to achieve deep relaxation in 1922 and EMG lead applications in biofeedback, as evidenced by the numerous research publications, it appears that Berger's discovery of the human EEG marks the birth of biofeedback (Anchor et. al., 1982) due to the development of stable, high gain amplifiers and associated sensors, packaged into commercially available instruments (Crider, 1982).

Kimmel (1986) stresses that his pioneering research in 1958 on the operant conditioning of skin conductance among the many other avenues of exploration by other researchers did not place reputations on the line, make radical breaks from the past, or make radical paradigm shifts. The original investigations that served as the foundation for the beginning of applied biofeedback came from traditional scientific psychology. However, he did speak of the raging political climate of that time. Apparently, operant conditioning was thought of as externally imposed on the individual therefore associated
with fascism and that biofeedback was conceived as a method of achieving self control thereby being antifascist. The fact that the two, biofeedback and operant conditioning, were inextricably combined was not generally appreciated.

Modern applied biofeedback is defined as a process where a group of therapeutic procedures utilize instrumentation to accurately measure, process, and feedback to persons information about their neuromuscular and autonomic activity, both normal and abnormal, in the form of analog or binary, auditory and/or visual feedback signals (Olson, 1987). Olson states the main objective of biofeedback is to foster greater awareness and control over physiological processes by first controlling the external signal, and then by the use of internal psychophysiological cues.

Several modalities of biofeedback have been developed and include electromyography (EMG, muscle contraction), thermal (peripheral skin temp), electrodermal (EDR, skin conductance), electroencephalography (EEG, brain electrical activity), blood pressure (BP), electrocardiogram (EKG), and respiratory feedback. The two most popular modalities of feedback used in the treatment of ADHD are EMG and EEG (Cobb & Evans, 1981).

Neurofeedback

Neurofeedback, which has been around in the biofeedback community since the 1970's, was rediscovered soon after the work of Eugene G. Peniston and Paul J. Kulkosky (1989) on alcoholism was published in the journal Alcoholism: Clinical and Experimental Research. As a result there was a renewed interest in the work of Dr. Joel Lubar on ADHD. A pioneer in the field of neurofeedback, Lubar interpreted the slow- wave
evidence in the early neurological studies as an inability to produce beta activity above 14 Hz (1991). Most psychophysiologists associate beta activity with active mental processing, alpha activity with relaxation, and delta and theta activity with underarousal (Andreassi, 1989). Collaborating with M. B. Sterman in his work with sensorimotor rhythm (SMR) training for seizure management, Lubar observed that along with a reduction of seizure activity some patients demonstrated increased attentiveness and ability to focus and concentrate.

Lubar and Shouse (1976) explored the potential application of SMR training to hyperkinesis in the absence of a history of seizures. In a single subject design, there were three condition changes following a no drug baseline (no feedback) and drug only baseline (no feedback): 1. SMR (12-14-Hz EEG activity) reward/theta (4-7-Hz EEG activity) inhibit, 2. SMR inhibit/theta reward (contingency reversal), 3. and SMR reward/theta inhibit. Chin muscle activity (EMG) was measured and eight subject behaviors were recorded by classroom observation during the changing conditions. These behaviors included self stimulation, object play, noninteraction, out-of-seat, time on-task, sustained attention, cooperation, and opposition. Chin muscle activity decreased and behaviors improved during the SMR reward conditions, and worsened during the contingency reversal condition. With the switch back to SMR reward/theta inhibit condition, the gains in behavior, as well as EEG and EMG measures, returned. The authors concluded that the SMR/theta protocol was most beneficial for children presenting with predominantly hyperkinetic symptoms.
In a follow up study, Shouse and Lubar (1979) replicated their previous results. The conditions were no drug, drug only, drug and SMR training I, drug and SMR reversal training, drug and SMR training II, and no drug and SMR training. The results revealed that SMR production increased in all subjects during the drug only phase. The subjects with the lowest baseline SMR (highest pretreatment overactivity) during the no drug condition showed the greatest increase in SMR during drug only as well as the first combined drug/SMR condition. Brainwave microvolt level data were not presented or discussed in this study. Two important observations were made from this study. First, that improvements with SMR training exceeded those obtained with medication alone. Second, the greatest effects were obtained in the combined drug/SMR condition. These results suggest that not only is SMR training beneficial, it is beneficial whether or not medication is being administered.

Tansey (1983) employed combined EMG/SMR training with a 10 year old hyperactive boy with developmental reading disorder. The EMG component addressed the symptoms of hyperactivity after the first three sessions. The SMR training employed auditory feedback modulated to the amplitude of the SMR. The author utilized a phase shift system that adjusted the audio feedback to become synchronous with the EEG. The author acknowledged that this system could in effect drive the EEG rather than be a reflection of it. In Lubar and Lubar's (1984) review of this process, they believed that not only was SMR being reinforced but also alpha due to the high amplitudes reported. Tansey (1993) conducted a ten year follow up of this patient and confirmed long-term stability of his EEG as well as academic gains.
Lubar and Lubar (1984) provided long-term biofeedback utilizing SMR training followed by beta training with theta inhibition with six males presenting with specific learning disabilities. The training protocol involved obtaining increases in SMR production prior to switching to beta training. The authors have always stated that concurrent academic training was necessary in order to fully maximize the effectiveness of training. Just as a treadmill reveals a heart condition not visible at rest, the academic task reveals excessive slow activity not visible under non-attention conditions. If excessive slow activity appeared while the subject was reading, the subject shifted all of his attention from the reading task to his brain waves. As soon as he was successful in diminishing the slow activity, he would return to the reading task. This type of training operates on many levels. First the subject becomes more aware of his inner dynamics during reading. Second, state learning is taking place. By intermixing theta inhibition under conditions of academic demand, the subject slowly becomes accustomed to maintaining theta inhibition while reading.

The authors reported brainwave microvolt levels in this study for some subjects as well as percentage time activity. Theta levels were reported to have dropped several microvolts during treatment for at least one subject. Some subjects also received concurrent family therapy. All six subjects increased both SMR and beta production, decreased EMG and slow wave levels, and improved their academic performance.

Lubar, Swartwood, Swartwood, and O'Donnell (1995) recently evaluated the effectiveness of EEG neurofeedback training in a clinical setting. The subjects were 23 participants in a 2-3 month summer program for intensive neurofeedback training.
Dependent measures were a continuous performance test (T.O.V.A.), behavior ratings, WISC-R performance, and EEG activity. Two training protocols, both designed to decrease theta activity, were utilized in this evaluation. One training protocol was designed to decrease theta activity by rewarding increased beta production. The other training protocol was designed to decrease theta activity by rewarding decreased theta production. Thresholds were raised or lowered depending on the training protocol to maintain an average of 14 to 25 rewards per minute.

It is not entirely clear how the authors arrived at the EEG Change and No EEG Change groups. It appears as though all subjects received neurofeedback treatment and seven out of the 23 subjects were unsuccessful in decreasing their theta amplitudes comprising the No EEG Change group. The authors then compared the performance of these two groups. The subjects in the EEG Change group decreased their theta amplitude from an average of 15.5 microvolts to less than 13 microvolts over 40 sessions. The No EEG Change group EEG profile remained the same throughout all 40 sessions. The authors reported that they did not expect the beta microvolt levels to change and did not report beta change amplitudes. The T.O.V.A. measures three variables, including errors of omission, errors of commission, and response time. A fourth variable, variability of the response time, is a calculated figure. Rather than report the absolute performance change scores, the authors assigned a score from 1 to 4 based on the number of these four scales they improved on. No subject worsened in performance. The EEG change group improved on an average of three T.O.V.A. scales while the No EEG Change group improved on only 1.5 T.O.V.A. scales. Behavioral measures revealed that significant
improvement was obtained following treatment. The authors acknowledge the possibility of parental expectancy effect.

The effect that neurofeedback had on WISC-R performance was addressed by a subset of 10 subjects included in the original 23 subjects. Pretest administration was reported to be approximately two years prior to the study. All subjects in this group made significant changes in their EEG profiles. Significant differences were found on the verbal, performance, and full scale measures of the WISC-R, with all scales improving approximately 10 points. The authors conclude that for children below the age of 14, reduction in theta activity appears to be the key variable associated with improvement in ADHD. For adults they believe beta to be the more important variable.

**Neurofeedback research Models**

Shellenberger and Green (1986) examined over 300 theoretical papers and research reports regarding biofeedback training, and found that most conceptualizations were either based upon an operant conditioning model or a drug model. The operant conditioning model involves stimulus-response learning. An organism learns a behavior in response to an external stimulus. The perception of the stimulus is needed to produce the response (Carlson, 1994). External reinforcement strengthens the association between the stimulus and response. Applied to neurofeedback, the brain wave information might be considered the stimulus and the feedback tones reinforcement. The behavior of the subject (decreased theta or the behavior that elicits it) is believed to be brought under the control of the stimulus (brainwave information). The behavior (decreased theta) should not occur unless the stimulus (brainwave information) is present. The “drug model,” as described by
Shellenberger and Green (1986), operates under the assumption that biofeedback has specific effects similar to drugs. The behavior of the subject, decreased theta, is believed to be caused by the "drug," or biofeedback. The active ingredient is considered to be the feedback or its contingency.

Shellenberger and Green (1986) proposed an alternative way to conceptualize the process of biofeedback training. They termed their approach the mastery learning model. This model does not recognize the feedback or its contingency as an active ingredient. In addition, neither the stimulus or the reinforcement is considered external to the organism.

The subject is considered the source of the stimulus, reinforcement, information, and behavior. They all happen essentially at the same time in a continuous feedback loop which, when established, allows awareness of the self. The only component or variable within that homeostatic loop that possesses any specific power to initiate a shift is the subject, who learns to control theta through the use of psychophysiological strategies. The mastery learning model recognizes the power inherent in the subject with specific effects considered "to be related to the training procedures and not to the machine and signals from it" (pp. 92). Feedback information is considered necessary during the learning process because it provides information not normally available to the subject. The feedback information is utilized by the subject as an indication of the effectiveness of their psychophysiological strategies. Adjustments can be made by the subject based on that information. The therapist, considered an integral part of the feedback loop by Lubar (1992), provides the necessary coaching, motivation, and praise to guide the subject in the development and application of new psychophysiological behaviors. Once the subject has
learned how to make the internal homeostatic shift, and can recognize the associated physiological changes with that shift, the biofeedback machine and its signals can be dispensed with.

**Current Issues and Controversies**

Areas of current interest and debate regarding neurofeedback involve the measurement of attention with computerized continuous performance tests and research methodology.

**Continuous performance Tests**

Current methods to measure attention include behavior rating scales, the Freedom from Distractibility factor from the Wechsler scales, cancellation tasks, and the continuous performance test (Halperin, 1991). Reaction time tests can serve as relatively direct means of measuring processing speed (Lezak, 1995), thus avoiding many of the weaknesses of rating scales. Attention by some is divided into sustained attention and selective attention (Halperin, 1991). Continuous performance tests represent a class of computerized test which measures sustained attention, the maintenance of information processing over time. In the past several years computerized tests of sustained attention have gained in popularity at the same time discussions such as the possible over diagnosis of ADHD and over prescription of Ritalin have dominated the popular media.

One study conducted by Halperin, Newcorn, Sharma, Healey, Wolf, Pascualvaca & Schwartz (1990), examined the performance of ADHD children on continuous performance test and found that as many as 50 percent of children did not reveal a
measurable deficit in sustained attention. The authors acknowledged that their results should be considered preliminary because the identification of ADHD and normal children was accomplished with only one source, the Conners Teachers Questionnaire.

While some believe the increased use of computerized assessment has brought increased control and accuracy to dependent measures, others are uncertain whether the subjects' behavior and performance on the CPT is relevant to the subjects' behavior and performance in the real world, and question the ecological validity of the instruments. DuPaul, Anastopoulos, Shelton, Guvevremet, and Metevia (1992) examined the diagnostic utility of the Continuous Performance Test (CPT) in the identification of ADHD. The subjects, 68 children referred from an outpatient psychiatry clinic that specialized in the assessment of ADHD, completed the CPT and their classroom teachers completed several behavioral checklists including the Child Behavior Checklist, School Situations Questionnaire, and the ADHD Rating Scale. Correlations between the CPT and behavioral measures were all highly insignificant leading the authors to question the ecological validity of the CPT. The authors acknowledged, however, that the poor results may have been due to a number of factors which made the test too easy. First, their CPT was only 9 minutes long, which failed to measure deterioration in performance over time. In addition, the time the stimulus was displayed was quite long, 800msec. Hooks, Milich, and Lorch (1994) used a 13 minute CPT with multiple time blocks and verified that performance does degrade over time. They found that ADHD and control groups did not differ in performance in the first time block but over time the ADHD group exhibited a sustained attention deficit.
There are several well normed CPT's on the market now, including the Test of Variables of Attention, or T.O.V.A. (Greenberg & Waldman, 1993), which has a normative sample in excess of 700 children. The present researcher interviewed Dr. Greenberg regarding the apparent lack of agreement between CPT’s and behavioral scales. Dr. Greenberg was well aware of the disparity between the measures, and stated that among the ADHD children who have completed the T.O.V.A., approximately 50 percent had no measurable deficit in sustained attention. Those children, he added, tended to achieve high ratings on the conduct scale of the Child behavior Checklist.

Halperin (1990), who has conducted several studies involving computerized continuous performance tests, believes that ratings scales tend to overestimate the prevalence of ADD symptomatology and are susceptible to rater bias and expectancy effects. He believes that CPT’s are adding to the research base by providing an alternative method of establishing homogeneity among children with ADHD. One of his research interests appears to be how inattentive children, as identified by the CPT, might have more learning problems as compared to noninattentive children. He is also interested in the relationship between CPT performance profiles and conduct disorder.

Research Methodology

Children with Attention Deficit Disorders, or C.H.A.D.D., is the largest national parent support association for ADHD. The national headquarters for C.H.A.D.D. received an overwhelming number of phone calls for more information after an article entitled “My Child Couldn’t Pay Attention” was published in Womans Day magazine (Aduci, 1991). Lynn Adduci is the parent of a child who made significant gains after participating in a
summer treatment program developed by Dr. Lubar for children with ADHD. She is also a freelance writer and, with much skill and use of literary drama, took her readers from the time they received the phone call they had been dreading for years (their son experiencing academic difficulty) to the time after much soul searching and with one month to borrow money and find an apartment they drove to Tennessee to participate in Dr. Lubar's summer treatment program for children with ADHD. Considering the credentials of the author and the publication venue, the article was not written in scientific jargon nor APA format as one might expect if it were published in a professional journal. Adduci very effectively conveyed in a few short paragraphs her family's story in dealing with ADHD to her audience--mothers reading a woman's magazine. Russell A. Barkley, an acknowledged leader in the research and treatment of ADHD, offered his commentary on that article as well as neurofeedback in general (Barkley, 1992). His critique sparked a professional debate which was carried out in the newsletters for C.H.A.D.D., EEG Spectrum, Inc., and the Association for Applied Psychophysiology and Biofeedback.

In his review of the Aduci article (Barkley, 1992), Barkley stated that he, the C.H.A.D.D. executive board, and the Attention Deficit Disorder Association executive board “seriously questioned whether this one case provided any sound evidence in support of Dr. Lubar's therapy,” and offered several important and interesting points about the research methodology utilized in the published studies involving neurofeedback.

Control Groups

Barkley (1992) cited the lack of control groups in the neurofeedback literature. He stated that control subjects should receive the identical treatment as the treatment group
but instead receive sham feedback. The issue neurofeedback researchers have with sham training, such as using feedback from another person, is that the subject becomes aware the feedback is a sham and they quickly lose interest (Othmer, 1994). Although Lubar (1992) has not published studies utilizing this type of control group, he did conduct an ABA crossover study which revealed that when children were provided feedback for increasing SMR activity between 12 and 15 Hz. and decreasing theta activity, behaviors in classroom as well as other EEG parameters improved. When feedback was reversed, the children's behavior deteriorated as well as the EEG measurements, and when the conditions were reversed again the children showed a favorable response.

Maturation

Barkley (1992) cited maturation as possibly having contributed to the improvement noted in some subjects in the neurofeedback literature. He acknowledges that brain waves in normal children become more active as they grow older and generalizes this fact to ADHD children. Othmer (1992) says maturation is what neurofeedback is all about allowing the child to produce a more mature EEG. Othmer's point is that the child may not be able to achieve this on his own unless his brain is provided the appropriate information. Othmer draws a distinction between maturation which would have occurred anyway and maturation which is facilitated during training.

The pertinent point, period of time, gets obscured in the rhetoric. Barkley, with his reference to the fact that brain waves mature, suggests to the reader that this might happen during the period of neurofeedback treatment. In principle he is right. However, the literature describes this process as taking place over a period of several years. Othmer, on
the other hand, suggests that the data reveal brainwave changes in a matter of weeks. The available data reviewed by this writer suggests that significant changes in brain waves do not become apparent until after 40 (Lubar, 1995).

**Placebo Effect**

Barkley (1992) cited that in most types of psychological treatment or research the placebo effect is always operating. He accurately states that neurofeedback has the potential to produce tremendous placebo effects rendering its subjects very susceptible to suggestion. Othmer (1992), however, questions how placebo can enter the equation when teachers and educational therapists, who may not know that children underwent EEG training, observed and commented on rapid changes in performance and behavior. Othmer’s point reflects a basic misunderstanding of the placebo effect. The question is whether the improvements observed by the teachers and educational therapists were due to placebo or the neurofeedback treatment.

**Concurrent Treatments**

Barkley (1992) stated that most of the cases at Lubar's clinic received intensive academic tutoring, relaxation training, and self control training in addition to neurofeedback. The presence of concurrent treatments, if not controlled for, introduces the question of whether the subject improved due to the feedback intervention or the concurrent treatments. Barkley cited the muscle biofeedback literature which found that related treatments, such as those mentioned above, proved more beneficial than the biofeedback itself in subject improvement.
Lubar (1992) responded to Barkley's criticism by stating that all of his published work and research was done purely with neurofeedback alone without additional tutoring. He did, however, acknowledge that Barkley was accurate in that the clinic treatment incorporated other forms of treatment. Lubar's publications outline his protocol of integrating desynchronized brain activity (beta) with academic tasks. He has found that ADHD children tend to display increased theta activity rather than beta activity under conditions of academic demand.

**Practice Effects**

Barkley (1992) cited that the neurofeedback literature failed to consider possible practice effects on the measures that were used to evaluate the ADHD children. Barkley stated that he has conducted numerous research projects that utilized parent and teacher ratings of child behavior, and he has observed that parent and teacher ratings tend to improve even in the absence of treatment.

**Small subject numbers/case Studies**

Barkley (1992) cited insufficient published research to support the effectiveness of neurofeedback. He stated that only seven case studies appeared in the literature even though hundreds were reported to have been treated. Barkley cites the lack of any double-blind, placebo-controlled rigorous research procedures as the primary reason why scientists have been justified in remaining skeptical of neurofeedback. Until such time that more controlled research involving larger groups of subjects is done, Barkley and other scientists are unlikely to alter their position. Barkley supports his position not anecdotally...
but by citing an actual example--cognitive therapy. Cognitive therapy, originally found to be effective in a small number of case studies, revealed far less dramatic results when subjected to large group studies.

Lubar (1992) agreed with Barkley in that the definitive double blind study with large numbers of children has not yet been carried out with neurofeedback and that those in the field are instead relying on the force of numbers. If 60 to 80 percent of children treated with neurofeedback are responding favorably and these results are being replicated around the country the results must be genuine, according to Lubar. However, the reader is reminded that only seven case studies were published in the neurofeedback literature at the time of Barkley’s original critique.

Construct Validity

Barkley (1992) cited the importance of identifying the specific nature of the problems ADHD subjects are experiencing. If the symptoms are not provided in sufficient detail, how is the researcher or reviewer to know whether the subjects are truly ADHD, learning disabled, or simply doing poorly in school? Barkley has an excellent point here. However, the pursuit for the homogeneous ADHD child may be forever elusive. Current opinions suggests that it simply may not exist. Biederman, Faraone, and Lapey (1992) found that even with strict diagnostic criteria about 50% of ADHD diagnoses exhibit comorbidity.
Barkley's Conclusion

Barkley (1992) concludes his critique by stating there is not sufficient evidence from well-controlled, large group, studies at this time to support the effectiveness of neurofeedback for ADHD children. He does not recognize the published case studies as the scientific evidence necessary to demonstrate that it is specifically neurofeedback and not nonspecific effects or bias creating these dramatic results. He suggests that until better research is conducted, those offering neurofeedback should show far more humility, scientific caution and balance, and professional ethics and responsibility in advertising their services. He believes they should cease making outrageous claims about improving children's intelligence, and curing learning disabilities, and ADHD in the absence of scientific evidence.

Summary

At a time when the diagnosis of ADHD and its treatment with stimulant medication appears to be coming under increased scrutiny, the popular media are paying more attention to neurofeedback. Not surprisingly, along with this growth and exposure comes criticism from the traditional scientific community citing insufficient and poorly controlled research. Some leaders in neurofeedback view these criticisms as premature and too strong (Lubar, 1992) and others as carefully constructed arguments against heresy rather than scientific inquiry into the truth (Othmer, 1992).

This paper reviewed the major traditional treatments for ADHD currently available and by far the most effective treatment supported by empirical research is stimulant medication therapy. However, Barkley (1992) does acknowledge that no single treatment,
including Ritalin, has been found to provide long lasting improvement in ADHD children. This suggests that there is ample need for the improvement of existing treatments as well as the development of new treatments.

Anyone working with ADHD children and their families understands the sense of desperation that can result when interventions are ineffective. Barkley certainly deserves credit for conducting his critique of neurofeedback with parents in mind. After conducting a thorough review of the neurofeedback literature, and completion of the present study, this writer can state that many of his criticisms are in fact accurate.

The literature on brainwave differences with ADHD children does provide a clear rationale for the treatment of ADHD children with neurofeedback. Not so clear, however, is the issue of clinical efficacy. The Association for applied Psychophysiology and Biofeedback considers neurofeedback to be a procedure which has been demonstrated by research to be clinically efficacious (Striefel, 1995). According to the guidelines established by APA (Task Force on the Promotion and Dissemination of Psychological Procedures, 1993), there does not appear to be sufficient evidence to be considered a well-established treatment. At best the published research meets the criteria for a probably efficacious treatment. The APA allows sufficient latitude with regards to research methodology: ...in some cases a treatment for a disorder for which no other treatments have been shown to be successful may have been demonstrated to be extremely powerful by an open trial without a control condition. It could be argued that even without evidence from controlled outcome studies such a treatment should be disseminated, since the treatment appears very promising and no other treatments have been successful.
However, controlled outcome studies, or a large series of single case designs, are likely to remain the source of most policy decisions and clinical recommendations.

Although the professionals involved in this debate maintained a modicum of decorum and respect in their articles, the language used revealed their passion regarding this subject. Barkley's critique utilized language such as "particularly appalled," "deeply concerned," "the possibility of fraud," and "caveat emptor (buyer beware)." Lubar titled his rebuttal paper "Innovation or Inquisition: The Struggle for Ascent in the Court of Science: Neurofeedback and ADHD," and Othmer interpreted the criticism of neurofeedback as "carefully constructed arguments against heresy rather than scientific inquiry into the truth." However, considering the possibility that some neurofeedback providers may have, and continue to advertise unethically, as suggested by Dr. Barkley, his choice of language appears to be justified.

The neurofeedback community has been challenged to prove their claims under more stringent criteria. This writer considers Barkley's review a wake up call for the neurofeedback community and an excellent guide for further research.

**Major elements of review incorporated into Study**

The present study was administered in the school setting, which has been identified as the single largest site of psychosocial intervention for children with behavioral difficulties (Cohen, 1995). Additional support for this decision was the belief that neurofeedback treatment might be permanent if it were integrated with academic work and administered in the classroom setting (Lubar, 1991). The training task for the subjects in this study was to reduce their theta/beta ratio, within the school setting, amidst all the
normal demands and distractions. The desired learning will be for the subjects eventually to be able to reproduce, maintain, or access this new theta/beta ratio without the aid of neurofeedback equipment. Many components of the mastery learning model, as described by Shellenberger & Green (1986), including the facilitation of learning under adverse conditions (training conducted within school setting), reinforcement of self control in the subject (internal attribution), and transfer of skills and freedom from the feedback equipment and from the therapist (post treatment demonstration of learning without feedback). The intent of this approach was to directly address one of Barkley’s major criticisms—the length and cost of treatment. The neurofeedback information was used to help the subjects learn how to beta-meditate. The traditional meditation model was adapted to facilitate and cultivate increased beta brainwave activity rather than increased theta brainwave activity, which normally occurs during traditional mantra meditation.

Although many of the controls cited by Barkley were not able to be incorporated into the present study, controls were utilized wherever possible.
CHAPTER 3
DESIGN OF STUDY

Subjects

Special education teachers and guidance counselors from 22 schools in a large local school district identified children with documented attention disorders and provided this information to the school system Director of Special Services. From that list of students, only those who had a primary diagnosis of ADHD were invited to attend a general information in which the study and selection process was explained. Only those students who were within the ages 8 and 11, diagnosed with ADHD by a physician or psychologist, and without specific sensory defects or any other functional illness (e.g. mental retardation, epilepsy, etc.) that might contribute to or otherwise be confounded with ADHD, were invited to complete the prescreen evaluation, which entailed the completion of a behavioral rating scale and the Test of Variables of Attention, a computerized measure of sustained attention. Students were grouped according to their T.O.V.A. profiles, and the students from the largest homogeneous group were invited to participate in the study. The largest homogeneous group consisted of students who had performed poorly on the T.O.V.A. variables response time and variability. Thus, strictly inattentive and/or impulsive students were excluded from the study.

Apparatus

Electroencephalograph

Assessment and neurofeedback training was conducted with the Autogenics A620, single channel, fully computerized, neurofeedback system that measured the frequency and
amplitude of the subjects brain waves. The EEG sampling rate was set at 128 samples/second. Auditory and visual feedback were provided to the subjects based upon meeting the training criteria established by this researcher. The A620 detected information in the raw EEG by using three active adjustable band pass filters, theta (4-8 Hertz), alpha (8-13 Hertz), and beta (13-26 hertz). This study monitored beta activity (16-20 hertz), theta activity (4-8 hertz), and EMG activity (50-150 hertz) from active cranial sensors. A clinician display aided in the setting of thresholds for EEG reward, EEG inhibit, and EMG inhibit.

Electrode configuration and Application

A monopolar electrode configuration was utilized and applied in accordance with the international 10-20 electrode placement system (Jasper, 1938) at location Cz ½ Fz, midway at the sensorimotor cortex along the rolandic fissure. Pads saturated with 70% isopropyl alcohol and pumice were used to cleanse the skin of both earlobes, and a half inch square area of the scalp at location CZ ½ Fz. A small amount of Omni Prep, a skin preparation medium, was then be rubbed onto the scalp surface. Ten20 Conductive EEG paste, a conduction medium, was then applied to the electrode cups prior to placing the reference electrode to the left earlobe; ground electrode to the right earlobe; and active electrode to the scalp. Baseline testing was conducted only after electrode impedance values were at or below 5 kilohms. The impedance values prior to each neurofeedback training session were between 5 and 10 kilohms.
Dependent Measures

Because the subjects did not discontinue taking their stimulant medication for the duration of the study, some dependent measures were administered both on and off stimulant medication.

Test of variables of Attention

The Test of Variables of Attention (T.O.V.A.), a 22.5 minute, visual, non-language-based, fixed interval, continuous performance test designed for use in the diagnosis and monitoring pharmacotherapy and other treatments of children and adults with attention deficit disorders (Greenberg, 1993), was administered to all subjects. Subjects sat in front of a computer screen and pressed a micro switch when a target (orange square with black hole on top) appeared and refrained from pressing the micro switch when the non-target (orange square with black hole on bottom) appeared on the screen. The T.O.V.A. variables included errors of omission (inattention), errors of commission (impulsivity), mean correct response time (processing and response time), standard deviations (variability), anticipatory responses, post commission mean correct response time, and multiple responses. Two reliability measures, anticipatory responses and commission errors, determined if the subjects properly attended to the task. Practice effects were deemed negligible. The authors of the T.O.V.A. indicated the presence of a novelty effect with the repeated measures. Test-retest data revealed that subjects often showed a deterioration in performance. The T.O.V.A. pretest was administered over the weekend at least 24 hours after subjects received their last dosage of stimulant medication. All pretesting and posttesting was conducted between the hours of 8AM and 12am.
Stroop color and word Test

The Stroop Color and Word Test (Golden, 1978), a measure of cognitive flexibility and resistance to interference from extraneous stimuli, was administered both on (at subjects' school) and off stimulant medication (clinic) prior to beginning treatment. The Stroop was administered following treatment in the same manner. Subject read as many of the words "RED", "GREEN", and "BLUE" as they could in a 45 second period. The subjects then repeated the procedure but this time they named the colors of "XXXX" which were printed in either red, green, or blue ink. In the final condition the subjects named the colors of the words "RED", "GREEN", AND "BLUE". The word and the color it was printed in never matched.

The test-retest reliability of the Stroop has been found to range between .71 to .88 for the three scores in several studies. The Stroop is normed on subjects between the ages of 17 and 45. Although the authors stated that the use of the Stroop with younger subjects was considered experimental, it was used in this study for change scores only.

Attention-deficit hyperactivity disorder Test

The Attention-Deficit Hyperactivity Disorder Test (ADHDT), an objective behavioral measure which identifies individuals with ADD (Gilliam, 1995), was completed by the subjects' parents and their classroom, music, and art teachers prior to the beginning of treatment. The ADHDT was also completed following treatment. The ADHDT test has a normative sample of 1,279 subjects, age range 1 month to 12 years, from 47 states and Canada and consists of 36 items related to the three core symptoms of ADD--hyperactivity, impulsivity, and inattention. Internal consistency was found to be .97 for the
entire scale; .93 for hyperactivity scale; .92 for impulsivity scale; and .93 for the inattention scale. Test-retest reliability was also excellent exceeding .85 for all of the scales. The scales have been shown to correlate to a significant degree with those from the Attention Deficit Disorders Evaluation Scale-School Version (r = .88), ADD-H Comprehensive Teacher's Rating Scale (r = .71), Behavior Evaluation Scale (r = .61), and Connors' Teacher Rating Scales (r = .72).

**Electroencephalograph Measures**

Theta (4-8 hertz) and beta (16-20 hertz) EEG activity were recorded during the assessment as well as during the neurofeedback training phases. The EEG assessment was conducted both on (at the subjects school) and off stimulant medication (clinic) prior to beginning treatment. The assessment consisted of a three minute recording for each of the following conditions (1.) Baseline, eyes open and fixed (2.) Reading, grade appropriate book (3.) Writing, copying figures from Bender Gestalt (4.) Abstract stimuli, viewing black & white Rorschach plate #1 (5.) Abstract stimuli, viewing color Rorschach plate #10. The raw EEG record was saved to 3.5" disc and reviewed in two second epochs. Only those epochs most free of artifact (eye blinks, eye rolls, yawns, etc.) were retained and subjected to Fast Fourier Transform (FFT) analyses. The same assessment was administered following treatment. Because the actual EEG records were saved and not averaged, they were able to be examined for the presence of seizure activity.
Parents also completed the Parenting Stress Index (PSI) before and after treatment (Abidin, 1995). The PSI provided an indication of the extent to which the parental-child systems were under stress. The PSI tapped into three major source domains of stressors, the child, parent, and life stress domains. The child domain examined characteristics within the subjects that may have made it difficult for their parents to fulfill their parenting roles. The parent domain examined characteristics within the parents which may have contributed to dysfunction within the parent-child system. The life stress domain provided an index of the stress being experienced outside of the parent-child system.

The PSI has a normative population of 2,633 mothers and 200 fathers. Internal consistency was found to be .95 for the entire scale; .90 for the Child Domain; and .93 for the parent domain. Test-retest reliability was supported by four different studies which produced coefficients ranging from .55 to .82 for the child domain; .69 to .91 for the parent domain; and .65 to .91 for the total stress score.

Behavior rating profile, second Edition

The sociogram component of the Behavior Rating Profile (BRP-2), a peer nominating technique that elicits the perceptions of the subjects' peers (Brown & Hammill, 1990), was administered by the subjects' classroom teachers prior to and following treatment. Neither the subjects nor their peers were aware of the true intent of the sociogram or its association with this study. The subjects and their peers were given a piece of paper with the following two questions (1.) Which of the students in your class would you most like to work with on a project in school? (2.) Which of the students in
your class would you least like to work with on a project in school? The classroom teacher read these questions verbally and each student wrote their responses with first name and last initial only. The sum of the positive responses minus the negative responses resulted in a classroom social ranking.

Procedure

Design/Controls

This study was a Single Subject design. Parents and teachers were informed that some of the subjects in the study would be administered a placebo treatment, in which EEG thresholds would not be manipulated, in order to compensate for the strong expectancy effects in behavior ratings, as noted by Lubar (1995). They were assured that the real treatment would be made available to those that received the placebo treatment following completion of the study. In actuality, all subjects received the real treatment. The students’ art and music teachers were not informed that one or more of their students were involved in a study.

Attention training Protocol

The attention training protocol utilized the theta threshold as the changing criterion, which was designed to shape theta in a downward direction. Guided by the work of Janzen and his colleagues (1995), who found that theta differences in children with ADHD appeared more robust than beta differences, no attempt was made to increase beta levels. The beta threshold was set at one microvolt, well below the average beta amplitude, which allowed the subjects to focus on reducing theta activity.
Initial baselines of theta (4-8 hertz) were obtained with eyes open and fixed. Thresholds were initially estimated by viewing the clinician screen. The objective was to set the theta threshold so that theta performance remained below it 60% to 65% of the time. The subject was then trained to increase their success rate to 70% at which time the threshold was lowered again to readjust their success rate to 60% to 65%. Any EMG activity above 6-9 microvolts activated an inhibit circuit preventing feedback for that time period. Subjects were rewarded by audio and visual feedback when their theta levels were below the threshold setting. To encourage sustained effort, reward criteria was set so that 50 sampled events (above beta, below theta, and below EMG) needed to occur in .5 seconds in order for a reward to be delivered. Feedback rewards were triggered .5 second after the EEG criteria were met. This procedure was utilized in all training session conditions except the reading condition, in which the data were measured and recorded only. Each 27 minute neurofeedback session was conducted at school. The EEG data were saved to the computer hard drive and averaged into one data point for each of the five training conditions. Those conditions were (1.) eyes open and fixed, 2 minutes (2.) visual and audio feedback, vertical bars display only, 10 minutes (3.) reading, no feedback, 5 minutes (4.) visual & audio feedback, vertical bars display only, 5 minutes (5.) visual & audio feedback, subjects choice of feedback display, 5 minutes. The EEG data were analyzed using Spearman Rank Order Correlations.

**Therapist Instructions**

The attribution Statement. The first priority was to foster and reinforce the subjects understanding that the computer and the information on the feedback screen was
merely a mirror of themselves with no special powers. Any information they observed was reinforced to be a reflection of themselves and any changes that were affected were accomplished by their own efforts. The following statement was given while the electrodes were being applied to the subjects before the eyes-fixed baseline: "The red bar to the right is EMG, your muscle movement. When you are nice and still it goes real low. The green bar on the left is beta. Beta is a measure of your ability to concentrate. You may notice it goes up and that's fine. You going to focus on theta, the red bar in the middle. Remember, you're looking at yourself. The computer is just a mirror of yourself with no special powers. You have the power." This statement was eventually condensed.

The effortless attention Statement. The objective was to teach the subjects how to deal with normal distractions while attending to their training. This was accomplished by providing instruction on how to integrate distractions with their focusing activity. Effortless attention was facilitated by training the subjects to simply "notice" the theta without any cognitive strategy. If there was a noise or distraction, the subjects were instructed to let their attention move to the distraction, acknowledge it, then let it go and return to noticing the theta. The following statement was given immediately following eyes-fixed baseline: "Just notice the movement of theta. Ever so gently just continue to notice theta and the beeps. Don't try--just notice. Don't try to ignore sounds you hear or things you see. Let your attention go there, acknowledge it, and then...let it go. Ever so gently...back to theta." This statement was eventually condensed into the aphorism "Notice...back to theta."
The effortless intention Statement. The behavior of noticing, explained in the previous paragraph, involved no intention. The objective of this effortless intention instruction was to teach the subjects how to direct and manipulate their attention at will. Every thirty seconds or so the subjects were encouraged to let their attention go to the thought "theta down," immediately let it go in the same fashion as a distraction, and then return to their noticing of theta. The importance of letting it go as they would a distraction was to cultivate an integrated state of thinking with a reduction in theta. The intent was to lessen their elevated theta responses to the many cognitive demands of school. The following statement was introduced: "As your noticing theta, every thirty seconds or so just let your attention go to the thought 'theta down' for just a second then ever so gently...back to theta. Noticing.. theta down... noticing ...theta down...noticing...theta down... and so on".

The wandering mind Statement. In traditional meditation, one’s attention often shifts from the mantra, a meaningless sound, to an extraneous thought. Before long, and without awareness, the meditator becomes immersed in a cognitive dialogue or mental image of some kind. When the meditator becomes aware of this distraction, attention is simply returned to the mantra. This same dynamic might also happen while attention training. When the subjects became aware that they had drifted off task, they were simply instructed to return to noticing theta. The following instruction was given periodically during training: "If you ever find yourself totally lost in a thought, perhaps what you're going to have for lunch, or a movie you saw last night, that's perfectly natural and O.K. When you realize it just move back to theta, ever so gently".
Condensation of therapist Statements

The role of the therapist was to facilitate subject learning. As this became evident during the training, the instructional statements were condensed into aphorisms and eventually eliminated completely. Condensation of instructional statements was an acknowledgment of the subjects understanding and ability to perform as directed. This was the first step toward the subjects developing mastery learning. The last step was beta-meditation on their own without the aide of the feedback.

Training for Mastery

A major criticism of neurofeedback is the length of treatment required. Lubar (1995) recommended forty sessions and placed emphasis on the neurofeedback itself. Although subjects in this study completed significantly less sessions than the forty recommended by Lubar, they were administered a structured training protocol designed to assist them in acquiring the feedback task.

Demonstration of mastery Learning. Subjects demonstrated their level of mastery learning in two stages at the last training session. First, with electrodes attached, and after the two minute eyes fixed baseline condition, subjects attempted beta-meditation without the aid of feedback. Noncontingent feedback tone was then provided to the subjects while they attempted to beta-meditate. They were not aware that the tone was noncontingent.
CHAPTER 4

RESULTS

Subject Selection

Of the eighteen subjects who completed the prescreen evaluation, only three were female (Table 4.1). Five subjects were involved with special education and were receiving services at the time of testing. Sixteen subjects were diagnosed as having ADHD by their family physician with five having been initially identified and referred by a school psychologist and two by licensed psychologist. One subject was diagnosed solely by a licensed psychologist and one subject did not carry any DSM diagnosis. With regards to other psychiatric diagnoses, only one parent disclosed that their son also carried the diagnoses of Conduct Disorder. Fourteen subjects were receiving methylphenidate, one was receiving imipramine, and one was receiving dexedrine. Seven subjects continued to take their medication throughout the weekend and summer. Only one subject had received any type of individual therapy and none had ever been involved in family therapy. With regards to other illnesses, two subjects had a head injury and allergies, two subjects had allergies and asthma, two subjects with allergies alone, two subjects with asthma alone, and one with brain injury due to an anoxic episode during birth. Although every attempt was made to obtain an objective behavioral rating and T.O.V.A. profile for each subject (Table 4.2), behavior scales were not returned for subject 05. This subject was excluded from the correlation calculation between the to ADHDT and T.O.V.A.. A Pearson correlation between the variables T.O.V.A. impulsivity and ADHDT impulsivity revealed a significant negative correlation ($r = -0.58$, $P =<.05$). Higher scores on the ADHDT and
Table 4.1. Subject pool information. Homogenous groups formed based upon T.O.V.A. profiles. Grade (Gr), special education (SPED), source of ADHD diagnosis (Dx), psychopharmacological management (Rx), medication on weekends and during summer (WE/Sum), DSM diagnosis (DSM), involvement in psychotherapy (Ther), and illnesses, non-impulsive subjects (bold print) selected for study.

<table>
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<th>Subject</th>
<th>Age/Sex</th>
<th>Gr</th>
<th>SPED</th>
<th>Dx</th>
<th>DSM</th>
<th>Rx</th>
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<td>ADHD</td>
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<td>X/X</td>
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<td>14</td>
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<tr>
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<td>11f</td>
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<td>R</td>
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</tr>
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<td></td>
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<td>4</td>
<td>X</td>
<td>FF</td>
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<td>R</td>
<td>-</td>
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</tr>
<tr>
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<td>X/-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
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<td>ADHD</td>
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<td>R</td>
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55
Table 4.2. Subject pool performance on ADHDT and T.O.V.A.. Mean of raters (*), quotient score (Q), hyperactivity (Hyp), inattention (Inat), Impulsivity (Imp), Response time (RT), Variability (Var), neuropsychological (n), unreliable testing (u), non-impulsive subjects (bold print) selected for study.

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<th>ADHDT Q</th>
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<td>115</td>
<td>101</td>
<td>110</td>
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<td>104</td>
<td>115</td>
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<td>092</td>
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<td>085</td>
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<td>055 -</td>
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<td>104</td>
<td>116</td>
<td>051</td>
<td>078 -</td>
<td></td>
</tr>
<tr>
<td>S.C.</td>
<td>06/7.5/11*</td>
<td>088*</td>
<td>104</td>
<td>114</td>
<td>069</td>
<td>082 -</td>
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</tr>
<tr>
<td>Drop-Outs</td>
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<tr>
<td>19</td>
<td>10.5/10/11.5*</td>
<td>103*</td>
<td>&lt;25</td>
<td>095</td>
<td>049</td>
<td>040 n</td>
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<tr>
<td>09</td>
<td>8.5/7/9.5*</td>
<td>89*</td>
<td>103</td>
<td>119</td>
<td>054</td>
<td>081 -</td>
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</tr>
</tbody>
</table>
lower scores on the T.O.V.A. indicated increased severity of symptomatology. Analysis of scatter plot data (Figure 4.1) revealed the presence of one outlier (subject 16), which was excluded from the correlation calculation. A Pearson correlation between the variables T.O.V.A. inattention and ADHDT inattention also revealed a significant negative correlation ($r = -.63, P < .05$). Higher scores on the ADHDT and lower scores on the T.O.V.A. indicated increased severity of symptomatology. Analysis of scatter plot data (Figure 4.1) revealed the presence of two outliers (subjects 19 and 20), which were excluded from the correlation calculation.

Subjects were selected according to their T.O.V.A. performance profile. Out of 18 subjects who completed the prescreen evaluation, six tested in the normal range, one in the borderline range, and eleven in the abnormal range (Table 4.2). Of the eleven subjects who obtained abnormal profiles, four were highly impulsive and seven non-impulsive. The seven non-impulsive subjects with significant abnormal T.O.V.A. profiles were selected for the study. Although all seven subjects began the study, two were dismissed early on. Subject 09 was dismissed from the study for principally two major reasons. First, the only space available in the school for treatment was a utility closet directly adjacent to an electrical closet. The electromagnetic field from the electrical system (appeared as background noise on the EEG) interfered to such a degree that it was determined that EEG data could not be reliably measured. In addition, subject 09 was performing very poorly academically. He was being removed from the classroom daily to receive intensive tutoring services from educational specialists. This experimenter decided that more time out of the classroom was not in his best interest academically. Subject 19 was dismissed
Figure 4.1. Scatter plots of T.O.V.A. with ADHDT. Plot A: Standardized residual vs. TOVA Impulsivity standard score. Pearson correlation coefficient = -.58, P = <.05. Plot B: Standardized residual vs. T.O.V.A. Inattention standard score. Pearson correlation coefficient = -.63, P = <.05. Outliers greater than 2 standard deviations omitted from correlation calculations.
from the study due to significant abnormal behavior during the initial treatment sessions. She was often unresponsive to verbal commands and questions and, when she did respond, her reaction time was extremely slow. She was referred for a comprehensive neuropsychological evaluation.

**Data Roadmap**

The same dependent measures were administered to each of the five subjects. Therefore, the data are presented in the same graphical format and order for each subject. The two primary dependent measures were the T.O.V.A. and the EEG. Secondary measures included the ADHDT, Parenting Stress Index, classroom sociogram, and the Stroop Color and Word Test. The following paragraphs provide a brief explanation of these graphs and how to derive the most meaning from them. The data graphs for subject J.H. are referenced throughout the discussion.

The single most important dependent measure used in this study was the T.O.V.A., therefore, these data were presented first. The T.O.V.A. established subject homogeneity and provided a posttest measure free of practice effects. All five subjects achieved normal performances on the variables inattention and impulsivity, and decreased performances on response time and variability (Figure 4.2). Neurofeedback, the changing criterion training protocol, was the primary intervention used to facilitate an improvement on the T.O.V.A. variables response time and variability. Thus, the EEG data were presented next by a series of four graphs (Figure 4.3). These data represent the core of the philosophy of neurofeedback training, that brain waves can be conditioned and brought under the control
of the subject. The theta threshold (dashed line) and actual theta performance (solid line) are plotted on the same graph (Graph A) to discern the extent to which, if at all, both variables trended downward. The intent of the EEG changing criterion training protocol was to facilitate lower and more normal theta/beta ratios (Graph B) by decreasing the ratio numerator--theta. However, in some instances theta/beta ratio decreased due to an increase in the ratio denominator--beta. These data were presented in Graph C. Regression lines were provided for data that achieved either a significant negative or positive correlation with time (number of sessions). Graph D presented the EEG data according to the five conditions (2-minute baseline, 10-minute feedback, 5-minute reading, 5-minute feedback, 5-minute feedback choice) within each training protocol. Each bar graph represented the mean of all sessions for that particular condition within the training protocol. This afforded an opportunity to examine the subjects theta/beta ratio's under different conditions.

The EEG data from the changing criterion training protocol, with the exception of baseline and reading, were generated with the aide of contingent feedback. Would those subjects that showed evidence of learning with feedback be able to perform similarly without feedback? These data were presented on the two power ratio graphs found in Figure 4.4. Different academic demands, such as reading, writing, and the Rorschach, were administered between baseline and mastery conditions to demonstrate EEG responsiveness without contingent feedback. The mastery conditions, administered on posttest only, were compared to baseline to discern whether learning had occurred in the absence of contingent feedback.
The secondary dependent measures took a preliminary look at other variables associated with the subjects. Did those subjects who evidenced improvement on the T.O.V.A. and EEG improve similarly in other areas as well? Behavioral ratings were provided by several raters and were plotted on the same graph to facilitate comparisons (Figure 4.5). The reader is reminded that the art and music teachers were unaware a study was in progress, and the classroom teacher and parents were not sure whether their particular student/child was receiving placebo (noncontingent feedback) or real (contingent feedback) treatment. The value in this graph is its ability to show how varied the subjects behaviors were on both pretest and posttest. Parenting stress was examined on pretest and posttest. Due to the large number of variables within this instrument, these data are presented in table format (Table 4.3). The tables list the variables that comprise the child domain and the parent domain. Elevated variables within the parent domain suggests stress due to the spousal relationship. Elevated variables within the child domain suggests stress due to the child. The total stress score is a composite of both child and parent domain scores.

The remaining two dependent measures, sociometric ranking and Stroop, are presented last. The classroom sociogram provided an indication of the subjects social status among his peers. The neurofeedback training protocol systematically exposed the subjects to a method of selective attention through the use of the attribution, effortless attention, effortless intention, and wandering mind statements. The Stroop provided a noncomputerized measure of selective attention, specifically the subjects ability to selectively attend to information in the face of competing stimuli (Figure 4.6).
Subject J.H.

Background Information

J.H. was 9-years-old and in the third grade at the time of this study. He received 20mg of Methylphenidate in the morning and 15mg at lunch time throughout the duration of training. Training sessions were conducted twice weekly in the school principal’s office during the regular school day. The school principal did not alter in any way the manner in which he conducted his business. He made announcements on the school intercom, conducted meetings with school personnel, and spoke on the phone often while training sessions were taking place at a small round table located at the other end of his office. He completed 24 training sessions over a 4-month period.

Results

Although J.H.’s response time on the T.O.V.A. improved by more than 25 standard score points on posttest, his performance remained highly variable (Figure 4.2). EEG data were analyzed using Spearman Rank Order Correlations. A Spearman Rank Order Correlation of the theta/beta ratio (mean of 3 feedback conditions: 10' bars display, 5' bars display, and 5' choice display) across sessions indicated a significant negative correlation (r = -.51, p<.05). The theta/beta ratio at the first session was in the range of 2.9/1 to 3/1 and by session #24 in the range of 2.6/1 (Figure 4.3). Although variability accompanies brainwave data, the theta/beta ratio graph (Graph B) displays a clearly discernable downward trend in the theta/beta ratio’s. Although this decline was expected, the manner in which it decreased was not. The changing criterion design involved the
Figure 4.2. Subject J.H.: T.O.V.A. The four T.O.V.A. variables.

lowering of the theta threshold which, in turn, was expected to have a corresponding
effect on theta performance. The theta threshold/performance graph (Graph A) displays
the theta threshold setting and actual performance for each session. Rather than decrease,
the threshold levels needed to be consistently raised for the first 14 sessions (after an initial
acclimation period) in order to maintain the designed rate of feedback. Threshold and
theta levels reached their peak during session # 15, which also coincided with a significant
decline in motivation. The training protocol statements were re-initiated in their entirety at
this point in order to reinforce his ability to handle the frustration and boredom. Rather
than instructing him to try harder, the statements reassured him that all he needed to do
was relax and “not mind.” At that point, theta threshold levels trended downward, while
the desired rate of feedback was maintained, and returned to pretraining levels by the last
session.
Figure 4.3. Subject J.H.: EEG data. Graph A: Theta thresholds and session mean of feedback theta performances. Graph B: Session mean of feedback theta/beta ratio's. Graph C: Session mean of feedback beta performances (recorded while subject received theta brainwave feedback). Graph D: Theta/Beta ratio condition mean (mean of 24 sessions). Condition #1 (2-minute baseline), #2 (10-minute feedback w/bars display), #3 (reading w/o feedback), #4 (5-minute feedback w/bars display), and #5 (5-minute feedback with choice of display). Outlier's omitted from graphs and excluded from Spearman Rho' and regression calculations. Regression lines shown for conditions which achieved significant Spearman Rho' Correlations.
Although the beta threshold was set at minimal, and J.H. was instructed to ignore beta, beta levels showed a significant upward trend (Graph C). A Spearman Rank Order Correlation of beta microvolts (mean of 3 feedback conditions: 10' bars display, 5' bars display, and 5' choice display) across sessions indicated a significant positive correlation ($r = .62, p < .01$). Levels increased from approximately 7.7 microvolts to approximately 9 microvolts which suggests that, although J.H. was not trained in any specific mental strategies intended to increase beta, he may have developed a cognitive strategy in his attempt to decrease theta levels. Although the ratios are within a few tenths of a point, his theta beta ratios were most elevated under conditions of academic demand—the reading condition (Graph D).

Although theta/beta ratios decreased with the aid of feedback, they did not decrease consistently without feedback (Figure 4.4). In the without methylphenidate condition (Graph A), the theta/beta power ratios remained at baseline levels on both mastery conditions. Thus, J.H. was not able to produce lower theta/beta ratios upon demand with neither silence (mastery 1) nor noncontingent feedback tone (mastery 2). While taking methylphenidate, however, he was able to obtain ratio values below that of baseline with the noncontingent feedback tone (Graph B). The more dramatic observation of these data is the significant difference between EEG levels with and without methylphenidate.

J.H.'s behavior was highly variable depending on the environment and/or rater. Figure 4.5 displays the ADHDT scores for father, mother, art teacher, music teacher, and classroom teacher. Higher standard scores indicate a higher probability that ADHD exists
Figure 4.4. Subject J.H.: EEG power ratio assessment. Ratio of percent power activity for theta (4-8 Hz.)/beta (13-21 Hz.) at Cz (top of the head). ADHD children between the ages of 8-11 typically have ratio’s of 5.5/1. Children w/o ADHD are estimated to have ratio’s 25% lower. Baseline (eyes open and fixed), reading (age appropriate book), writing (VMI), Rorschach monochrome and color card (think of answers), Mastery1 (no feedback), Mastery2 (with tone recorded from earlier session).
with that particular subject. Overall behavior, as measured by the ADHD quotient score, was relatively unchanged according to the ratings of the music teacher, classroom teacher, and mother. Both art teacher and father, who initially reported the highest probability scores on pretest, reported the largest improvement with scores moving to the below average to average range respectively.

![Bar chart showing ADHD quotients](image)

Figure 4.5. Subject J.H.: ADHDT. ADHDT quotient scores represent the probability of having ADHD.

Both mother and father reported total stress levels in the elevated range on the Parenting Stress Index (Table 4.3). They described J.H. as a highly distractible, moody, inflexible, and very demanding child who fell short of their expectations. With regards to her own feelings, mother reported that she did not experience J.H. as a source of positive reinforcement and experienced a sense of detachment from him. Father, however, reported that he felt controlled and dominated by his son’s demands and needs and experienced a
very strong sense of social isolation. On posttest, father rated his son’s behavior in the normal range for distractibility and adaptability. He also felt significantly less isolated from others and less constrained by his son’s needs. Mother, however, reported no change in her son’s behavior on posttest. Although she felt more attached and emotionally closer to her son, she still struggled with elevated total stress levels.

With regards to social ranking within the classroom, J.H. was ranked 15th in a class of 27 on pretest and 8th on posttest. An additional question was asked on posttest, “Which of the students in your class would you most/least like to have in your class at school next year?,” and he achieved a ranking of 12.

Although the Stroop Color and Word Test generated four basic scores, word, color, color-word, and interference, the score of most importance for the purposes of this study was interference (Figure 4.6). This was a calculated variable based on the subjects base reading and color naming scores. Although all scores were at or above the average range, there was a larger improvement noted without methylphenidate.

Discussion

Although the research design utilized, with the accompanying threats to internal validity (discussed in another section), made meaningful comparison between the variables very difficult, the data were still able to be examined in a preliminary or exploratory fashion. The objective was take a few steps back and examine where, and to what extent, changes occurred. Overall, out of the seven dependent measures used in this study, J.H. evidenced improvement on five. With regards to the primary dependent measures, he
Table 4.3. Subject J.H.: Parenting Stress Index. Normal Range 16-84th percentile, 'e' indicates elevated variable, 'e*' indicates elevated variable that decreased to within normal range, 'e**' indicates variable that increased from normal to elevated range.

<table>
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<th>DOMAIN</th>
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<td>- Distractibility</td>
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<td></td>
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<td>[96/96] e</td>
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made a large improvement on one T.O.V.A. variable and obtained a significant decrease in theta/beta ratio. His inability to consistently demonstrate mastery learning in the absence of feedback may have been due to insufficient sessions. Lubar recommended at least 40 sessions and J.H. completed only 24, which may have been insufficient to internalize a set of psychological or physiological markers that would indicate he was in a decreased theta
Figure 4.6. Subject J.H.: Stroop Color and Word Test. He had 45 seconds to quickly and accurately name words (the words red, green, and blue), colors (names of colors of X’s), and the colors of the words red, green, and blue when the word and the color never matched (Color-Word). The Interference score was a calculated variable based on the subjects base reading and color naming scores.

state. His inability to demonstrate mastery learning in the absence of feedback also might be an indication that feedback is a necessary component in the achievement and maintenance of the decreased theta/beta ratio. There might have been a number of possible results had more sessions been possible, including another increasing threshold pattern, decreased theta performance, or no change at all.

The academic component (reading condition) was incorporated within the neurofeedback training protocol, and the protocol was administered at school, with the intent of improving behavior within the classroom. Thus, although J.H.’s behavior
improved with his father and art teacher, the behavioral data of most interest to this researcher was that of the classroom teacher. Unfortunately, the classroom teacher reported little change in behavior. However, J.H. fared much better on the posttest sociogram, which suggests an improvement in social behavior with his peers.

It is not difficult for even the lay person to understand the probable connection between child behavior and parenting stress. However, due to the limitations of the research design, conclusions cannot be made in this area. Father reported an improvement in behavior and parenting stress. The fact that mother did not observe similar changes suggests a dynamic within the family which might account for the different stress levels. Father reported feeling very restricted by his son’s demands on pretest, and he appears to have coped by isolating himself socially. In essence, he may have removed himself from the stressful environment. Mother may not have had this opportunity. She apparently coped by establishing emotional rather than physical distance. She was most distant when stress levels were at their highest, which was on pretest. On posttest, although there were no changes in stress level, she appeared to have increased her emotional availability which may have had the unfortunate consequence of increasing her stress level.

**Subject D. B.**

**Background Information**

D.B. was 10-6 years old and in the fourth grade at the time of this study. He carried the special education coding of “Other Health Impaired” and received services in the areas of homework guidance, organizational skills, and special seating in the
classroom. He received 10 mg of methylphenidate in the morning and 5 mg at lunch time throughout the duration of training. He did not receive stimulant medication over the summer and very infrequently on weekends. He had received approximately six individual psychotherapy sessions in the year prior to this study which focused on ADHD symptomatology. Although D.B. was not a behavior problem in school, he walked to school every morning and was often tardy. Because he attended the same elementary school as J.H., D.B. was scheduled for training first thing in the morning with the hope that his interest in the program would have the added benefit of getting him to school on time. Training sessions were conducted twice weekly in the school principal’s office during the regular school day. The school principal did not alter in any way the manner in which he conducted his business. He made announcements on the school intercom, conducted meetings with school personnel, and spoke on the phone often while training sessions were taking place at a small round table located at the other end of his office. D.B. completed 26 neurofeedback training sessions over a 4-month period.

Results

D.B.’s performances on the T.O.V.A. variables, response time and variability, improved slightly on posttest. Response time performance remained in the severe deficit range while variability performance, which was at the upper end of the moderate deficit range, improved to the normal range (Figure 4.7). EEG data were analyzed using Spearman Rank Order Correlations. A Spearman Rank Order Correlation of the theta/beta ratio (mean of 3 feedback conditions: 10' bars display, 5' bars display, and 5' choice display) across sessions indicated no correlation. The theta/beta ratio’s, theta performance,
Figure 4.7. Subject D.B.: T.O.V.A.. The four T.O.V.A. variables.

and beta performance, all remained steady through throughout the sessions (Figure 4.8). However, Graph A, the theta threshold/performance graph, displays a threshold pattern very similar to subject J.H. Rather than decrease, the threshold levels needed to be consistently raised for the first 11 sessions (after an initial acclimation period) in order to maintain the designed rate of feedback. Threshold and theta levels reached their peak during session # 11, which also coincided with a significant decline in motivation. The training protocol statements were re-initiated in their entirety at this point in order to reinforce his ability to handle the frustration and boredom. Rather than instructing him to try harder, the statements reassured him that all he needed to do was relax and “not mind.”

Within a few sessions, theta threshold levels trended downward, while the desired rate of feedback was maintained, and returned to pretraining levels by the last session. Although the ratios are within a few tenths of a point, his theta beta ratios were most elevated under conditions of academic demand--the reading condition (Graph D).
Figure 4.8. Subject D.B.: EEG data. Graph A: Theta thresholds and session mean of feedback theta performances. Graph B: Session mean of feedback theta/beta ratio’s. Graph C: Session mean of feedback beta performances (recorded while subject received theta brainwave feedback). Graph D: Theta/Beta ratio condition mean (mean of 24 sessions). Condition #1 (2-minute baseline), #2 (10-minute feedback w/bars display), #3 (reading w/o feedback), #4 (5-minute feedback w/bars display), and #5 (5-minute feedback with choice of display). Outlier’s omitted from graphs and excluded from Spearman Rho’ and regression calculations. Regression lines shown for conditions which achieved significant Spearman Rho’ Correlations.
D.B. was also unable to consistently achieve lower theta/beta power ratio's without the use of contingent feedback (Figure 4.9). In the without methylphenidate condition (Graph A), the theta/beta power ratio's were slightly below that of baseline for the first mastery condition, silence, and significantly below for the second mastery condition, noncontingent feedback. With methylphenidate (Graph B), both mastery conditions were at or above baseline levels.

D.B.'s behavior was highly variable depending on the environment and/or rater. Figure 4.10 displays the ADHDT scores for his mother, art teacher, music teacher, and classroom teacher. Higher standard scores indicate a higher probability that ADHD exists with that particular subject. Overall behavior, as measured by the ADHD quotient score, was relatively unchanged according to the ratings of the music and classroom teachers. Both art teacher and mother, however, reported large improvements with probability scores that dropped 50 and 13 points respectively.

Although the Stroop Color and Word Test generated four basic scores, word, color, color-word, and interference, the score of most importance for the purposes of this study was interference (Figure 4.11). This was a calculated variable based on the subjects base reading and color naming scores. Although all scores were at or above the average range, there was a larger improvement noted without methylphenidate.

With regards to social ranking within the classroom, D.B. was ranked 23rd, in a class of 27, on pretest and 24th on posttest. An additional question was asked on posttest, "Which of the students in your class would you most/least like to have in your class at school next year?" and he achieved a ranking of 25.
Figure 4.9. Subject D.B.: EEG power ratio assessment. The ratio of percent power for theta/beta at Cz (top of the head). ADHD children between the ages of 8-11 typically have ratio’s of 5.5/1. Children w/o ADHD are estimated to have ratio’s 25% lower. Baseline (eyes open and fixed), reading (age appropriate book), writing (VMI), Rorschach monochrome and color card (think of answers), mastery1 (no feedback), mastery2 (with tone recorded from earlier session).
ADHD Quotients

Low (70-79) Below Avg (80-89) Avg (90-110) Above Avg (111-120) High (121-130)

ADHD Quotient Pre  ADHD Quotient Post

Figure 4.10. Subject D.B.: ADHDT. ADHD quotient scores represent the probability of having ADHD.

Figure 4.11. Subject D.B.: Stroop Color and Word Test. He had 45 seconds to quickly and accurately name words (the words red, green, and blue), colors (names of colors of X’s), and the colors of the words red, green, and blue when the word and the color never matched (color-word). The Interference score was a calculated variable.
Neither parent reported total stress levels in the elevated range on the Parenting Stress Index (Table 4.4). Father described D.B. as moody, inflexible, and demanding. Mother, however, did not see him as moody. She described him as a highly distractible, inflexible, and demanding child who fell short of her expectations. On posttest, both father and mother reported major improvements on all variables that were elevated on pretest.

Table 4.4. Subject D.B.: Parenting Stress Index. Normal Range 16-84th percentile, 'e' indicates elevated variable, 'e*' indicates elevated variable that decreased to within normal range, 'e**' indicates variable that increased from normal to elevated range.

<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>Father [Pre/Post] Percentile</th>
<th>Mother [Pre/Post] Percentile</th>
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<td>- Reinforce Parent</td>
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<td>[97/25] e*</td>
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<td>- Mood</td>
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<tr>
<td>- Acceptability</td>
<td>[80/70]</td>
<td>[85/70] e*</td>
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<td>[12/23]</td>
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<td>- Attachment</td>
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<td>- Health</td>
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<tr>
<td>- Spouse</td>
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<td>[30/13]</td>
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<tr>
<td>TOTAL STRESS</td>
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<td>[50/27]</td>
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<tr>
<td>LIFE STRESS</td>
<td>[20/20]</td>
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</table>
Discussion

Overall, out of the seven dependent measures used in this study, D.B. evidenced improvement on only two—the T.O.V.A. and parenting stress index. With regards to the primary dependent measures, he made small improvements on both T.O.V.A. variables and not only failed to obtain a significant decrease in theta/beta ratio but, showed no learning trend whatsoever. The theta threshold/performance data suggests that, although he did not evidence learning in the end, the feedback process was dynamic. Again, insufficient sessions may have contributed to this result as discussed previously.

Although neither parent reported elevated total stress levels, mother did report elevated stress on the child domain, which also happens to coincide with an improvement in behavior. This was also evident with the previous subject, J.H.

Subject T.W.

Background Information

T.W. was 10-4 years-old and in the fourth grade at the time of this study. He was diagnosed as having ADHD by his family physician and was not involved with special education. He received 20 mg of methylphenidate in the morning, 10mg at lunch time, and 10mg as soon as he arrived at home after school throughout the duration of training. He did not receive stimulant medication over the summer and very infrequently on weekends. Although he was also diagnosed with Tourette’s Disorder, no symptoms were observed throughout the training period. Training sessions were conducted twice weekly in one of the school audiovisual/book closets. Although a sign was affixed to the door, teachers
often entered the room to get materials for their class. Announcements on the school intercom and general conversation were not audible from the treatment room. T.W. completed 17 training sessions over a 4-month period.

Results

T.W.’s performance on the T.O.V.A. variable response time remained in the moderate deficit range on posttest. However, variability improved by almost 30 points and moved from the bottom end of the severe deficit range to the top of the moderate deficit range (Figure 4.12).

![Graph A: TOVA Variables](image)

Figure 4.12. Subject T.W.: T.O.V.A.. The four T.O.V.A. variables.

EEG data were analyzed using Spearman Rank Order Correlations. Rather than decrease, theta performance trended upward along with the threshold (Figure 4.13), which contributed to a positive Spearman Rank Order Correlation (\(r=.52, p < .05\)) for the theta/beta ratio (Graph B). Beta performance (Graph C) remained steady throughout the sessions. The theta threshold/performance graph (Graph A) displays a threshold pattern
very similar to the previous subjects. Rather than decrease, the threshold levels needed to be consistently raised for the first 9 sessions (after an initial acclimation period) in order to maintain the designed rate of feedback. Threshold and theta levels reached their peak during session # 9, which also coincided with a significant decline in motivation. The training protocol statements were re-initiated in their entirety at this point in order to reinforce his ability to handle the frustration and boredom. Rather than instructing him to try harder, the statements reassured him that all he needed to do was relax and "not mind." Within a few sessions, theta threshold levels trended downward, while the desired rate of feedback was maintained, and approached pretraining levels by the last session. Unlike the previous subjects, the condition mean ratios were most all at 3.1 (Graph D). There were no discernable differences between the feedback and academic demand conditions.

Although T.W. was unable to achieve lower theta/beta ratios with the aide of feedback, he consistently achieved lower ratio's in the power ratio assessment. Both with and without methylphenidate, he consistently produced mastery ratio's below that of baseline (Figure 4.14). There were no discernable differences between the two mastery conditions.

T.W.'s behavior was highly variable depending on the environment and/or rater. Figure 4.15 displays the ADHDT scores for his mother, father, art teacher, music teacher, and classroom teacher. Higher standard scores indicate a higher probability that ADHD exists with that particular subject. Mother was the only rater who observed a change in his
Figure 4.13. Subject T.W.: EEG data. Graph A: Theta thresholds and session mean of feedback theta performances. Graph B: Session mean of feedback theta/beta ratio’s. Graph C: Session mean of feedback beta performances (recorded while subject received theta brainwave feedback). Graph D: Theta/Beta ratio condition mean (mean of 24 sessions). Condition #1 (2-minute baseline), #2 (10-minute feedback w/bars display), #3 (reading w/o feedback), #4 (5-minute feedback w/bars display), and #5 (5-minute feedback with choice of display). Outlier’s omitted from graphs and excluded from Spearman Rho’ and regression calculations. Regression lines shown for conditions which achieved significant Spearman Rho’ Correlations.
Figure 4.14. Subject T.W.: EEG power ratio assessment. Ratio of percent power activity for theta/beta at Cz (top of head). ADHD children between the ages of 8-11 typically have ratio’s of 5.5/1. Children w/o ADHD are estimated to have ratio’s 25% lower. Baseline (eyes open and fixed), reading (age appropriate book), writing (VMI), Rorschach monochrome and color (think of answers), Mastery1 (no feedback), Mastery2 (with tone recorded from an earlier session).
behavior on posttest. She rated his behavior in the average probability range on pretest and below average probability range on posttest.

Although the Stroop Color and Word Test generated four basic scores, word, color, color-word, and interference, the score of most importance for the purposes of this study was interference (Figure 4.16). This was a calculated variable based on the subjects base reading and color naming scores. Although most scores were within the average range, there was a larger improvement noted without methylphenidate.

With regards to social ranking within the classroom, T.W. was ranked 22nd, in a class of 27, on pretest and 22nd on posttest. An additional question was asked on posttest, “Which of the students in your class would you most/least like to have in your class at school next year?,” and he achieved a ranking of 25.

Both parents reported total stress levels in the elevated range on pretest according to the Parenting Stress Index (Table 4.5). Both parents described T.W. as a highly distractible, moody, and demanding child who fell short of their expectations. Reportedly, neither parent experienced their son as a source of positive reinforcement. On posttest, mother reported an improvement in her son’s moodiness and her total stress levels moved to within the normal range. Although father also saw an improvement in T.W.’s moodiness on posttest, he also saw him as less flexible. In addition to an unchanged elevated total stress level, father reported a high degree of detachment from his son as well.
Figure 4.15. Subject T.W.: ADHDT. ADHD quotient scores represent the probability of having ADHD.

Figure 4.16. Subject T.W.: Stroop Color and Word Test. He had 45 seconds to quickly and accurately name words (the words red, green, blue), colors (names of colors of X’s), and the colors of the words red, green, and blue when the word and the color never matched (color-word). The interference score was a calculated variable based on the subjects base reading and color naming scores.
Table 4.5. Subject T.W.: Parenting Stress Index. Normal Range 16-84th percentile, 'e' indicates elevated variable, 'e*' indicates elevated variable that decreased to within normal range, 'e**' indicates variable that increased from normal to elevated range.

<table>
<thead>
<tr>
<th>DOMAIN</th>
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<th>Mother [Pre/Post]</th>
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<td></td>
<td>Percentile</td>
<td>Percentile</td>
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<tr>
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<tr>
<td>- Distractibility</td>
<td>95/94 e</td>
<td>97/92 e</td>
</tr>
<tr>
<td>- Adaptability</td>
<td>87/92 e</td>
<td>90/85 e</td>
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<tr>
<td>- Reinforce Parent</td>
<td>97/96 e</td>
<td>85/90 e</td>
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<tr>
<td>- Demandingness</td>
<td>80/92 e</td>
<td>70/84 e</td>
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<tr>
<td>- Mood</td>
<td>90/50 e*</td>
<td>98/60 e*</td>
</tr>
<tr>
<td>- Acceptability</td>
<td>97/96 e</td>
<td>85/90 e</td>
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<tr>
<td>PARENT</td>
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<td></td>
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<tr>
<td>- Competence</td>
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<td>72/67</td>
</tr>
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<td>- Isolation</td>
<td>80/60</td>
<td>50/70</td>
</tr>
<tr>
<td>- Attachment</td>
<td>75/95 e**</td>
<td>65/80</td>
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<td>- Health</td>
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<td>- Role Restriction</td>
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<td>- Depression</td>
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<td>- Spouse</td>
<td>40/50</td>
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<td>TOTAL STRESS</td>
<td>87/87 e</td>
<td>92/84 e*</td>
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<tr>
<td>LIFE STRESS</td>
<td>80/85 e**</td>
<td>90/50 e*</td>
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</table>

Discussion

Overall, out of the seven dependent measures used in this study, T.W. evidenced improvement on three. With regards to the primary dependent measures, he made a large improvement on one T.O.V.A. variable. Not only did he fail to obtain a decreased theta/beta ratio, he obtained a significant increase theta/beta ratio. Even more interesting
was his successful performance in demonstrating mastery learning during the power ratio assessment. There is at least one tenable hypothesis regarding this apparently unexplainable finding. This subject evidenced the peculiar pattern of an increasing, rather than decreasing, theta threshold. It did occur to this researcher, while watching this interesting phenomenon, that he might have unintentionally tried to turn the feedback tone off rather than increase its frequency. If this dynamic did occur, it could explain why T.W. was able to produce the desired decreased theta/beta ratio in the absence of feedback. Mother, who reported improved behavior, also reported an improvement in parenting stress, which is consistent with the findings of previous subjects. He appeared to cope with stress within the family by distancing himself emotionally. It is interesting that father was experiencing significant stress from events not related to his family life.

Subject S.C.

Background Information

Subject S.C. was 8-years, 11-months old and in the third grade at the time of this study. He was not identified within the special education system and did not receive any special services throughout the duration of the study. He was diagnosed with ADHD by the family physician and received methylphenidate, at the dosage of 5mg TID, throughout the duration of this study. He also received methylphenidate on weekends and during the summer. Because he attended the same elementary school at subject T.W., S.C. was scheduled for training immediately following T.W. He completed 21 neurofeedback sessions over a four month period.
Results

S.C.'s performance on both T.O.V.A. variables, response time and variability, worsened on posttest (Figure 4.17). However, the data are considered uninterpretable due to his uncooperative attitude and behavior during posttesting.

![Graph A: TOVA Variables](image)

Figure 4.17. Subject S.C.: T.O.V.A. The four T.O.V.A. variables.

EEG data were analyzed using Spearman Rank Order Correlations. No significant correlations over sessions were found. The graphs for theta/beta ratio, theta, and beta are found in Figure 4.18. The theta threshold/performance graph (Graph A) displayed a threshold pattern very similar to the previous subjects. However, in this case, theta performance tracked along with the threshold in a more consistent manner. Rather than decrease, the threshold levels needed to be consistently raised for the first 13 sessions (after an initial acclimation period), after which the training protocol statements were re-initiated in their entirety. Theta threshold levels soon trended downward. Unlike the
Figure 4.18. Subject S.C.: EEG data. Graph A: Theta thresholds and session mean of feedback theta performances. Graph B: Session mean of feedback theta/beta ratio’s. Graph C: Session mean of feedback beta performances (recorded while subject received theta brainwave feedback). Graph D: Theta/Beta ratio condition mean (mean of 24 sessions). Condition #1 (2-minute baseline), #2 (10-minute feedback w/bars display), #3 (reading w/o feedback), #4 (5-minute feedback w/bars display), and #5 (5-minute feedback with choice of display). Outlier’s omitted from graphs and excluded from Spearman Rho’ and regression calculations. Regression lines shown for conditions which achieved significant Spearman Rho’ Correlations.
previous subjects, the highest theta/beta ratio's were found in the feedback conditions (Graph D). Reading elicited a ratio at baseline level.

Consistent with his feedback performance, S.C. was also unable to achieve theta/beta ratio's below baseline on the power ratio assessment (Figure 4.19). His ratio's were consistently higher than baseline. These data are also considered uninterpretable due to his behavior as mentioned earlier.

S.C.'s behavior was highly variable depending on the environment and/or rater. Figure 4.20 displays the ADHDT scores for his mother, father, art teacher, music teacher, and classroom teacher. Higher standard scores indicate a higher probability that ADHD exists with that particular subject. All raters essentially saw little or no change in behavior from pretest to posttest. His behavior appeared to be best in art and music class.

Although the Stroop Color and Word Test generated four basic scores, word, color, color-word, and interference, the score of most importance for the purposes of this study was interference (Figure 4.21). This was a calculated variable based on the subjects base reading and color naming scores. All scores were within the average range on pretest and posttest. There were no discernable differences between the performances with and without methylphenidate.

With regards to social ranking within the classroom, S.C. was ranked 5th, in a class of 25, on pretest and 13th on posttest. An additional question was asked on posttest, "Which of the students in your class would you most/least like to have in your class at school next year?,” and he achieved a ranking of 20.
Figure 4.19. Subject S.C.: EEG power ratio assessment. Ratio of percent power activity for theta/beta at Cz (top of head). ADHD children between the ages of 8-11 typically have ratio's of 5.5/1. Children w/o ADHD are estimated to have ratio's 25% lower. Baseline (eyes open and fixed), reading (age appropriate book), writing (VMI), Rorschach monochrome and color card (think of answers), Masteryl1 (no feedback), Masterly2 (with tone recorded from earlier session).
Figure 4.20. Subject S.C.: ADHDT. ADHD quotient scores represent the probability of having ADHD.

Figure 4.21. Subject S.C.: Stroop Color and Word Test. He had 45 seconds to quickly and accurately name words (the words red, green, and blue), colors (names of colors of X's), and the colors of the words red, green, and blue when the word and the color never matched (color-word). The interference score was a calculated variable.
Only the mother reported total stress levels in the elevated range on pretest (Table 4.6). She described her son as distractible, inflexible, moody, and very demanding. Although he reportedly met her expectations, he was not a source of positive reinforcement. She also reported many symptoms of depression and was quite emotionally detachment from him at the time. Father described his son in a similar fashion, however, he did not report significant distractibility or demandingness. Although mother reported feeling more emotionally close to her son on posttest, all other variable remained elevated along with her total stress level. Father also reported an improvement on only one variable, reinforces parent. Not only did the remaining variables remain elevated, but two variables that were in the normal range on pretest moved to the elevated range on posttest. His son became much more demanding on posttest and no longer met his expectations.

Discussion

Subject S.C. expressed little motivation to participate in this study. He did not want to complete the posttesting, engaged in purposeful off-task behavior for the entire duration, and was almost dismissed prematurely. Although all subjects received a surprise gift after completing the posttest T.O.V.A. (the completion of the study), and knowledge of this more than likely would have improved his behavior and the manner in which he approached the task, S.C. was not informed. This researcher felt that his behavior might be typical for a small percentage of children who receive this type of therapy and the results should be reported as such. Overall, he did not evidence improvement on any of the
Table 4.6. Subject S.C.: Parenting Stress Index. Normal Range 16-84th percentile, ‘c’ indicates elevated variable, ‘c*’ indicates elevated variable that decreased to within normal range, ‘c**’ indicates variable that increased from normal to elevated range.

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<td>- Reinforce Parent</td>
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<td>- Demandingness</td>
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seven dependent measures used in this study. Although his attitude, more than likely, had the greatest impact on the results obtained, he was later diagnosed with Tourette’s Disorder. Tourette’s might have impeded his ability to learn, which might have contributed to his poor attitude.
Subject T.J.

Background Information

T.J. was 9-years, 1-month old and in the third grade at the time of the study. Although he was not coded within the special education system, he participated in a reading group occasionally. He was diagnosed with ADHD by the family physician, and received methylphenidate at the dosage of 10mg BID throughout the duration of the study. He also received methylphenidate on weekends and during the summer on an as-needed basis. His parents were very involved in his treatment and provided tutoring services twice weekly for reading, art therapy, and counselling which was focused on organization and study skills. EEG training was conducted in a small booth accessed through the school principal's office. Although the booth door was closed, auditory and visual distractions were constant. School teachers often entered the room during EEG training sessions to get materials for their classes and the principal conducted meetings, made announcements on the school intercom, and others spoke to teachers on the school phone. The environment was not as distracting as with subjects J.H. and D.B., however, it was by no means as quiet as with subjects S.C. and T.W. T.J. completed 19 training sessions over a 4-month period.

Results

T.J.'s performance on both T.O.V.A. variables, response time and variability, worsened on posttest (Figure 4.12). The data is considered uninterpretable due to his uncooperative attitude during testing.
Figure 4.22. Subject T.J.: T.O.V.A.. The four T.O.V.A. variables.

EEG data were analyzed using Spearman Rank Order Correlations. No significant correlations over sessions were found for theta or beta, however, the theta/beta ratio achieved a significant positive correlation ($r = .51$, $p<.05$). The theta threshold/performance graph (Figure 4.23, Graph A) displayed a threshold pattern somewhat similar to the previous subjects. However, in this case, the theta threshold did not trend downward to the extent as the other subjects. T.J. obtained his highest ratios in the feedback conditions and the lowest ratio in the reading condition (Graph D), much in the same way that S.C. did. Reading elicited a ratio below that of baseline.

Although T.J. was able to achieve theta/beta ratios below baseline levels on the power ratio assessment (Figure 4.24), the data is deemed unreliable due to his extremely oppositional behavior during the posttest.

T.J.’s behavior was highly variable depending on the environment and/or rater. Figure 4.25 displays the ADHDT scores for his mother, father, art teacher, music teacher,
Figure 4.23. Subject T.J.: EEG data. Graph A: Theta thresholds and session mean of feedback theta performances. Graph B: Session mean of feedback theta/beta ratio's. Graph C: Session mean of feedback beta performances (recorded while subject received theta brainwave feedback). Graph D: Theta/Beta ratio condition mean (mean of 24 sessions). Condition #1 (2-minute baseline), #2 (10-minute feedback w/bars display), #3 (reading w/o feedback), #4 (5-minute feedback w/bars display), and #5 (5-minute feedback with choice of display). Outlier's omitted from graphs and excluded from Spearman Rho' and regression calculations. Regression lines shown for conditions which achieved significant Spearman Rho' Correlations.
Figure 4.24. Subject T.J.: EEG power ratio assessment. Ratio of percent power activity for theta/beta at Cz (top of the head). ADHD children between the ages of 8-11 typically have ratio’s of 5.5/1. Children w/o ADHD are estimated to have ratio’s 25% lower. Baseline (eyes open and fixed), reading (age appropriate book), writing (VMI), Rorschach monochrome and color card (think of answers), Mastery1 (no feedback), Mastery2 (with tone recorded from earlier session).
and classroom teacher. Higher scores indicated a higher probability that ADHD existed with that particular subject. All raters, with the exception of the classroom teacher, reported improved behavior. The classroom teacher rated his behavior at the bottom end of the below average probability range on pretest, and in the average probability range on posttest.

Although the Stroop Color and Word Test generated four basic scores, word, color, color-word, and interference, the score of most importance for the purposes of this study was interference (Figure 4.26). This was a calculated variable based on the subjects base reading and color naming scores. All scores were within the average range on pretest and posttest. There were negligible differences between the performances with and without methylphenidate.

With regards to social ranking within the classroom, T.J. was ranked 2nd, in a class of 24, on pretest and 1st on posttest. An additional question was asked on posttest, “Which of the students in your class would you most/least like to have in your class at school next year?,” and he achieved a ranking of 2.

Neither parent reported elevated total stress levels on the Parenting Stress Index (Table 4.7). On pretest, mother described her son as highly distractible and demanding. On posttest, in addition to neither scale improving, mother reported that T.J. did not meet her expectations and she reported feeling incompetent in dealing with his behavior. Father described T.J. as inflexible, demanding, and moody on pretest. He felt dominated by T.J.’s demands and needs and reported poor health. On posttest, T.J. was less moody and less demanding. Father reported that his son was meeting more of his expectations.
Figure 4.25. Subject T.J.: ADHD. ADHD quotient scores represent the probability of having ADHD.

Figure 4.26. Subject T.J.: Stroop Color and Word Test. He had 45 seconds to quickly and accurately name words, colors, and the colors of the words red, green, and blue when the word and the color never matched (color-word). The interference score was a calculated variable based on the subject's base reading and color naming scores.
Table 4.7. Subject T.J.: Parenting Stress Index. Normal Range 16-84th percentile, 'e' indicates elevated variable, 'e*' indicates elevated variable that decreased to within normal range, 'e**' indicates variable that increased from normal to elevated range.

<table>
<thead>
<tr>
<th>DOMAIN - Variable</th>
<th>Father [Pre/Post] Percentile</th>
<th>Mother [Pre/Post] Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHILD</td>
<td>[96/94] e</td>
<td>[90/92] e</td>
</tr>
<tr>
<td>- Distractibility</td>
<td>[99/99] e</td>
<td>[99/97] e</td>
</tr>
<tr>
<td>- Adaptability</td>
<td>[70/70]</td>
<td>[70/80]</td>
</tr>
<tr>
<td>- Reinforce Parent</td>
<td>[45/55]</td>
<td>[15/15]</td>
</tr>
<tr>
<td>- Demandingness</td>
<td>[97/98] e</td>
<td>[96/96] e</td>
</tr>
<tr>
<td>- Mood</td>
<td>[85/75] e*</td>
<td>[50/60]</td>
</tr>
<tr>
<td>- Acceptability</td>
<td>[95/80] e*</td>
<td>[80/96] e**</td>
</tr>
<tr>
<td>PARENT</td>
<td>[40/23]</td>
<td>[42/60]</td>
</tr>
<tr>
<td>- Competence</td>
<td>[25/10]</td>
<td>[65/87] e**</td>
</tr>
<tr>
<td>- Isolation</td>
<td>[10/10]</td>
<td>[50/15]</td>
</tr>
<tr>
<td>- Attachment</td>
<td>[35/10]</td>
<td>[10/25]</td>
</tr>
<tr>
<td>- Health</td>
<td>[92/94] e</td>
<td>[35/70]</td>
</tr>
<tr>
<td>- Role Restriction</td>
<td>[90/45] e*</td>
<td>[55/45]</td>
</tr>
<tr>
<td>- Depression</td>
<td>[03/04]</td>
<td>[20/45]</td>
</tr>
<tr>
<td>- Spouse</td>
<td>[55/70]</td>
<td>[75/80]</td>
</tr>
<tr>
<td>TOTAL STRESS</td>
<td>[77/62]</td>
<td>[70/80]</td>
</tr>
<tr>
<td>LIFE STRESS</td>
<td>[35/20]</td>
<td>[40/40]</td>
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</tbody>
</table>

Discussion

Subject T.J. was very similar to subject S.C. regarding lack of motivation to participate in this study. He also did not want to complete the posttesting, engaged in purposeful off-task behavior for the entire duration, and was almost dismissed prematurely. As done for subject S.C., T.J. was not informed that he was going to receive...
a surprise gift after completing the posttesting. Overall, he evidenced improvement on two of the seven dependent measures used in this study—objective behavior and classroom sociogram. Although T.J. did not improve, and actually worsened, on the primary dependent measures, his objective behavior did improve. He was the only subject who achieved behavioral improvements from at least three out of the five behavioral raters. Unfortunately, the rater identified as most important by this researcher, the classroom teacher, reported a worsening of behavior. His behavior apparently had little impact on his peer relationships, as evidenced by his improving from second rank to first rank on the classroom sociogram.
CHAPTER 5

GENERAL DISCUSSION

Primary Questions

The three main purposes of this study were to explore; 1.) the utility of a continuous performance test in identifying students with ADHD, 2.) whether a program designed to enhance attentional skills could be administered within the school setting, and 3) whether problematic profiles of attention could be remedied. However, the issue of validity is addressed first in order to develop a context in which to consider the answers to these questions.

Threats to Internal Validity

Selection Process

Having administered the attention enhancement program within the school setting had its obvious advantages, as outlined earlier. However, many unforeseen obstacles and challenges surfaced which not only affected the research design, execution, and results, but also the selection process.

The single major stumbling block to the successful implementation of this study was the depth of mistrust between the parents of prospective study participants and the school system’s special education department. Although most parents understood the potential value of the proposed treatment for their children, they were extremely suspicious of the special education department’s motives. First and foremost, they were concerned about losing special education services. Interestingly, this was not limited to the fear of their child obtaining normal profiles in the screening evaluation. Many were also
concerned about losing services if the program was actually successful in treating their children. In addition, the parents of children who were not currently receiving special education services were assured that they could utilize any information from the study to support a request for special education services. Most parents were unswayed by the special education director’s assurances that the school system would not have, nor seek to gain, access to any identifying information regarding their children’s participation in this study. The full extent of the adversarial relationship became evident when several parents became agitated and questioned why programs such as this were not implemented much earlier. This adversarial culture resulted in only a handful of signed consents from an initial sample pool of 17,000 students, which severely compromised the research design. The manner in which the subject selection process evolved, not only resulted in a change to the use of single subjects but, may have inadvertently increased the likelihood of selecting subjects with more severe ADHD symptomatology and multiple comorbid conditions.

Heterogeneity is one of the most difficult aspects to control for in research with ADHD subjects. This researcher chose to establish homogeneity based upon one dependent variable, the T.O.V.A., which revealed three distinct profiles of attention among the subjects who completed the prescreen evaluation—normal, impulsive, and non-impulsive. The subjects who obtained impulsive profiles were impaired on all four T.O.V.A. variables and they either exhibited clear signs of neurological dysfunction or extremely oppositional behavior. The subjects who obtained non-impulsive profiles were impaired on only two T.O.V.A. variables, reaction time and variability, and they were markedly less oppositional. The subjects who obtained normal profiles were not impaired.
on any variables, they found the task extremely easy, and they were very pleasant and cooperative. Thirteen students obtained T.O.V.A. profiles consistent with their ADHD diagnoses (or lack thereof in one case) and only five students did not.

Although these results appear to be largely supportive of the clinical utility of the T.O.V.A. in the identification of ADHD, other factors may have affected the data obtained. First, the two T.O.V.A. variables that were significantly correlated with behavioral measures, impulsivity and inattention, were not solely responsible for the identification of ADHD by the T.O.V.A. among the subjects. Six out of the seven subjects in the non-impulsive group achieved normal performances on inattention and impulsivity and abnormal performances on response time and variability. These latter two variables appeared to have made the differentiation between non-impulsive and normal subjects. Had inattention and impulsivity been the only variables measured, only one of the seven subjects in that group would have been identified as having ADHD.

In addition, the correct identification of ADHD subjects may have been affected by a skewed subject screening sample and parent reporter bias. Only one subject among the prescreen evaluation sample did not carry the diagnosis of ADHD. Although this subject was correctly identified by the T.O.V.A., the subject sample was largely restricted to the identification of true positives and false negatives. The success in identifying true positives might have been affected by parent reporter bias. Parents were the sole providers of objective behavioral ratings for their children during the prescreen portion of this study. Because family physicians made most of the ADHD diagnoses, they likely relied heavily upon parents to provide behavioral information as well.
**Single subject changing criterion Design**

The use of a single subject research design in the present study had a major impact on the conclusions that could be made. The single most apparent methodological limitation was a lack of generalizability. The lack of a control group limited any conclusions, with regards to the effectiveness of the attention enhancement program, to the individual subjects in this study. Inferences could not be made about ADHD children in general from the characteristics of the subjects in the present study.

The single subject, changing criterion design utilized in the present study was limited in that the discernment of functional relationships could only be made with EEG data. The strength of this design was that it provided an excellent methodology to test whether a functional relationship existed between the dependent variable (a well documented deficit in fast wave activity) and independent variable (EEG theta threshold) all the while attempting to decrease the undesired behavior (decreased slow brain wave activity). Single-subject designs acquire strength from repeated measures of the dependent variable over an extended period of time (Alberto & Troutman, 1990). In this study, there were 128 observations per second of the dependent variable, theta brainwave activity, over several 27-minute periods. The extensive number of observations of the dependent variable were more than sufficient to discern whether a relationship existed with the independent variable. Correlations were also able to be conducted to determine whether the EEG changed significantly over time. However, the reader is reminded that the intent of changing the EEG was to affect improved subject performance on the T.O.V.A. The changing criterion was not able to address whether EEG changes had anything to do with
improved subject performance on the T.O.V.A. or the other secondary dependent measures. The small number of subjects and the loss of the control group (explained earlier) relegated these variables to a one-group, pretest-posttest design, exposed the data to several possible threats to internal validity (discussed in the present section), and made it impossible for the present researcher to determine whether improvement on these variables was caused by EEG performance. Without a control group for comparison, changes on the dependent variables could not reliably be attributed to changes in the independent variable.

Instrumentation

This threat to internal validity involves the effect of any change in observational technique or measurement instrument which might account for a change in pretest and posttest performance (Huck, Cormier, & Bounds, 1974). The use of the EEG instrumentation can certainly result in unintended measurement changes, such as environmental electromagnetic interference, electrode placement, uniformity of skin preparation, and type of EEG measurement (analog vs. digital, monopolar vs. bipolar). As mentioned earlier, one subject was dismissed from the present study due to the uncertainty that the electromagnetic field generated from an adjacent utility room might have upon the results. EEG electrode placement can also have an unintended affect on the results. Every attempt was made to apply the electrodes to the same site for all feedback sessions. However, this was not always possible. Some subjects developed slight sores on the scalp due to repeated cleansing of the same area which necessitated application of the electrode on an adjacent area. Other subjects who began the study with longer hair obtained short
haircuts during the treatment, which made electrode placement more difficult. In short, every time an electrode is removed and reapplied at a later date, there is the possibility of error.

Skin preparation was another area of potential problem. In the beginning of the study, a significant amount of time was committed to obtaining low electrode impedance values prior to beginning treatment. However, as time progressed, some classroom teachers became less patient with regards to the time their student was out of the classroom. Thus, hook-ups had to be performed much quicker. Although the skill of this researcher in obtaining excellent hook-ups increased significantly over time, it is possible that some sessions were conducted with excessive electrode impedance values.

There are differences of opinion with regards to how EEG electrodes should be placed, EEG’s measured, and EEG’s interpreted which exceed the skills of this researcher and the scope of this study. The present study addressed these issues by how often samples, or individual measurements, were made (previous paragraph). In addition, feedback were generated to the subject only after 50 successful events (training criteria met) occurred. Although electrical artifact generated from adjacent muscles (eye rolls, blinking, facial grimaces) were addressed by an EMG inhibit circuit, the artifact could not be eliminated from the data. However, even with these limitations, the extent to which these data were collected and reported afforded a reasonable opportunity to visually discern within session and between session trends.

With regards to the data generated from the changing conditions assessment, which was conducted on pretest and posttest, an additional level of control was afforded
by the manner in which brain wave data were subjected to analysis. The raw EEG was recorded during the different conditions and saved to computer diskettes for later analysis. The raw EEG was examined in two second epochs. Epochs that contained wave forms consistent with eye blinks and/or eye rolls were rejected. Only those epochs most free of artifact were selected by this investigator and subjected to analysis. This introduced the possibility of researcher bias in the selection of epochs. The changing conditions assessment design was chosen, not to determine the relationship between the dependent variable (theta) and independent variable (theta threshold) but, to examine the effect of different academic conditions on the dependent variable. The reader is reminded of the previous discussion regarding concurrent treatments in which Dr. Lubar (1992) had found that ADHD children tend to display increased theta activity under conditions of academic demand.

The other type of instrumentation error arises when human beings are utilized as observers and raters. Pretest and posttest differences might be a result of the raters increased experience in filling about the forms, fatigue, increased knowledge about the study, or different behavioral standards at posttest (Huck, Cormier, & Bounds, 1974). In the present study, all parents willingly completed the pretest forms necessary to be considered for the study. However, obtaining the requisite forms on posttest proved to be much more difficult. The parent for subject D.B. did not submit their posttest forms until a month after the completion of the study, a time which is likely characterized as less stressful due to the absence of school academic demands.
Experimenter Bias

Although EEG biofeedback was an integral component to the attentional enhancement program, it was never intended to be the sole component. The role of this investigator was also an integral component to the effective implementation of the attribution, effortless attention, effortless intention, and wandering mind statements in order to teach the subjects how to complete the feedback task. Having the functions of neurofeedback therapist and experimenter performed by the same individual introduced the possibility of experimenter bias—impartiality of persons in direct contact with the subjects or the data. This issue became obvious during posttesting when two subjects became extremely belligerent and uncooperative, and purposely did not try. This experimenter knew, without a doubt, that if these two subjects were informed they were about to receive a walkman radio at the conclusion of the study, they would have performed significantly better on the posttest measures. However, informing them of this would have introduced differential treatment. This example was obvious to this examiner. What other biases remained unnoticed and possibly affected the results obtained? Perhaps less emphasis to perform on pretest and increased emphasis on posttest. The use of the T.O.V.A. and EEG provided a degree of insulation from experimenter bias, nevertheless, it is accepted as a major limitation.

History

History appears to be more of a threat to the objective behavioral and parenting stress ratings. Outside events not controlled for certainly could have occurred between these repeated measures and affected the results. For example, subject J.H. may have had
significant family stressors (alcoholism) that were unreported during the study. While revisiting his home multiple times, in order to obtain the posttest parenting stress and behavioral information, this examiner met a neighbor who remarked that the parent in question “fell off the wagon” and probably would not answer the door. A change in family dynamics of this proportion certainly could have had an impact on parent report as well as the subjects behavior in school. Although all parents agreed to inform this experimenter of any medication changes, the possibility exists that changes occurred (dosages, weekend usage etc.) without notification. The mother of subject T.J. was strongly biased against the use of methylphenidate and in the past had discontinued its use in the new school year. The parenting stress index provided some measure of outside variables that might have affected the results of the study, like job changes and changes in living location, however, the parent decided what to report. The threat of concurrent treatments is always present when studies are conducted over an extended period of time. The parents of a subject in this study might have begun, or increased their level of, tutoring support thus affecting the results in some insidious manner.

With regards to behavior, an improvement in art or music class on posttest might reflect the independent variable or the subject’s acclimation to the unstructured environment. This is why these measures were considered secondary.

**Maturation**

The subjects in this study certainly could have made developmental, emotional, social, and educational changes during the study. For example, the EEG protocol utilized a five minute reading condition in between feedback conditions. If a subject experienced
difficulty with reading on pretest, and had made significant gains in the following months, the resulting confidence might have affected his performance on the EEG following the reading condition. The argument presented earlier by Barkley, regarding decreased slow wave activity due to increased age on posttest, is highly unlikely due to the extremely short period of time that elapsed between pretest and posttest.

Could a school system identify specific profiles of attention with a continuous performance test, and could those deficits identified be Remedied?

Although the selection process may have influenced the subject sample, and perhaps the results as discussed above, there was sufficient evidence to support the clinical utility of the continuous performance test in identifying specific profiles of attention. The question remains regarding its diagnostic capabilities.

The results of this study with regards to the improvement of problematic attention profiles were equivocal. First, the T.O.V.A. performances of all five subjects on inattention and impulsivity were in the normal range on pretest and posttest. On the remaining two variables, response time and variability, the performances of two subjects improved (not on same variable), the performance of one subject improved only slightly, and the performances of two subjects worsened (on both variables). Although homogeneity was established by the selection of study participants based upon T.O.V.A. profiles, unforseen comorbid factors not apparent during the selection process may have contributed to the equivocal results. Subjects S.C. and T.J., who were oppositional throughout the study, were referred for educational evaluations for learning disabilities.
Could a school system administer an attention enhancement program within the school setting?

The single most prominent obstacle to the successful administration of this study within the school setting was the poor, distrusting relationship between parents and the special education department of the school system. The second most prominent obstacle was equipment expense. Although the T.O.V.A. research corporation provided the T.O.V.A. interpretation reports at no charge, and this investigator provided a laptop computer, the cost of equipment still exceeded $5,000.00. The school system was unable to purchase the equipment due to a budget crisis. However, they were able to defray a large portion of the equipment costs by contracting with this investigator to conduct the research program. The third major impediment to the implementation of this program was the level of logistical difficulty. This investigator attended an 60-hour EEG certification training program which provided detailed instruction in EEG operation and neurofeedback training protocols. What the training program could not provide was practical experience with doing difficult EEG hook-ups very quickly. The logistics of transporting the equipment among the five different schools, finding appropriate space, and getting set up were easy compared to getting the subjects hooked-up properly and the 27-minute training protocols completed within the 35-40 minute time periods allotted by the classroom teachers. The bulk of this investigators difficulty occurred early in the program and involved obtaining the proper electrode impedance and rate of feedback. High electrode impedance values necessitated the removal of electrodes, cleaning of the electrode sites again (scalp and ear lobes), application of new electrode paste, reapplication of the electrodes, and verification of proper electrode impedance prior to beginning each training
session. Again, in the early sessions, the theta thresholds needed to be adjusted in order to obtain the appropriate rate of feedback. These difficulties resulted in the subjects being out of the classroom for longer periods in the early phase of the program.

There were positive experiences in the administration of this program as well. Teaching and school administration staff expressed great interest in the treatment program. They welcomed the alternative nature of the program and applauded the use of modern, computerized technology. Building principals offered the use of their personal offices when space within their schools could not be allocated.

In spite of the positive aspects outlined above, these anecdotal data, combined with the equivocal results on dependent measures, do not support the conclusion that this program was successfully administered within the school setting. The effort expended to administer the program was tremendous and burdensome and the training required was extensive. At present, this researcher would not recommend a school system invest in the equipment and personnel costs associated with this procedure.

Secondary dependent Measures

The secondary dependent measures included brainwave data, objective behavior, parenting stress, social ranking among peers, and an additional attention measure.

Did the subjects brainwaves Change?

The fact that a shaping protocol was utilized, invited the question of whether the subjects brain waves would respond to the changing criterion (theta threshold). The results were equivocal. The theta/beta ratio of one subject (J.H.) significantly decreased, the theta/beta ratio’s of two subjects (D.B., S.C.) remained the same, and the theta/beta
ratio's of two subjects (T.W., T.J.) increased. There were no discernable patterns among the measures used in this study to explain the varied results. Although subjects S.C. and T.J. were highly unmotivated throughout the study, motivation can not explain why a highly motivated subject, T.W., also did poorly. The most obvious discrepancy between these data and those of previous researchers is the significantly reduced number of treatment sessions. Lubar (1992) suggested that 40 sessions were necessary in order to facilitate learning. Subjects J.H. and D.B. completed the most sessions (24 and 26 respectively) and subjects T.W. and T.J. completed the least (18 and 19 respectively).

The most interesting finding among these data were the EEG response to the changing criterion (theta threshold). The theta thresholds appeared to be driven by the theta values. When theta levels increased the threshold needed to be continually reset in order to maintain the desired rate of feedback to the subject. A tenable hypothesis for pattern, which occurred with all five subjects, might be a progressive waning of their initial fascination of the EEG equipment and training program. The highly repetitive nature of the biofeedback task may have elicited boredom and a corresponding increase in theta performance and threshold levels. The function of manipulating the theta threshold may have been limited to facilitating interest (obtain more auditory feedback) to counteract the feelings of boredom and to reengage the subjects attention. The function of the therapist and attribution statements might have been limited to providing reassurance and instruction on how to remain on task while working through their feelings of boredom. The function of the biofeedback instrumentation might have been limited to measuring and recording the subjects brain waves.
Additional evidence to support this hypothesis were the behavioral difficulties exhibited by all subjects when thresholds were at their peak. Most subjects wanted to discontinue the task at a time when the therapists statements were significantly simplified into short phrases of a few words, or aphorisms. In order to assist the subjects through this difficult time period, all attribution statements were reinitiated in their entirety. Soon thereafter, theta levels began to steadily decrease along with a corresponding decrease in oppositional behavior. This suggests that any repetitive task that elicits a high level of initial interest and then becomes progressively boring might produce a similar effect.

Were the subjects able to change their brainwaves without the aid of Neurofeedback?

After having completed their training, the subjects theta/beta power ratio's were assessed in order to answer the question of whether they had learned to produce, access, or maintain a decreased theta state on their own--a type of beta meditation. Only one subject (T.W.) achieved lower theta/beta power ratio values in all four conditions assessed. The remaining subjects achieved ratio values at or above baseline values indicating that learning had not occurred. Although the insufficient number of sessions might have been responsible for these results, the present study employed a number of techniques not employed by Lubar, which introduces a level of doubt regarding the affect of additional sessions. The beta-meditation procedure employed in the present study might have impeded, rather than enhanced, the ability of the subjects to acquire the EEG task.
Parenting Stress

The most apparent finding from the parenting stress data was that parents of the children in this study were experiencing significant levels of stress which, in all cases except one, they attributed to factors within the parent/child relationship rather than the spousal relationship. Although the total stress levels of two parents decreased to within the normal range on posttest, only one parent reported a significant decrease in stress attributed to the child.

Objective Behavior

The main finding regarding the subjects behavior was that behavior was highly dependent upon the rater and/or setting. Due to the small number of subjects, change was defined as movement of scores into another “ADHD probability” classification. Out of 24 raters, 42% reported a decrease in ADHD behaviors, 46% reported no change, and 12% reported an increase in ADHD behaviors. The most striking finding from these data was that the classroom teachers reported the least amount of change. This was generally consistent with the negligible change in classroom sociometric ranking. Although both art and music teachers were blind raters, the music teacher reported little change and the art teacher reported very large improvements.

Noncomputerized measure of Attention

The subjects will most likely remember the Stroop test the most. They enjoyed the challenge and were highly motivated to perform their best. Although there were some indications of differential performance on the Stroop, with and without MPH, the affect of
practice could not be ruled out. Subjects were administered the Stroop four times, twice on pretest and twice on posttest. This examiner expected a larger improvement between the first and second administrations than the second and third, and third and fourth administrations. Examination of Stroop data in this manner was consistent with an initial practice effect. The mean improvements between administrations were as follows: first and second (4.4 points), second and third (3 points), and third and fourth (1.2 points). Thus, the larger degree of improvement while off MPH might have been affected by it being administered first and last, thereby affording the subjects ample opportunity for practice.

Two year follow-Up

Two years after completing data collection, this investigator interviewed the parents of subjects J.H., S.C., and S.C. Subjects D.B. and T.W. could not be located and may have moved out of the school district. Subject J.H.’s parents reported a significant worsening of school performance and very low levels of motivation. Both parents reported that after having requested the school to evaluate their son, all that was provided was a behavioral scale which was administered by the school learning disabilities specialist. The parents were extremely frustrated with the special education department and were in the process of moving to another school district. This investigator counseled the parents on how to make referral for a comprehensive evaluation, what to expect, and how to elicit the assistance of the legal profession if they felt their child’s educational needs were not being met.

The parents of subject S.C. reported that the results of an educational evaluation, which began toward the end of the attention enhancement program, did not reveal the
presence of any learning disabilities. Their son’s behavior, however, had continued to worsen in the following year and he was referred for a social-emotional evaluation, which revealed the presence of severe emotional issues. In addition, the school psychologist who evaluated S.C. noticed what might be motor tics and, after having interviewed the family, referred S.C. to a neurologist who diagnosed Tourette’s Disorder. S.C.’s brother, father, and grandfather were also referred to the neurologist for evaluation as well. Evidently, tics were common in the men of the family and no one thought much about it until S.C.’s difficulty.

The parents of subject T.J. reported that they had discontinued T.J.’s methylphenidate at the beginning of the school year following the completion of the attention enhancement study. T.J.’s behavior in the classroom was totally unmanageable and the parents immediately placed him back on medication. Although they also reported excellent grades in school and continued social success, they were challenged by their son’s behavioral difficulties.

Implications

Although the difficulties of this large, city school system may not be representative of all schools, many are likely to be present to some degree. Future researchers can avoid these pitfalls by developing trusting relationships with school administrative personnel, classroom teachers, parents, and most importantly, the students. This might be best accomplished if the program were implemented by a school employee. Then, issues such as suitable space, close proximity of subjects, integration of treatment into the students daily school schedule, and minimizing time out of the classroom would be easier to
address. School systems might have an easier time eliciting support from their staff, as well as parents, if encouraging research results were provided to them. Schools are increasingly working with community organizations in bringing services to their students. The local therapeutic community might see the value of increasing their level of integration with the school system and provide the services necessary for the development of a therapy only control group.

This investigator accepted the limitations inherent with using single subjects because there was insufficient time to obtain additional subjects within the time frame that was allotted by the school system. Without these constraints, future researchers can obtain larger sample sizes, appropriate control groups, and more sessions. Emotional disturbance, learning disability, and neurological screens should be conducted to best control for many of the comorbid factors that manifest in young subjects. A research design that tests the relative contribution of the EEG and therapist would be extremely valuable. The incorporation of a noncontingent feedback control group is an absolute necessity if the EEG is to be utilized for future research. This has been highly criticized by the neurofeedback community due to the confounding potential of boredom and disengagement in the process once the subjects realize their feedback is noncontingent. All five subjects in the present study quickly became aware of the noncontingent feedback during the mastery learning assessment conducted on posttest.

The results of this research suggests that boredom and disengagement might not be confounds, but actually insidious components of the attention disorder. Research geared toward eliciting these responses in a controlled manner while teaching coping strategies
might be very fruitful. Much in the same way that some continuous performance tests might miss important diagnostic information about a subject, so might research that is geared toward avoiding the variables of boredom and disengagement. The effectiveness of the EEG might involve the gradual eliciting of boredom while support of the therapist is provided. Although this hypothesis might not bode well for the sales of single channel EEGs, it certainly begs the question of whether this dynamic is occurring in the classroom.


