BIOFEEDBACK AS A TREATMENT FOR ATTENTION DEFICIT HYPERACTIVITY DISORDER

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BY

JUDY N. ANDERSON, M.A.

DENTON, TEXAS

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TEXAS WOMAN'S UNIVERSITY

DENTON, TEXAS

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Date

To the Associate Vice President for Research and Dean of the Graduate School:

I am submitting herewith a dissertation written by Judy N. Anderson entitled "Biofeedback as a Treatment for Attention Deficit Hyperactivity Disorder". I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in School Psychology.

Daniel C. Miller

Daniel C. Miller, Ph.D.
Major Professor

We have read this dissertation and recommend its acceptance:

Basil Hamilton

Accepted

Leslie M Thompson

Associate Vice President for Research
and Dean of the Graduate School

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ABSTRACT

Biofeedback as a Treatment for Attention
Deficit Hyperactivity Disorder

Judy N. Anderson

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The purpose of this study was to examine biofeedback training and its relationship to Attention-Deficit/Hyperactivity Disorder (ADHD). Six boys between the ages of 9 and 12 who were diagnosed as Attention-Deficit/Hyperactivity Disorder were randomly assigned to either an experimental or control group. The experimental group underwent 25 sessions of EEG biofeedback training. Pre- and post-test scores from the Woodcock-Johnson Psychoeducational Battery, the Attention Deficit Disorders Evaluation Scale-Home Version, and the Children's Depression Inventory were compared for the two groups. Traditional and non-traditional biofeedback data were analyzed for the experimental group. Results of this study found changes in traditional biofeedback data for the experimental group. However, these did not translate to changes in cognitive, achievement, or behavioral functioning.

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Chapter I

Introduction

The syndrome of Attention-Deficit/Hyperactivity Disorder (ADHD) continues to spark debate in terms of definition, etiology, identification, and treatment. Parents, educators, and professionals within both the medical and mental health fields are often confronted with an array of confusing information in their attempts to aid individuals who are affected by this diagnosis. Estimates of the prevalence of ADHD also vary with figures ranging from three to five percent of children (American Psychiatric Association, 1994; Barkley, 1990). While these numbers may represent a conservative estimate, it is important to remember that even minimal estimates encompass a significant number of children. The impact of this disorder is further revealed by referrals to child guidance clinics where concerns with ADHD have been cited as one of the most common reasons for referral (Barkley, 1990).

A diagnosis of ADHD affects not only the child who is referred but also the family, school environment, and interactions of the child in the social setting (Barkley, 1990). Parents have a strong desire for their child to be successful. For this reason, they have often gone to great lengths and even greater expense to provide opportunities and interventions that would be of benefit to their children. Unfortunately, many of their ventures into the arena of remediation have been in vain. The vulnerable nature of these consumer parents have often led to experimentation with techniques that have not been subjected to rigorous assessment by the scientific community. As a result, the efficacy of some treatment programs may not be adequately assessed before presentation to the public.

One goal of this investigation was to put into perspective the current status of ADHD in terms of definition, etiology of the disorder, identification problems related to comorbidity, and modes of treatment. The research then focused on the use of biofeedback as a method of treatment for ADHD.

Assumptions

A primary goal of any experimental procedure is to control for as much error as possible. The following assumptions were made in the design and implementation of this study.

It was assumed that the computer equipment and software used in the research accurately measured and assessed human responses as purported by the manufacturer.

It was assumed that administration of objective test data followed standardized procedures.

It was assumed that all objective test data were accurately scored.

It was assumed that all entries into computer scoring programs were accurate.

It was assumed that the environments to which the participants were subjected during the evaluation component were not significantly different.

It was assumed that any errors related to human manipulation, the environment, or the biofeedback equipment were random in nature.

Chapter II

Literature Review

In order to clarify issues and concepts related to Attention-Deficit Hyperactivity/Disorder, a review of the literature will illustrate the evolution of the definition of ADHD over time. The etiology of the disorder will be discussed as well as identification techniques and treatment methodologies. The reliability and validity of various assessment instruments often used in the identification of children with ADHD will be considered. The components of this research study will be described and the hypotheses presented.

Definition of ADHD

Accurate diagnosis and treatment of ADHD as well as research in the field has been hampered by the lack of a consistent, universally accepted definition of the disorder (Barkley, 1990; Frick & Lahey, 1991; Wicks-Nelson & Israel, 1991). When analyzing the definition of ADHD from an historical perspective, it is apparent that shifts have occurred in the behaviors that have been emphasized. Initially, the emphasis was on excessive motor activity. However, during the 1970's, recognition of attention deficits and impulsivity came to the forefront (Wicks-

Nelson & Israel, 1991). In 1980, the Diagnostic and Statistical Manual of Mental Disorders, Third Edition (DSM-III: American Psychiatric Association, 1980) defined the disorder to differentiate between children who exhibited attention deficits and impulsivity with hyperactivity from children who manifested attention deficits and impulsivity without hyperactivity.

Publication of the Diagnostic and Statistical Manual of Mental Disorders, Third Edition - Revised (DSM-III-R: American Psychiatric Association, 1987) resulted in a revision of the definition once again. Rather than having categories that distinguished between children with or without hyperactivity, the new definition collapsed all individuals into one group labeled as Attention-Deficit Hyperactivity Disorder.

In a critical review of this definition, Frick and Lahey (1991) summarized numerous studies which pointed to the problems associated with its usage. A major concern was that all children were grouped together with no differentiation made for those exhibiting hyperactivity and those who did not. Thus, a child may have been diagnosed as ADHD and yet displayed no evidence of hyperactivity. An additional disadvantage noted by the authors as a result of this method of classification was in the identification of appropriate behavioral or pharmacological modes of treatment.

Continuing research and increased understanding of ADHD resulted in further changes in the definition of this disorder. With the publication of the Diagnostic and Statistical Manual-IV (DSM-IV: American Psychiatric Association, 1994) a shift in focus occurred once again. The changes included recognition of three main subtypes under the umbrella of Attention- Deficit/Hyperactivity Disorder. One subtype, Attention-Deficit/Hyperactivity Disorder, Predominately Inattentive Type, primarily focuses on the inattentive characteristics of the individual. Furthermore, no requirement is made for demonstration of evidence of impulsivity. A second category, Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type, emphasizes behavior that reflects hyperactivity and impulsivity. While no minimum number of inattentive symptoms are required for this diagnosis, inattention is recognized as a feature that may remain prevalent in clinical cases. The third subtype, Attention-Deficit/Hyperactivity Disorder, Combined Type, incorporates both the symptoms of inattention and hyperactivity-impulsivity.

This distinction of symptoms found in DSM-IV is currently employed in the identification of Attention-Deficit/Hyperactivity Disorder and is detailed as follows:

A. Either (1) or (2):

(1) six (or more) of the following symptoms of inattention have persisted for at least **six months** to a degree that is maladaptive and inconsistent with developmental level:

Inattention

(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

(b) often has difficulty sustaining attention in tasks or play activities

(c) often does not seem to listen when spoken to directly

(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)

(e) often has difficulty organizing tasks and activities

(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)

(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)

(h) is often easily distracted by extraneous stimuli

(i) is often forgetful in daily activities

(2) six (or more) of the following symptoms of hyperactivity-impulsivity have persisted for at least **6 months** to a degree that is maladaptive and inconsistent with developmental level:

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat

(b) often leaves seat in classroom or in other situations in which remaining seated is expected

(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

(d) often has difficulty playing or engaging in leisure activities quietly

(e) is often "on the go" or often acts as if "driven by a motor"

(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed

(h) often has difficulty awaiting turn

(i) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years.

C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the courses of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorders and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder). (p. 83-85)

A diagnosis of Attention-Deficit/Hyperactivity Disorder, Combined Type is given when an individual exhibits the criteria for both A1 and A2 for the past 6 months. When Criterion A1 is met but Criterion A2 is not met for the past 6 months, a diagnosis of Attention-Deficit/Hyperactivity Disorder, Predominately Inattentive Type is given. Attention-Deficit/Hyperactivity Disorder, Predominately Hyperactive-Impulsive Type is diagnosed when Criterion A2 is met but Criterion A1 is not met for the past 6 months.

Etiology of ADHD

A variety of theories have been proposed over the years to address the cause of ADHD. Brain damage, pregnancy and birth complications, diet, environmental variables, and psychosocial factors have been considered. Despite much research a clear-cut response to the question of etiology remains unresolved (Wicks-Nelson & Israel, 1991).

More recent studies have focused on central nervous system dysfunction specifically with respect to the frontal and frontal-limbic areas. In a review of the literature related to a neurological basis of ADHD, Hynd, Hern, Voeller, and Marshall (1991) noted that through the use of neuroimaging techniques differences have been identified between ADHD and normal children. Evidence appears to indicate that for children with ADHD there is a deficiency in the metabolic systems involved in motor inhibition and motor control which project to the frontal lobes. In addition, studies were reviewed by Hynd et al. (1991) which pointed to structural differences in the brains of ADHD children when compared to normal children. When comparisons were made of the widths of the frontal lobes, normal children typically exhibited right lobes of greater width than the left lobes. In contrast, ADHD children have right and left lobes of equal width. Hynd et al. (1991) suggest that this lack of asymmetry in ADHD children may result in a less efficient system for neural processing. Studies involving biochemical research were also reviewed by Hynd et al. (1991). Findings suggest that ADHD children have deficits in the catecholamines which are the neurotransmitters involved in the control of motivation and motor behaviors.

Another hypothesis related to the etiology of ADHD involves the arousal-inhibitory processes of the brain. Findings suggest that ADHD children may actually be underaroused and thus exhibit excessive activity to acquire stimulation (Anastopoulos & Barkley, 1988). Evidence for a genetic involvement in ADHD also appears to be mounting (Barkley, 1993). In their review, Hynd et al. (1991) found several studies which support a genetic link between ADHD children and positive family histories for the disorder. However, not all children diagnosed as ADHD manifest a genetic component.

The current status of the etiology of ADHD suggests a neurological basis for the disorder. Due to the complexity of the disorder, it may not be possible to identify one specific neural structure or biochemical process responsible for the symptoms and behaviors observed. It is also unlikely that ADHD encompasses a homogenous group. This possibility may have a significant impact on treatment. A positive response to treatment my depend upon the individual's primary problem. Attentional deficits may require different interventions than manifestations of hyperactivity. In addition, behaviors related to structural differences may require different remediations than behaviors that are related to a neurochemical imbalance.

Identification of ADHD

Efforts in the research and treatment of ADHD have been hampered by the heterogeneity of the disorder as well as comorbidity with other diagnostic categories. Whalen and Henker (1991) point to the differences that exist in children who are identified as ADHD. When confronted with academic tasks, ADHD children may respond in very diverse ways. Some may be unable to control their impulses and focus attention on the instructions presented. One group of ADHD children might experience difficulty sustaining adequate focus and concentration to complete a task while others may lack the ability to organize the necessary cognitive skills or material objects to even begin the assignment. Distractibility resulting from extraneous stimuli may further impede progress in some ADHD children. Diversity may also be apparent in social interactions. In their review of studies in this area, Landau and Moore (1991) reported that ADHD children are often highly rejected by their peers and may experience deficits in the performance of social skills or in the production of appropriate responses in social situations. Thus, it is apparent that even within a group that has met the necessary criteria for diagnosis as ADHD, vast differences may exist.

Taking the identification process a step further, it can be seen that numerous problems have surfaced in attempts to distinguish between ADHD and both learning disabilities and conduct disorders. Barkley, DuPaul, and McMurray (1990) compared children with attention deficit disorder with hyperactivity to those without hyperactivity, to learning disabled children, and to a control group. Their findings revealed that children displaying attention deficit disorder with hyperactivity (ADD+H) were twice as likely to receive a diagnosis of oppositional defiant disorder as were children identified as having attention deficit disorder without hyperactivity (ADD-H). In addition, the ADD+H group was three times more likely to be diagnosed as having a conduct disorder. When academic placements were reviewed, the ADD+H children were more often placed in classes for the emotionally disturbed. The ADD-H children, on the other hand, were more often placed in classes for the learning disabled.

In a review of comorbidity patterns, Abikoff and Klein (1992) reported that according to the DSM-III criteria, 89% of the children who could receive the classification of conduct disorder (CD) could also be categorized as attention-deficit disorder with hyperactivity (ADDH) either at school or home. In addition, the majority of CD children without ADDH at present had a history of ADDH in the past. With respect to treatment, the authors question whether a disorder identified in isolation is representative of the same syndrome when it is found to exist with another disorder. There appears to be a lack of research evidence in the literature investigating differences in treatment effects for children with a comorbid disorder as opposed to a solitary diagnosis.

Modes of Treatment

Numerous interventions have been employed to address deficits observed in the behavioral, academic, and social functioning of children diagnosed as ADHD. The most popular modes of treatment will be reviewed.

Pharmacological approach. Psychostimulant medication is by far the most frequent treatment response to ADHD

(Gomez & Cole, 1991, O'Brien & Obrzut, 1986). The effect of psychostimulant medications is to elevate alertness or increase the arousal of the central nervous system (DuPaul, Barkley, & McMurray, 1991; McCall, 1989). The medications most frequently employed are methylphenidate (Ritalin), d-amphetamine (Dexedrine), and magnesium pemoline (Cylert) (Mercugliano, 1993). Of the psychostimulants in use, Ritalin represents 90% of the medication market (DuPaul & Barkley, 1990).

In a review of the effects of stimulant medication, DuPaul et al. (1991) reported positive outcomes in sustaining attention, control of impulsive behavior, academic performance, and social interactions. DuPaul and Rapport (1993) compared a group of 31 children diagnosed with Attention Deficit Disorder who were participating in a placebo controlled trial of MPH with 25 normal control children. All subjects in the experimental group received each of four doses of MPH in addition to a placebo following baseline assessment of academic and behavioral performance. Results indicated MPH significantly increased on-task attention, academic efficiency, and classroom conduct. Improvement was most noticeable when dosage levels were in the mid to high range. Further analyses revealed that on an individual level, approximately 75% of the children exhibited normalized functioning on the measures of classroom performance after receiving medication. As noted by the authors, 25% of the ADD children failed to show normal levels of classroom functioning despite the rigorously designed MPH trials.

To examine the effects of MPH on the impulsive responding tendency of ADHD children, Malone and Swanson (1993) compared 26 ADHD children with a control group of 14 non-ADHD children. A double-blind placebo-controlled design was employed with the ADHD group. Between-group comparisons were made for the ADHD-placebo group, ADHD-MPH group, and the control group. On a word matching task, the ADHD-placebo group made the most impulsive as well as regular errors. In addition, they had the fewest number of correct responses. The ADHD-MPH group along with the control group had more correct responses with fewer impulsive and regular errors. The performance of the control group was only slightly better than the MPH group.

Hypothesizing that the impulsive behavior associated with ADHD would result in greater levels of creative thinking, Funk, Chessare, Weaver, and Exley (1993) compared a group of ADHD boys with a control group. The ADHD group was assessed both on and off medication. The authors further predicted that medication in the form of Ritalin would depress creative functioning. Results were not supportive of either superior creativity for the ADHD group or decreased functioning due to medication.

Adding complexity to the issue of the effectiveness of stimulant medication is a study by Forness, Swanson, Cantwell, Guthrie, and Sena (1992). In their study of 71 ADHD children each receiving the four conditions of placebo, low, medium, or high doses of MPH, an attempt was made to assess positive response to medication. The authors determined that differences in effectiveness were noted depending on how one defined the response. If the goal was a reduction of the disruptive behavioral symptoms of ADHD, then favorable responses were reported at a level of 70% or greater. However, on tasks that involved academic skills or new learning, the rate of favorable response was only around 50%.

The effects of stimulant medication on learning and long term academic achievement have been difficult to establish. Swanson, Cantwell, Lerner, McBurnett, and Hanna (1991) proposed that one reason for this difficulty may be related to the dosage level of medication. A dosage that is high enough to control the behavioral symptoms of ADHD may have the adverse side effect of impairing learning. Furthermore, the positive effects of medication for some children may be hidden if both favorable and nonfavorable responders to drug therapy are grouped together. Differences in the effects of medication have also been documented for children with attention deficit disorder with and without hyperactivity (Barkley, DuPaul, & McMurray, 1991). ADHD children without hyperactivity respond favorably to low doses; whereas, moderate to high doses are most effective for those with hyperactivity.

Due to the widespread use of psychostimulant medication, concern has been expressed over possible side effects which may include insomnia, tics, reduced appetite, headaches, stomach aches, and suppression of height and weight gain (DuPaul et al., 1991; Gomez et al., 1991). In the first systematic evaluation of the side effects from methylphenidate, Barkley, McMurray, Edelbrock, and Robbins (1990) evaluated parent and teacher ratings on 83 ADHD children participating in a triple-blind, placebo-controlled, crossover evaluation of the psychostimulant. Their findings indicated that for a large percentage of the group, problems were noted with insomnia, tendency toward crying, irritability, anxiety, sadness, and staring even before the onset of the medication trials. Furthermore, less than half of the subjects exhibited an increase in side effects when on medication. Of the side effects that were experienced in moving from the placebo to the low and high dose conditions, a 37% to 41% increase was reported for insomnia and a 22% to 28% increase was noted for appetite suppression, the two most common side effects reported by parents. Stomach aches and headaches also increased in severity by 21% and 10 to 15%, respectively. In a similar vein, Ahmann, Waltonen, Olson, Theye, Van Erem, and La Plant (1993) reported increases in insomnia, appetite suppression, stomach ache, headache, and dizziness as a result of Ritalin treatment. In addition, high dose levels nearly doubled the incidence of decreased appetite as compared to low dose levels. The authors concluded that the number of side effects as a result of Ritalin therapy was small and limited.

In a review of medication treatment, Gomez and Cole (1991), noted the value of psychostimulant medication in improving the behavior and academic achievement of many children. Despite these positive results, they report that as many as 30% of treated children show no improvement. Side effect issues, which are for the most part minor, are for some children serious and result in discontinuation of drug treatment. Concern was also expressed that the use of medication might send a message to the child that external aids are needed to control behavior.

Behavior management. An alternative approach to medication therapy that has gained popularity is behavior management. The focus of this method is on an analysis of the environment in which the child exists and the use of contingency controls to alter behaviors. Age-appropriate reinforcers and punishments have been employed in a systematic manner to control such behaviors as activity level, attention to tasks, and social interactions to name a few (O'Brien & Obrzut, 1986; Wicks-Nelson & Israel, 1991).

Abramowitz and O'Leary (1991) reported on numerous studies that have investigated both the antecedents and consequences of behavior. From an historical perspective, they concluded that early efforts by educators to reduce extraneous stimuli in an attempt to decrease hyperactivity and distractibility have been abandoned due to a lack of research support. Other variables including size as well as the structure and design of tasks are antecedent conditions that warrant further investigation.

Investigations related to the efficacy of contingency management in treating ADHD were also considered by Abramowitz and O'Leary (1991). They concluded that the most effective course of action for this diagnostic group should include some form of response cost or negative consequence for inappropriate behavior. Praise alone was found to either have no impact or be significantly less effective than reprimands.

Parent training programs incorporating contingency management techniques have also been employed for ADHD children. One such program discussed by Anastopoulos and

Barkley (1990) involves a ten-step procedure that includes developing an understanding of the disorder and behavior management principles. Instructional techniques are aimed at improving the attending skills of parents and teaching more effective communication methods. Home token systems, time-out, and plans for handling inappropriate behavior are taught. Booster sessions to review and refine previously learned skills are also part of the program. Direct benefits from this approach include improvement of behavior in the targeted child as well as an increase in parental knowledge and skill. Indirect benefits observed through clinical experience with the families in the program included reduced stress, improvement in sibling behavior, and increased parent self-esteem.

One problem associated with the use of behavior therapy has been a lack of generalization to situations beyond the treatment setting. Without proper training, carry over effects are not likely. Furthermore, there does not appear to be enough evidence to assess the durability of training effects over time (Abramowitz & O'Leary, 1991; O'Brien & Obrzut, 1986; Wicks-Nelson & Israel, 1991).

Cognitive-behavioral interventions. These treatment methods are designed to help the child with self-regulation (Wicks-Nelson & Israel, 1991). Techniques may include self-monitoring which trains children to observe and record their behaviors. Another approach is self-reinforcement which allows children to give themselves points for appropriate behavior. Points can then be traded for reinforcements. Another technique is self-instruction which teaches children to talk to themselves in order to focus and stay on a task. Abikoff (1991) surveyed research from the last decade and found that despite its logical association with ADHD, cognitive training has not proven to be effective in the development of self-regulation skills for this clinical population. Kendall (1993) concluded that one difficulty in assessing the effectiveness of cognitive-behavioral strategies was the substantial difference in the form of treatment used across the various studies.

In summary of the various treatments utilized for the ADHD population, no one method emerges as a panacea for this very heterogenous group. Techniques that are effective for some children may have either no effect or adverse side-effects for others. Selected strategies may have a positive impact on behavior but limited impact on academic functioning. Because ADHD children may exhibit multiple problems, it is quite likely that multiple treatments may be necessary.

Biofeedback training. Research evidence strongly points to a neurological basis for the etiology of ADHD (Hynd et al., 1991; Anastopoulos & Barkley, 1988; Barkley, 1993). When this position is integrated with an examination of treatment methodologies that influence physiological functioning, the intuitive appeal of biofeedback becomes apparent. More specifically, electroencephalographic (EEG) biofeedback has garnered attention recently as a technique in the treatment of ADHD (Barkley, 1993).

Simply stated, EEG biofeedback involves the monitoring of various electrical activity patterns emitted by the brain (Blumenthal, 1985). The frequency of brain waves is measured in terms of cycles per second or hertz (Hz) (Graham, 1990). Various patterns have been identified and associated with subjective states. Theta (4-7 Hz) and alpha (8-12 Hz) frequencies have been associated with states of relaxation; whereas, Beta activity (greater than 14 Hz) is observed in alert, cognitively active conditions. Sensorimotor rhythm (SMR) is activity recorded in the 12-15 Hz range and corresponds to an absence of movement (Lubar, 1991).

EEG biofeedback has been employed in the treatment of such medical conditions as epilepsy. In a review of the clinical applications of biofeedback, Blumenthal (1985) noted that training to increase SMR activity has led to either a reduction or absence of seizure frequency in patients diagnosed with epilepsy. As was noted by the author, epilepsy is not a homogeneous condition.

Consequently, it is essential to match the type of seizure disorder to an appropriate treatment. For seizures associated with hyperactivity, EEG biofeedback may be the method of choice.

As an outgrowth of SMR training with high school and college age seizure patients in the 1970's, Lubar (1991) reported that an increase in attentiveness, concentration, and the ability to focus was noted. In an early work, Lubar and Shouse (1976) employed EEG biofeedback to train an 8 year, 11 month old child with hyperactivity on medication to increase SMR activity and decrease Theta activity. An ABA design was employed. Initially, behavioral and attentional improvements were noted. When the condition was reversed, a loss of the previous gains was observed. A reinstatement of the training condition restored the level of success previously achieved. As a final step, the child was removed from medication and was able to maintain the gains. Lubar (1991) noted that his initial research in this area led to the conclusion that the main effect of SMR training was to decrease motor activity. Less impact was noted with respect to attentional deficits.

Subsequent to these initial investigations, Lubar and Lubar (1984) described six case studies in which EEG biofeedback was employed for increasing SMR or Beta activity while at the same time inhibiting excessive Theta activity, gross motor, and muscle tension as reflected by the electromyograph (EMG) data. Following extensive biofeedback training ranging from ten to 27 months, all six children increased SMR and Beta activity levels while at the same time decreased gross motor movement, EMG, and Theta activity. Academic training was also incorporated in the treatment phase for each of the children. Both behavioral and academic improvements were noted for all participants based upon gains in achievement scores, grades, and teacher and school evaluations. Weaknesses expressed by the researchers included the combination of academic training and biofeedback as well as differences in treatment for each child which precluded statistical analyses. The fact that the case studies were conducted in a clinical setting involving fees was given as a rationale for the procedure employed.

A case study by Tansey and Bruner (1983) detailed EEG biofeedback treatment of a ten-year-old boy diagnosed as having Attention Deficit Disorder with Hyperactivity as well as a developmental reading disorder. Three sessions of EMG training were initially employed to reduce muscle tension. Twenty SMR biofeedback training sessions followed. Results included a reduction in tension levels and an increase in SMR levels. Parental reports revealed that behavioral problems had been reduced and academic gains had been made. It should be noted that the child undergoing treatment was also repeating the fourth grade.

In a subsequent study, Tansey (1984) continued EEG biofeedback training to increase SMR levels in six learning disabled boys. Each subject increased SMR activity over baseline recordings. In addition, all subjects exhibited an increase in their Full Scale I.Q. scores by at least one standard deviation. Similar results were obtained in a case study of eight learning disabled boys (Tansey, 1985).

Potashkin and Beckles (1990) compared three groups each consisting of six ADHD boys matched for age, I.Q., and race. One group received Ritalin as a treatment, a second group received biofeedback assisted relaxation training, and the third group served as a control with subjects playing a game with a research assistant. Results indicated that on a measure of muscle tension levels, only the biofeedback group significantly reduced muscle tension. All three groups exhibited improvements on teacher ratings of hyperactivity. Two parent rating scales were used with one recording improvement in all three groups and the other showing improvement for the biofeedback and control groups. Caution was voiced by the authors in interpreting parent ratings as they are often not a reliable assessment of hyperactivity. The authors suggest that results from the study indicate the value of biofeedback as an alternative to medication.

In a review of his more recent clinical work involving topographic brain mapping, Lubar (1991) found that compared to carefully matched controls, subjects diagnosed as ADD without hyperactivity or learning disabilities exhibited increased Theta activity and decreased Beta activity. These children also manifested greater increases in Theta and decreased Beta when presented with an academic task as compared to base line readings.

A critical review of the literature by Lee (1991) examined all available studies from 1970 to 1990 which employed biofeedback as a treatment for hyperactivity. Methodological flaws plagued most of the studies. Problems identified included small sample size, few control groups, and a lack of consistent guidelines for identifying a child as hyperactive. An analysis of the effectiveness of biofeedback was often confounded by the incorporation of other treatment modalities in the study. Many studies failed to use academic or social behaviors as dependent measures, thus making it difficult to reference applied settings. Follow-up of cases was often neglected; consequently, assessment of long-term benefits was impossible. In most of the available research, procedures for biofeedback training were not clearly delineated.

Barkley (1993) concluded that the case studies involving EEG biofeedback appear promising; however, studies to evaluate its effectiveness must be thorough, controlled, and subjected to peer review. Barkley's consideration of the available literature pointed to several issues that need to be addressed. The process for selection of subjects needs to be clarified so as to eliminate any bias. Proper diagnosis and classification of subjects must also be pursued. Many studies have not employed random assignment to treatment and control groups as part of their methodology. Rater bias may become a factor if evaluations are not blind to the treatment conditions experienced by the subjects. Studies to date have not revealed exactly what children are doing to alter their brian wave activity. To verify the initial promising results, Barkley stated that there is a need for well-controlled studies that employ random assignment to treatment and alternative therapy/placebo groups. Until studies demonstrate sound scientific methodology, results cannot be generalized.

Summary. In summary, ADHD refers to a heterogeneous group of subjects that often manifest significant problems with attention, impulsivity, and overactivity. The lack of a consistent, universally accepted definition of the disorder has hindered research, identification of children, and appropriate treatment methodologies. Although numerous theories have been proposed to identify the etiology of ADHD, the most widely accepted explanation to date points to central nervous system dysfunction. With this theoretical perspective in mind, intervention techniques that affect neurological functioning have emerged as the treatments of choice. The most frequently employed intervention is the pharmacological use of psychostimulant medication of which Ritalin is the most frequently prescribed. While medications have been successful, not all children experience a positive response. A significant number of children either derive no benefit or must discontinue use due to adverse side effects. Other methodologies such as behavior management and cognitive behavioral interventions have not provided sufficient results. Recently, EEG biofeedback has received a significant amount of attention as a treatment for ADHD. The technique involves the modification of brain wave patterns to resemble those of non-ADHD children. Success has been reported in reducing the symptoms of impulsivity, hyperactivity, and inattention. Although results have been promising, methodological flaws have hindered the validity and generalizability of results.

Description of the Current Study

The purpose of this study was to examine EEG biofeedback training and its relationship to ADHD. Efforts were made to clearly identify the subjects as having a diagnosis of ADHD and to ensure that other conditions such as conduct disorders or learning disabilities were not present. Methodological flaws identified in the literature (Barkley, 1993; Lee, 1991) were addressed by incorporating random assignment to treatment and control groups and utilizing objective pre- and post-test measures of academic and behavioral changes. No other intervention technique was incorporated in the design so as to prevent confounding of the results of EEG biofeedback training.

Changes in brain wave patterns were examined particularly with regard to Theta, Beta, and EMG activity. A consistent protocol was maintained for all subjects during the training in order to adequately assess the impact of treatment. Results from each biofeedback session were saved onto the computer program so that an individual profile for each subject could be prepared at the conclusion of the study.

The computer software employed for the EEG biofeedback training provided reinforcement in a visual only, auditory only, or combined visual and auditory format. Reinforcement in the form of a numerical score was given for brain wave patterns that had Theta and EMG activity below baseline levels and Beta activity above baseline. Access to this information allowed for an assessment of the efficacy of one modality over another.

During the initial phase of the study, a measure of cognitive and academic functioning was secured for both the experimental and control groups. At the conclusion of the biofeedback training for the experimental group, all subjects underwent a re-evaluation of cognitive and academic skills. This information aided in the evaluation of EEG biofeedback as a remediation technique for the academic deficits encountered by ADHD children.

Behavioral measures for the two groups were obtained prior to the treatment phase, at the midpoint of the study, and at the conclusion. Assessments were objective in nature and not anecdotal reports. Results allowed for an analysis of the relationship between biofeedback training and the behavioral problems that are characteristic of a child with this diagnosis.

Hypotheses

The following hypotheses with regard to EEG biofeedback and ADHD were made:

Changes in traditional biofeedback measures

1. There will be significant changes in EEG/EMG biofeedback thresholds (increased Beta, decreased Theta, and decreased EMG) across the total number of sessions for the ADHD experimental group.
2. There will be significant differences between

EEG/EMG biofeedback thresholds, (Beta, Theta, and EMG) across the four protocol conditions (baseline, reading, visual baseline, and listening) for the ADHD experimental group.

3. There will be a significant interaction between the total number of sessions and the four protocol conditions for the EEG/EMG biofeedback threshold measures (Beta, Theta, and EMG) for the ADHD experimental group.
4. There will be significant changes in EEG/EMG biofeedback amplitude values (increased Beta, decreased Theta, and decreased EMG) across the total number of sessions for the ADHD experimental group.
5. There will be significant differences between EEG/EMG biofeedback amplitude values (Beta, Theta, an EMG) across the four conditions (baseline, reading, visual baseline, and listening) for the ADHD experimental group.
6. There will be a significant interaction between the total number of sessions and the four protocol conditions for the EEG/EMG biofeedback amplitude measures (Beta, Theta, and EMG) for the ADHD experimental group.

<u>Changes in non-traditional biofeedback measures</u>

7. There will be a significant increase in the number of goals obtained across the total number of sessions for the ADHD experimental group.

<u>Changes in behavioral data</u>

8. ADHD children who receive EEG biofeedback training will have significantly higher post-test minus pre- test difference scores related to cognitive functioning and lower post-test scores, related to depression as compared to the ADHD control group.
9. ADHD children who receive EEG biofeedback training will have significantly higher post-test scores related to academic functioning (reading, math, and written language) than the ADHD control group.
10. ADHD children who receive EEG biofeedback training will have significantly less impairment on measures of parental reports of behavior (inattention, impulsivity, and hyperactivity) as compared to the ADHD control group.

Chapter III

Methodology

This chapter is devoted to a discussion of the methodological issues involved in the completion of this study. Attention will be given to a description of the subjects and to the screening instruments employed to assist in the accurate identification of participants. The cognitive, academic, and behavioral assessments utilized in the pre- and post-test analysis will be reviewed. Topographic brain mapping and the EEG biofeedback equipment employed in the research will also be described. Finally, the procedures implemented during data collection will be delineated.

Subjects

A letter describing the research study was mailed to the parents of all children in grades three, four, and five of two elementary schools in a suburban public school district of North Central Texas (see Appendix A). Inquiries were reviewed, and information was given about the long-term commitment required in the biofeedback study.

Potential subjects were screened with a variety of instruments to ensure proper identification. Screening instruments included the Attention Deficit Disorders

Evaluation Scale (ADDES)-Home Version, the Attention Deficit Disorder Evaluation Scale (ADDES)-School Version, the Child Behavior Checklist (both parent and teacher version), the Conners Parent Rating Scale-Revised, and the Children's Depression Inventory (CDI). The research spanned periods of time in which the subjects were in school, out of school for summer vacation, and then back in school again with a different teacher. Some of the subjects were not identified until the summer months when teacher input was not available. As a result, not all subjects were screened with the same variety of instruments. As the research progressed, it became difficult to identify subjects who were willing to commit to 25 hours of biofeedback training as well as the extensive testing involved. The subjects finally identified for participation in the study were all previously diagnosed as ADHD by their physicians and were positive responders to Ritalin. The children selected for participation in the study were six boys 9 to 12 years of age. All of the subjects were free of such co-existing conditions as conduct disorders and learning disabilities as reported by the parents. The study was approved by the Human Subjects Review Committee at Texas Woman's University. Informed Consent (see Appendix B) was provided, and parent permission was secured for each boy participating in the study. During the course of the study, the subjects were not involved in any other intervention strategy or academic remediation. All of the boys in the research were positive responders to Ritalin. However, all subjects discontinued their medication during the evaluation procedures, the biofeedback training, and the brain mapping. Parents of children who did not meet criteria for inclusion in the study were given feedback concerning the results of the screening instruments as well as suggestions for academic and behavioral interventions.

The six research subjects were evaluated with the Woodcock-Johnson Revised Tests of Cognitive Ability, the Woodcock-Johnson Tests of Achievement, the CDI, and the ADDES-Home Version. Topographic brain mapping was also employed. A review of all the instruments employed during the course of the study will follow.

Instruments

Attention Deficit Disorder Evaluation Scale (ADDES)-Home Version. The parents of each child participating in the study completed the ADDES-Home Version (McCarney, 1989a). The ADDES-Home Version is a forty-six item behavior rating scale designed to assess males and females, 4 to 20 years of age. The instrument is composed of three subscales which address the inattentive, impulsive, and hyperactive behaviors that must be considered when a diagnosis of ADHD is made. Parents are asked to rate a child's behavior on a five-point scale ranging from "does not engage in the behavior" to "one to several times per hour". Responses to test items can be compared to those for children of the same age and sex.

As noted in the technical manual (McCarney, 1989a), a test-retest reliability study involving 148 children and an assessment interval of thirty days yielded reliability coefficients of .91, .90, and .92 for the inattentive, impulsive, and hyperactive scales, respectively. An inter-rater reliability study yielded an average correlation of .82 across all age levels. Internal consistency of the ADDES-Home Version was assessed through the use of the Kuder-Richardson 20 formula. All three subscales exceeded values of .93.

A criterion-related validity study compared the ADDES-Home Version to the Conners Parent Rating Scale-48, On all three subscales, coefficients exceeded the .01 confidence level.

Attention Deficit Disorders Evaluation Scale (ADDES)-School Version. For some of the subjects, teachers provided ratings of behavior in the school setting by completing the ADDES-School Version (McCarney, 1989b). The sixty-item instrument is divided into the same subscales of inattentive, impulsive, and hyperactive as identified in the Home Version. The same five-point rating scale is utilized. As in the Home Version, responses can be compared to children of the same age and sex.

As noted in the technical manual (McCarney, 1989b), test-retest reliability coefficients were .97, .89, and .92 for the inattentive, impulsive, and hyperactive subscales, respectively. Ratings of 481 students over a thirty day interval were assessed in this reliability study. Inter-rater reliability was assessed by comparing the ratings of 462 students by 237 pairs of educators. The average correlation was .85. Employing the Kuder-Richardson 20 formula to obtain an estimate of internal consistency reliability, McCarney noted that all three subscales exceeded values of .90. A criterion related validity study comparing the ADDES-School Version with the Conners Teacher Rating Scale-Revised yielded coefficients which exceeded the .001 level of significance on all three subscales.

Child Behavior Checklist (CBCL/4-16). The CBCL for the 4-16 age group (Achenbach & Edelbrock, 1983) was one of the instruments employed for some children during the screening phase. The CBCL/4-16 is a 138 item instrument that asks parents to rate child behaviors on a three point scale ranging from "not true", "somewhat or sometimes true" to "very true or often true". The instrument is designed to assess the behavioral problems and skills of children as compared to other children of the same age and sex. Twenty items on the test assess Social Competence for which scores are obtained in three areas: Activities, Social, and School. The Behavior Problems Scale is composed of the remaining 118 items.

The CBCL Teacher's Report Form (TRF) (Achenbach & Edelbrock, 1986) was used for some children to obtain the teacher's views about the child's problems and adaptive functioning in a standardized format. The TRF is composed of an Adaptive Functioning Scale and a Behavior Problems Scale. Items are rated on the same three-point scale as described for the parent form.

Conners Parent Rating Scale-Revised (CPRS-R). The CPRS-R (Goyette, Conners, & Ulrich, 1978) was used for some children as an additional measure during the screening phase of the study to accurately identify the target population. As noted in the manual, agreement of ratings on this instrument between mothers and fathers ranged from .46 to .57. Lower agreement was noticed between parent and teacher ratings which ranged from .33 to .45. The factors assessed on this scale include Conduct Problems, Learning Problems, Psychosomatic, Impulsive-Hyperactive, and Anxiety. No test-retest reliability data were available. Barkley (1990) suggests that this version of the instrument may be useful in the evaluation of treatment effects.

Children's Depression Inventory (CDI). Each child was asked to complete the CDI (Kovacs, 1981) to obtain a self-rating of depression. The CDI was employed to determine the presence of depression as a co-morbid condition. The instrument has 27 items and is appropriate for ages eight to seventeen. The reading level is estimated to be at a first grade level; thus, children and adolescents are able to complete the task without assistance.

Woodcock-Johnson Revised Tests of Cognitive Ability (WJ-RC). Volunteers for the research project were given the WJ-RC (Woodcock & Johnson, 1989) which is a comprehensive measure of cognitive functioning appropriate for individuals from preschool to adulthood. The WJ-RC consists of 14 subtests with two tests each for seven cognitive cluster scores. The cluster scores include long-term retrieval, short-term memory, processing speed, auditory processing, visual processing, comprehension-knowledge, and fluid reasoning. In addition, a Broad Cognitive Ability Score is obtained. Reliability and validity information for the Woodcock-Johnson Psycho-Educational Battery - Revised (WJ-R) which includes both the cognitive and achievement portions of the test was based upon a sample of 593 subjects ranging in age from five to 95 (McGrew, Werder, & Woodcock, 1991). Sampling times ranged from one to 17 months. For the cognitive cluster, test-retest correlations ranged from .83 to .95. For the achievement scores, the range was from .93 to .97.

As reported in the technical manual (McGrew, Wender, & Woodcock, 1991), concurrent validity studies revealed a correlation of .80 between the comprehension knowledge cluster and the K-ABC achievement scale. A correlation of .82 was reported between the comprehension knowledge cluster and the verbal comprehension factor from the Wechsler scale.

Woodcock-Johnson Tests of Achievement (WJ-A). Subjects were also given the achievement portion of the Woodcock-Johnson Battery (Woodcock & Johnson, 1989). Data was used to obtain a current estimate of the child's academic functioning. Ten subtests compose the achievement portion of the battery and include letter-word identification, word attack, passage comprehension, calculation, applied problems, dictation, proofing, science, social studies, and humanities.

By comparing a child's performance on the cognitive and achievement portions of the test battery, a determination was made concerning any learning disabilities coexisting with the ADHD diagnosis. Children who had achievement levels significantly below cognitive functioning would not be included in the biofeedback study.

Topographic brain mapping. Those children who met the criteria for a diagnosis of ADHD were brain mapped using a 20 channel EEG data collection system developed by BioLogic Systems Corporation (Mundelein, IL.). This equipment allows for a comprehensive analysis of brain wave patterns.

Capscan Virtual EEG System. EEG biofeedback training utilized a computer software package and a two-channel EEG/EMG device called Capscan produced by Expanded Technologies Incorporated (Shreveport, LA.). This system provides an assessment of Theta, EMG, and Beta brain wave patterns. Visual feedback in the form of colored lights, auditory feedback in the form of tones, and a combination of both formats was utilized to provide the subject with information about brain wave patterns. Reinforcement in the form of a numerical score was provided when the subject achieved a goal.

Procedures

The six boys selected for participation in the study were evaluated with the Woodcock-Johnson battery to evaluate cognitive and academic functioning, the CDI, and the ADDES-Home Version. All tests were administered and scored by the author of the current study. The author holds a Master's Degree in Psychology with eight years of employment as a school psychologist. Evaluation profiles for each subject were reviewed, and subjects were matched and paired according to I.Q. and age. Subjects from each pair were then randomly assigned to either the EEG biofeedback training group or a control group. Brain wave patterns for all six subjects were assessed with topographic brain mapping equipment. Measurement of brain wave activity was conducted as the subjects sat in a relaxed state with eyes open and then eyes closed. Subjects then completed a sustained attention task called Letter Pairs (Miller, 1990).

Utilizing the Capscan Virtual EEG software and hardware, baseline levels of Theta, EMG, and Beta wave activity were established for the experimental group during an initial session of ten trials. A mean baseline level was established and employed as the benchmark for an evaluation of change in brain wave activity.

Biofeedback training sessions were conducted over a two and one-half month period of time with four sessions scheduled per week. Although illness and personal commitment resulted in fluctuations of scheduling, all subjects received a total of 25 biofeedback sessions. Location of the session and evaluator were held constant across the treatment phase of the study. The author of the research administered the biofeedback training. The location of the research was a quiet room within the researcher's home that was free of distraction. At the beginning of each session, subjects received an alcohol prep at the electrode sites. An electrocap was used as well as two ear-reference electrodes. Prior to initiation of each treatment, sensor impedance levels were checked using an impedance meter (EEG Impedance Meter Model 230, GDR Research Company). This procedure assisted with accurate data collection. Impedance levels of 10 K ohms or less were considered acceptable.

The protocol for each biofeedback session began with a reading of automatic threshold values for Theta, EMG, and Beta brain wave patterns. Although the values were recorded, the threshold levels were set based upon the averages obtained in the initial session of 10 trials. After a subject's average threshold values were entered in the program, the session proceeded with five minutes of biofeedback with both visual and auditory feedback, five minutes with auditory only feedback while reading from a book of the subject's choice, five minutes of visual-only feedback, and five minutes of both auditory and visual feedback while engaged in a listening task. The listening task consisted of the researcher reading from the book chosen by the subject.

When subjects reached their established criteria for reducing Theta and EMG levels as well as increasing Beta levels, feedback was given in the form of a visual display and/or a harmonious tone. The visual display on the computer screen alternated between a presentation of dials or meters. The dials resembled a speedometer and the meters were similar to a thermometer. A counter incorporated within the software was automatically increased when criteria were met indicating that the subject had achieved a goal. During the first week of training, verbal reinforcement was also given to ensure that the subject understood the task as well as the reward procedure. At the end of each segment of the protocol, the number of goals obtained by the subject was recorded. At approximately the half-way point of the experiment, parents of all six subjects were asked to complete the ADDES-Home Version in order to assess any changes in behavior. At the conclusion of the training, subjects in both the experimental and control groups underwent topographic brain mapping, cognitive and academic assessment with the Woodcock-Johnson Battery, and behavioral evaluations with the ADDES-Home Version, and the CDI.

Chapter IV

Results

Each of the stated research hypotheses was examined through statistical analyses of the data using the Systat (1992) computer program. Traditional biofeedback data that were examined for change among the experimental subjects included the threshold values and amplitude changes recorded at the end of each protocol condition within each biofeedback session. Amplitude refers to microvolt values which measure the amount of brain electrical activity produced within each of the bands (Theta, EMG, Beta) at any given time. Non-traditional measures of biofeedback progress were also analyzed. These non-traditional measures were based upon the goals obtained for each of the four parts of the biofeedback session. Subjects increased their score each time they were able to produce brain wave patterns that exceeded the previously identified threshold values. Subjects were reinforced for increasing Beta wave activity while at the same time reducing Theta and EMG activity. Changes in behavioral data for the experimental and control groups were assessed by an analysis of pre- and post-test scores on the Woodcock-Johnson Battery, the Attention Deficit Disorder Evaluation Scale-Home Version, and the Children's Depression Inventory.

Changes in traditional biofeedback measures

Hypothesis number 1 states that there would be significant changes in EEG/EMG biofeedback thresholds across the total number of sessions for the ADHD experimental group. To explore changes in threshold values for Beta, Theta, and EMG brain wave activity, a 25 x 4 (sessions x conditions) MANOVA was conducted to determine the significance of sessions, condition, and an interaction on threshold percentages. There was a significant main effect for session. The Wilks'-Lambda for sessions was noted (F (72, 583) = 1.97, p = <.001). Separate univariate F tests for sessions revealed that Beta and EMG percentages accounted for the significant difference (see Table 1). Hypothesis 1 was confirmed.

Table 1

Univariate F-Tests for EEG/EMG Threshold Percentages for 25 Sessions

Variable	SS	DF	MS	F	p
Theta	9655.08	24	402.30	1.12	.33
Beta	19926.63	24	830.28	2.56	<.001
EMG	7574.40	24	315.60	2.15	.002

Hypothesis 2 predicted significant differences between EEG/EMG biofeedback thresholds across the four protocol conditions. This hypothesis was supported. The main effect for condition resulted in a significant Wilks'-Lambda (F (9, 474) = 3.33, p = .001). Univariate F tests for condition revealed that Theta percentage accounted for the significant difference (see Table 2).

Table 2

Univariate F-Tests for EEG/EMG Threshold Percentages for Protocol Conditions

Variable	SS	DF	DS	F	p
Theta	3625.30	3	1208.43	3.35	.02
Beta	375.60	3	125.20	0.39	.76
EMG	612.88	3	204.29	1.39	.25

Hypothesis 3 stated that there would be a significant interaction between the total number of sessions and the four protocol conditions for the EEG/EMG biofeedback threshold measures. This hypothesis was not supported by the data.

Observations by the author during the course of the biofeedback training seemed to indicate decreased interest of the subjects as the sessions progressed. To explore this possibility different segments of the training were analyzed. These analyses included sessions 1-20 and 1-15. Also, sessions one through twenty were divided in half with comparisons made between the first half and the second half concerning threshold changes. The last five sessions were dropped from the exploratory analyses because the subjects returned to school where increased demands were placed on time and attention levels. A 20 x 4 (sessions x conditions) MANOVA was completed to assess the effects of the first twenty sessions on threshold percentages. There was a significant main effect for sessions. The Wilks'-Lambda for sessions was reported (F (57, 471) = 1.97, p = <.001). Univariate tests were examined. Threshold percentages for Beta and EMG accounted for the significant difference for sessions 1-20 (see Table 3).

Table 3

Univariate F-Tests for EEG/EMG Threshold Percentages for Sessions 1-20

Variable	SS	DF	MS	F	p
Theta	6784.91	19	357.10	1.11	.35
Beta	15480.80	19	814.78	2.77	<.001
EMG	6308.51	19	332.03	2.40	.002

For the 20 x 4 (sessions x conditions) MANOVA, a significant main effect for condition was observed. A significant Wilks'-Lambda was noted (F (9, 384) = 2.74, p = .004). Although there was a multivariate significant difference for the main effect of condition, the univariate F tests revealed that no one dependent variable accounted for the difference.

The first twenty sessions were examined for an interaction between sessions and conditions on threshold value. No significant interaction was found. To further assess changes in subject interest level, the first fifteen sessions were examined for changes in threshold values. A 15 x 4 (sessions x conditions) MANOVA was used to test for the effect of fifteen sessions on threshold values. There was a significant main effect for sessions. The Wilks'-Lambda for sessions was noted (F (42, 350) = 1.69, p = .01). Univariate F tests revealed Beta and EMG percentages accounted for the significant difference in sessions 1-15 (see Table 4).

Table 4

Univariate F-Tests for EEG/EMG Threshold Values for Sessions 1-15

Variable	SS	DF	MS	F	p
Theta	4842.43	14	345.89	1.14	.33
Beta	7770.55	14	555.04	2.08	.02
EMG	5172.49	14	369.46	2.52	.004

The effect of protocol conditions was also evaluated for the first fifteen sessions. A significant main effect for condition was noted. A significant Wilks'-Lambda was observed (F (9, 287) = 1.96, p = .04). Although there was a multivariate significant difference for the main effect of condition, the univariate F tests revealed no one dependent variable accounted for the difference.

Sessions 1-15 were examined for an interaction between sessions and conditions on threshold values. No significant interaction was found.

Additional statistical exploration was aimed at assessing the impact of the first half of the biofeedback sessions (1-10) versus the second half of the biofeedback sessions (11-20) on threshold values. A 2 x 4 (Part 1-sessions 1-10 versus Part 2-sessions 11-20) x (conditions) MANOVA was used for the analysis. A significant main effect for part was noted. A Wilks'-Lambda was reported (F (3, 230) = 10.38, p = <.001). Separate univariate tests revealed that Beta percentage accounted for the difference in part (see Table 5). In Part 1 (Sessions 1-10), subjects had Beta levels above threshold 26.37% of the time. During Part 2 (sessions 11-20), subjects were above threshold for Beta 33.40% of the time.

Table 5

Univariate F-Tests for EEG/EMG Threshold Values for Sessions 1-10 Verses Sessions 11-20

Variable	SS	df	MS	F	p
Theta	1.25	1	1.25	0.01	.95
Beta	2966.52	1	2966.52	10.31	.002
EMG	68.17	1	68.17	0.48	.49

A significant main effect for conditions was noted. A significant Wilks'-Lambda was identified (F (9, 559) = 3.12, p = .001). Univariate F tests revealed that no one dependent variable accounted for the difference.

The interaction between protocol conditions and session part on threshold values were examined. No significant interaction was identified.

Hypotheses 4 through 6 evaluated changes in Fast Fourier Transformation (FFT) amplitudes. Brain wave activity measured in amplitudes may be broken down into its various components in a manner similar to the way a prism separates white light into different colors. In this research study, Theta, EMG, and Beta amplitudes were considered for analysis. A 25 x 4 (sessions x conditions) MANOVA was conducted to assess the impact on the EEG/EMG amplitude values.

Hypothesis 4 predicted that there would be changes in EEG/EMG biofeedback amplitude values across the total number of sessions. This hypothesis was not supported. A Wilks'-Lambda multivariate analysis for session was not significant (F (72, 583) = 1.30, p = .06).

Hypothesis 5 stated that there would be significant differences between EEG/EMG biofeedback amplitude values across the four conditions. The main effect for condition resulted in a significant Wilks'-Lambda (F (9, 474) = 2.26, p = .02). Although there was a significant main effect, no one dependent variable accounted for the difference.

Hypothesis 6 predicted a significant interaction between the total number of sessions and the protocol conditions for the EEG/EMG biofeedback amplitude measures. This hypothesis was not supported by the data.

As with the threshold values, different segments of the biofeedback training sessions were analyzed to account for any declining interest that may have occurred. In an exploratory analysis of the first twenty sessions, a 20 x 4 (sessions x conditions) MANOVA was used to test for changes in amplitude values. There was a significant main effect for sessions. A Wilks'-Lambda for sessions was observed (F (57, 471) = 1.60, p = .01). Univariate F-tests indicated that EMG amplitude accounted for the difference for sessions 1-20 (see Table 6).

Table 6

Univariate F-Tests for EEG/EMG Amplitudes for Sessions 1-20

Variable	SS	DF	MS	F	p
Theta	1721.90	19	90.63	1.35	.16
Beta	246.54	19	12.98	1.49	.10
EMG	377.65	19	19.88	1.94	.01

No significant main effect for condition was noted (F (9, 384) = 1.72, p = .08). No significant interaction was found between sessions and conditions for session 1-20 on amplitude values (F (171, 474) = 0.44, p = 1.00).

The number of sessions was reduced to fifteen and a 15 x 4 (sessions x conditions) MANOVA was conducted. A significant Wilks'-Lambda for session was observed (F (42, 350) = 1.65, p = .01). Separate univariate tests indicated that both EMG and Beta amplitude values accounted for the significance in sessions 1-15 (see Table 7).

Table 7

Univariate F-Tests for EEG/EMG Amplitudes for Sessions 1-15

Variable	SS	DF	MS	F	p
Theta	1581.26	14	112.95	1.59	.09
Beta	188.10	14	13.44	1.88	.04
EMG	330.32	14	23.60	2.09	.02

No significant impact was found for either the effect of protocol conditions alone (F (9, 287) = .97, p = .47) or for an interaction effect of condition and session (F (126, 354) = .43, p = 1.00).

To explore for a difference between the first half of the biofeedback training and the second half, a 2 x 4 (Part 1 - sessions 1-10 versus Part 2 - sessions 11-20 x conditions) MANOVA was employed to test for significant differences between sessions one through ten and sessions eleven through 20. A significant Wilks'-Lambda was noted for the main effect of session part (F (3, 230) = 6.15, p = <.001). Univariate tests revealed that Theta amplitudes accounted for the difference in part (see Table 8). In Part 1 (sessions 1-10), subjects had a mean Theta amplitude value of 22.72. In Part 2 (sessions 11-20), the mean amplitude value was 20.03.

Table 8

Univariate F-Tests for EEG/EMG Amplitude for Sessions 1-10 Versus Sessions 11-20

Variable	*SS*	DF	*MS*	*F*	*p*
Theta	433.76	1	433.76	7.26	.01
Beta	4.13	1	4.13	0.53	.47
EMG	9.56	1	9.56	1.02	.32

No significant differences were noted when the effect of protocol condition was tested (F (9, 559) = 1.72, p = .08). In addition, no interaction effect was noted when the protocol condition and session grouping were analyzed (F (9, 559) = 0.23, p = 0.99).

Changes in non-traditional biofeedback measures

The software implemented in the research study allowed for an analysis of non-traditional measures of biofeedback progress. Within each of the four protocol conditions, subjects could earn a goal each time Beta levels were above threshold values while at the same time, Theta and EMG levels were below threshold values. Hypothesis 7 stated that there would be a significant increase in the number of goals obtained across the total number of sessions. A Hotelling's T^2 was used to assess changes in the number of goals achieved in each of the four conditions across the twenty-five sessions. No significant differences were noted (*F* (96, 182) = 1.07, *p* = .35). A Hotelling's T^2 was also employed to explore the impact of the first group of ten sessions compared to the second group of ten sessions on goals obtained. A significant Hotelling's T^2 was noted (*F* (4, 55 = 3.40, *p* = .02). Separate univariate tests revealed that the conditions of baseline, reading and visual baseline accounted for the difference (see Table 9).

Table 9

Univariate F Tests for Goals Obtained in Protocol Sessions Comparing Sessions 1-10 with Sessions 11-20

Variable	SS	DF	MS	F	p
Base	50112.60	1	50112.60	5.29	.03
Read	157491.27	1	157491.27	12.97	.001
Visual Base	99796.82	1	99796.82	5.20	.03
Listening	80300.42	1	80300.42	2.74	.10

In Part 1 (sessions 1-10) the mean number of goals for the condition of baseline was 150.03, the mean for reading was 140.97, and 184.33 for visual baseline. In Part 2 (sessions 11-20), the mean number of goals for baseline was 207.83, the mean for reading was 243.43, and 265.90 for visual baseline.

Changes in behavioral data

The experimental design of the study allowed for a comparison between the subjects who received biofeedback training and the control groups. Cognitive functioning along with an index for depression were two areas examined for change. Hypothesis 8 stated that ADHD children who received EEG biofeedback training would have significantly higher post-test scores related to cognitive functioning and lower post-test scores related to depression as compared to the ADHD control group. Post-test Woodcock-Johnson-Revised Broad Cognitive Ability Scores and Children's Depression Inventory total scores were subtracted form the pre-test measures. A Hotelling's T^2 revealed no significant differences between the post-test minus pre-test difference scores (F (2, 3) = .22, p = .82) for the two groups.

Hypothesis 9 predicted higher post-test scores related to academic functioning for subjects who received biofeedback training compared to a control group. To test for changes in academic achievement for the experimental and control groups, the Woodcock-Johnson-Revised Tests of Achievement were administered. Scores in the areas of reading, math, and written language were analyzed to assess for changes that may have occurred as a result of the biofeedback intervention. A separate Hotelling's T^2 was conducted with no significant differences found between the two groups on the post-test minus pre-test difference scores (F (3, 2) = 8.87, p = .10).

Hypothesis 10 predicted that subjects who received EEG biofeedback training would have significantly less impairment on behavioral measures as compared to an ADHD control group. Behavioral variables associated with a diagnosis of ADHD were evaluated for change through the use of the Attention Deficit Disorders Evaluation Scale-Home Version. Comparisons were made between the experimental and control groups at the midpoint of the biofeedback training. A Hotelling's T^2 was completed with no significant difference found between the two groups on the midpoint minus pre-test difference scores (F (3, 2) = 2.42, p = .31). A Hotelling's T^2 was also used to assess differences between the two groups that might have occurred from the midpoint to the end of the intervention. No significant differences were found on the post-test minus midpoint difference scores (F (3, 2) = 3.95, p = .21). A Hotelling's T^2 was also utilized to assess for pre- and post-invention differences between the two groups. No significant differences were observed on the post-test minus pre-test difference scores (F (3, 2) = .49, p = .73).

In summary, traditional measures of biofeedback training were the only areas to show significant change. Specifically, increases in Beta threshold percentages and decreases in EMG threshold percentages were found early in the training process. Decreases in Theta percentages were not found. Analyses of amplitude values revealed increases in Beta and decreases in EMG early in the training but not in later phases. Decreases in Theta were evident only in the first half of the training. Of the protocol conditions utilized in the current study, no one condition emerged as superior.

Behavioral data was also analyzed for change. No significant differences were found between the experimental group and the control group on measures of cognitive, academic, or behavioral functioning.

Chapter V

Discussion

The primary focus of this research was to investigate the efficacy of EEG biofeedback as an intervention technique for the treatment of Attention Deficit/Hyperactivity Disorder. Based upon the work of Lubar and Lubar (1984), there has been increased interest in the use of biofeedback as a treatment for ADHD. However, limited research is available to support the use of this expensive, time-consuming procedure. In the current research, volunteers were sought for the experimental study and were screened with a variety of instruments to verify the ADHD diagnosis. The six subjects selected for participation in the study received extensive evaluation in cognitive and achievement functioning. Ratings of behavior obtained from the parents addressed the areas of impulsivity, inattention, and hyperactivity. A self-report related to depression was also obtained from each subject. The subjects were matched and paired according to age and cognitive functioning. Random assignment was made to either the experimental or the control group. Subjects assigned to the experimental group received twenty-five biofeedback training sessions. The control group received no such training. At the conclusion of the intervention, all subjects were evaluated for change in the areas of cognitive, achievement, and behavioral functioning.

The data collected during the course of this investigation were analyzed and used to test the ten stated hypotheses. This section of the research study will be devoted to a discussion of the results obtained. Traditional biofeedback data will be reviewed along with data involving intellectual and behavioral variables. After the findings of this study are presented, a critical review of the limitations of the study will be conducted. Future research ideas will be discussed, and the impact of experimental interventions on the ADHD population will be considered.

Changes in traditional biofeedback measures

Hypotheses 1 through 6 predicted changes in brain wave activity resulting from biofeedback training. Threshold levels and amplitude values were two traditional biofeedback measures used to assess change. Threshold levels were recorded for each of the experimental subjects at the beginning of each biofeedback session. This investigation specifically focused on Beta, Theta, and EMG brain wave patterns. Lubar's (1991) clinical work in this area found that ADHD subjects had higher levels of Theta activity and lower levels of Beta activity when compared to a control group. Initial investigations by Lubar and Lubar (1984) revealed increased Beta and decreased Theta after biofeedback training. The current study found significant increases in Beta but did not reproduce the significant decreases in Theta. The significant increases in Beta were present across all 25 sessions, the first 20 sessions, and the first 15 sessions. This finding suggests that the increases in Beta are obtained after a relatively short period of biofeedback training. Little research evidence is available to support the optimal number of sessions required to achieve significant increases in Beta. However, these findings suggest that Beta increases may be found in as few as 15 sessions.

The current research also found significant decreases in EMG after biofeedback training. The EMG decreases were found after all 25 sessions, after 20 sessions, and after 15 sessions. EMG activity is related to overt signs of hyperactivity. These results suggest that the experimental subjects were able to inhibit hyperactive behaviors. From an electophysiological perspective, decreases in overt signs of hyperactivity were noted; however, these did not translate into behavioral measures as assessed by the parents. It may be that the instruments employed to detect behavior change are not sensitive to small degrees of improvement. Behavior changes may also be of short duration and not present hours after the session is over.

Changes in Theta were found when all 25 sessions were examined across the four protocol conditions. Any differences in Theta were eliminated when exploratory analyses looked at the impact of fewer sessions. The last five sessions were unique in that the subjects had returned to school. The impact of this change in routine and cognitive stimulation may have accounted for the difference. This finding should be discounted because no significant differences emerged when fewer sessions were examined. For this given population, it did not seem that the protocol conditions employing visual and/or auditory feedback made any significant difference in the traditional biofeedback measures investigated. The different conditions employed within one session may have served as a distraction. Protocol conditions might be evaluated more efficiently if only one mode is employed during a session.

Amplitude values were another traditional biofeedback measure analyzed in the study. Analyses assessed the impact of increasing numbers of sessions on amplitude values. It appeared that the greatest impact occurred during the first 15 sessions in terms of increasing Beta and decreasing EMG. The significance of Beta dropped out when 20 sessions were examined. There were not significant differences at all when 25 sessions were considered with respect to Theta amplitudes, the only significant effect that emerged was when the first ten sessions were compared to the second ten. This adds further credence to the notion that maximum changes occur early on in the training process. The significance of this finding has dramatic implications for consumers. Biofeedback training is very costly. If the number of sessions can be reduced, parents can save money and time.

An assessment of the effect of the protocol conditions on amplitude values indicated no real differences. The data suggest that for this given population there was no advantage to the different types of feedback offered during the biofeedback training. As noted earlier, perhaps providing only one type of feedback per session would be a more efficient way of assessing the effectiveness of a condition.

Changes in non-traditional biofeedback measures

Goals could be scored within each condition provided the criteria for Beta, Theta, and EMG were met. The software employed in the research study allowed for four different types of feedback to the subject as the session progressed. The initial portion of the session provided auditory and visual feedback to the subject. When the three elements of increased Beta, decreased Theta, and decreased EMG were present, a harmonious tone was sounded. Visually, sessions alternated between a visual presentation of dials and bars. The dials could be likened to a speedometer; the bars were similar to a thermometer. A second portion of the protocol involved auditory feedback while reading, a third part presented visual only feedback, and a fourth segment had auditory and visual feedback while engaged in a listening task.

By keeping the threshold settings (criteria for obtaining a goal) constant, consistency could be maintained and true differences detected. Manipulation of threshold settings could result in statistical differences when no real change had occurred. For this population, it appears that no particular protocol condition emerges as superior in assisting subjects to achieve goals. Future research might consider a comparison of a varied protocol with a consistent one. Any differences in the two types of protocols could then be analyzed.

When the first group of ten sessions was compared to the second group of ten sessions in relation to the number of goals obtained, conditions involving visual/auditory, auditory only while reading, and visual only seemed to be the most effective. The tasks involving reading and listening require a high level of attention. It may be that visual and auditory feedback is too distracting. As an anecdotal note, the researcher observed that one of the subjects consistently turned away from the visual display on the computer screen during the listening task. Future research might examine the effects of the four protocol conditions employed in the current study with other conditions. These conditions might include a one-condition format of auditory only or visual only. Matching the learning style of the subject to the protocol might be another avenue to explore.

Changes in behavioral data

Comparisons were made between the experimental and control group to determine if change in cognitive functioning occurred as a result of biofeedback training. No differences emerged between the pre- and post-test scores of the two groups. This data contradicts the case studies of Tansey (1985). Previous case study research had also documented changes in achievement levels following biofeedback training (Lubar and Lubar, 1984). When the two groups were compared in the current research for changes in achievement levels, no differences emerged. Previous studies reported gains in cognitive and achievement levels; however, other remediation techniques were employed along with the biofeedback training. The current research attempted to control for this contamination by focusing on biofeedback alone.

Impulsivity, inattention, and hyperactivity were the behavioral variables considered in this research. The parents provided information prior to the training, at the midpoint, and at the conclusion of the study. Despite changes in EMG data no differences were found between the two groups. The measures utilized to assess behavioral change may not have been sensitive to subtle improvements.

In summary, the current research data lend support to previous studies documenting brain wave activity change as a result of biofeedback training. These changes, however, did not translate into improvements in cognitive, achievement, or behavioral functioning. Previous research indicating change was not confirmed by this study.

A major limitation of the current research was the small sample size. Due to the labor-intensive procedures involved in the design, it would be beneficial to build upon the data with on-going research. An optimal scenario might be to incorporate the training in a school setting during the course of the academic day. Behavioral changes could be observed by the teachers as well as the parents. However, the legal mandates requiring schools to limit any time out of class makes such a research design almost impossible.

Another consideration for future research might be to investigate change in cognitive functioning with instruments that measure more subtle changes. Tests used in neuropsychological assessments might be reviewed for potential use. Techniques employed to assess neurological rehabilitation might also be explored.

Changes in cognitive and behavioral functioning are the areas of most concern to the children diagnosed as ADHD and their parents. An article devoted to problems encountered by schools in meeting the needs of ADHD children included an interview with an ADHD child. The fifth-grade child stated, "I wish they would just treat me like a normal kid. I am not an alien from outer space. I feel so mad and so left out." (Barrionuevo, 1993). Comments such as these are often echoed by children diagnosed as ADHD. Parents and educators often experience the frustration associated with the diagnosis and treatment of this disorder. This dilemma is compounded by research findings which suggest that many of the deficits experienced by ADHD children continue into adulthood (Teeter, 1991).

A variety of treatments have been proposed for individuals diagnosed with ADHD. However, evaluation of the effectiveness of various treatments have often been confounded by a failure to take into account the heterogeneity of the syndrome. Some children diagnosed as ADHD exhibit hyperactivity and impulsivity as well as inattention while other children do not have hyperactive characteristics. Coexisting conditions such as learning problems and conduct disorders may further confuse the issue. Evaluation of treatments has also been confounded in numerous instances when more than one intervention was in effect at a give time. Thus, a pure treatment effect could not be ascertained.

Within the last few years, media coverage in both the popular press and television have proclaimed the benefits of EEG biofeedback training as a treatment for ADHD. Clinics throughout the United States have advertised this method of treatment. Parents who are desperately seeking assistance for their children are willing to pay for services that may require long-term treatment. For the most part, the research to date on EEG biofeedback is anecdotal and has not been subjected to rigorous scientific control.

The vulnerable nature of the ADHD population makes it imperative that research exploring the efficacy of a treatment precede commercial endorsement of the procedure. Results from the current study indicate that more research is needed in the assessment of biofeedback as a viable tool for the remediation of ADHD. Additional research should expand on the findings of the current study which suggest that fewer sessions may be more appropriate. It is undeniable that the biofeedback procedures are time consuming and labor intensive. The research may be most effective when carried out at a university setting where students can earn credit without having to charge parents for the services.

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APPENDICES

APPENDIX A

Letter Describing Research Study

March , 1994

Dear Parents,

For my doctoral dissertation at Texas Woman's University, I am conducting a study which will investigate the use of biofeedback training for children with Attention Deficit Hyperactivity Disorder. Case studies using biofeedback for this disorder have yielded promising results; however, the technique has not yet been proven in scientifically designed research.

As subjects for my study, I will be looking for boys between the ages of 8 and 12 who have attention deficit disorder with or without hyperactivity. They should have no other co-existing conditions such as a learning disability or conduct disorder. Those individuals who are interested in the study will be screened with a battery of tests including an intellectual, academic, and behavioral evaluation. Subjects selected for the study will also receive topographic brain mapping.

Those children selected to participate in the study will be randomly assigned to either the biofeedback training group or to a control group which will be used for comparison purposes. The biofeedback training will be 3 times per week for 10 weeks for a total of 30 sessions. Each session lasts from 45 minutes to one hour. All training will be after school hours and will not interfere with the academic program. At the end of the study, subjects will receive academic and behavioral assessments as well as topographic brain mapping in order to detect any changes which may result from the biofeedback training. Behavioral assessments will also be conducted at specified intervals during the training.

Participation in this study is completely voluntary and will not be documented in school records. The evaluations and training will be provided at no cost to the subjects.

If you would like to participate in the study or would like more information, please contact me at the number listed below.

Thank you for your consideration of my research.

Judy Anderson

Judy Anderson, M.A., L.P.A., N.C.S.P.
214-596-7693

If you have any concerns about the way this research has been conducted, please contact the Texas Woman's University Office of Research and Grants Administration (817) 898-3375.

APPENDIX B

Sample of Informed Consent

TEXAS WOMAN'S UNIVERSITY
Informed Consent

I hereby agree to allow by child ______________________________ to participate in this research project which is designed to study the relationship between biofeedback training and Attention Deficit Hyperactivity Disorder. This research is being conducted by Judy Anderson, doctoral student, through Texas Woman's University

Interventions with ADHD children have included drug management, behavioral therapy, parenting training, dietary and nutritional management, vitamin therapy, allergy treatment, relaxation and biofeedback treatment, etc. All of these interventions have had varying degrees of success in the reduction of hyperactivity behaviors and in the increase in attention sustaining capabilities. Current research has clearly indicated that ADHD is a neurologically-biologically-based disorder; therefore treatment approaches which affect the physiological functioning of the child seem to hold the most promise. One such promising treatment approach, called biofeedback, is the direct manipulation of the brain wave frequencies elicited during resting and cognitive conditions.

As a research subject, I understand that my child may be evaluated with a battery of tests including the Woodcock - Johnson Revised Tests of Cognitive Ability, the Woodcock - Johnson Revised Tests of Achievement, the Children's Depression Inventory, the Conner's Parent Rating Scale - Revised, the Child Behavior Checklist (Parent and Teacher report forms), the Attention Deficit Disorders Evaluation Scale (Parent and Teacher forms), and topographic brain mapping.

If my child is selected as a subject for the research study, I understand that there will be random assignment to either a treatment or control group. If my child is assigned to the treatment group, I understand that the biofeedback sessions will be scheduled 3 times per week for 10 weeks for a total of 30 sessions. If my child is assigned to the control group, I understand that no biofeedback training will take place.

If my child is selected for the study, I understand that achievement and behavioral testing will be conducted at the end of the study as well as topographic brain mapping. I further understand that behavioral assessments will be conducted at 5, 10, and 15 week intervals.

I understand that all information will remain confidential and will not be documented in school records. I understand that in addition to Judy Anderson, my child may have contact with Dr. Dan Miller, Susan Fletcher (doctoral student), and Kathy DeOrnelles (doctoral student). I understand that all of these individuals are aware of and will adhere to the ethical responsibilities concerning confidentiality.

I understand that the procedures described have potential benefits to me and my child.

I understand that possible risks include loss of time which may range from 1 1/2 hours to 35 hours depending on my child's selection.

I understand that all test results will be discussed fully with me and that I may contact Judy Anderson for further information.

I understand that no medical service or compensation will be provided to me or my child by Texas Woman's University. However, emergency care will be provided as necessary. Although they are unlikely to occur, we want you to be aware of any possible risks to your child. The scalp may be rubbed, in a few students, to the extent that the skin will be sore for a period of time after the procedure. There is a slight risk that your child may be allergic to the electrogel (salt and water solution). If your child does have an allergic reaction to the electrogel the testing will be stopped immediately and the electrogel will be washed from your child's hair.

A description of the possible risks and discomforts have been discussed with me and an offer to answer any questions regarding the study has been made. I understand that I or my child may terminate participation in the study at any time. I understand that I or my child can choose not to participate in this research project and will suffer no prejudice or loss as a result of making that decision.

This research has been explained to me by Judy Anderson and I agree to have my child participate in the study.

______________________	______________________	__________
Participant's Printed Name	Participant's Signature	Date
______________________	______________________	__________
Parent/Guardian Printed Name	Parent/Guardian Signature	Date
______________________	______________________	__________
Witness' Printed Name (one required)	Witness' Signature	Date

If you have any concerns about the way this research has been conducted, please contact the Texas Woman's University Office of Research and Grants Administration (817) 898-3375.