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NEUROFEEDBACK AS AN ALTERNATIVE
AND/OR AN ADJUNCTIVE TREATMENT FOR
ATTENTION DEFICIT/HYPERACTIVITY DISORDER:
A PRESENTATION OF TWO CASE STUDIES
AND A BRIEF HISTORICAL REVIEW OF ADHD.

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Degree

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Jennifer Pauline Samples

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This thesis is dedicated to my parents
Lt. Col. W.D. Samples, Jr., USAF (retired)
and
Mrs. Joyce King Samples
who have both encouraged me in my pursuit
of a higher education.

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ABSTRACT

This research attempted to provide an historical perspective concerning the development of the diagnosis of Attention-deficit Hyperactivity Disorder (ADHD), review the most common treatments available, and explore the viability of neurofeedback as an additional treatment for ADHD. The development and rationale of neurofeedback and the procedures are fully explained in the text. The two case studies presented underwent the full neurofeedback program for the treatment of ADHD. Although both subjects showed some definite improvements post-treatment, the subject who was not hyperactive and not on any type of pharmacological regime, showed the most dramatic improvements, in terms of performance on I.Q. tests. It was concluded that neurofeedback can be considered a viable alternative and/or adjunctive treatment for the learning disorder known as ADHD, however, there is still considerable research to be conducted concerned with greater controls and more replication of the pioneering efforts already published.

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CHAPTER I

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is one of the most prevalent childhood disorders recognized today, occurring in an estimated 5 to 15% of school-aged children (Cantwell, 1975; Brosco & Robin, 1980; Barkley, 1990). In a discussion of a disorder of this prevalence and magnitude, there can be many points of controversy. The most controversial aspects of ADHD include its actual definition as well as which, of the varied treatment modalities available, should be used. One treatment being applied is neurofeedback, the use of computerized biofeedback equipment designed to recognize certain brainwave patterns and to present that information to the client so that he/she may learn to change his/her brain's electrical activity. The efficacy of neurofeedback as an adjunctive and/or alternative non-invasive treatment for ADHD is the primary focus of this thesis.

Definition of ADHD

At this point, in order to facilitate the reader's understanding of this disorder, a presentation of the current definition of ADHD will be included. Four major categories are described in the DSM III-R: attention

deficit disorder with and without hyperactivity, conduct disorder, and learning disabilities (DSM III-R, 1987).

Under these diagnostic criteria , whether the symptoms of hyperactivity are present or not, all children meeting the criteria listed are diagnosed as having attention-deficit hyperactivity disorder (ADHD). The two case studies to be presented in this paper were diagnosed and treated under this rubric; therefore, a specific and detailed presentation of these criteria is pertinent: According to the DSM III-R, if any 8 of the 14 criteria are present the diagnosis is pertinent.

Note: Consider a criterion met only if the behavior is considerably more frequent than that of most people of the same mental age.

A. A disturbance of at least six months during which at least eight of the following are present

1. often fidgets with hand or feet or squirms in seat (in adolescents, may be limited to subjective feelings of restlessness)
2. has difficulty remaining in seat
3. is easily distracted by extraneous stimuli
4. has difficulty awaiting turn in games or group situations
5. often blurts out answers to questions before they have been completed
6. has difficulty following through on instructions from others (not due to oppositional behavior or failure of comprehension), e.g., fails to finish chores
7. has difficulty sustaining attention in tasks or play activities
8. often shifts from one uncompleted activity to another
9. has difficulty playing quietly
10. often talks excessively

11. interrupts or intrudes on others, e.g., butts into other children's games
12. often does not seem to listen to what is being said to him or her
13. often loses things necessary for tasks or activities at school or at home (e.g. toys, books, assignments)
14. often engages in physically dangerous activities without considering consequences (not for the purpose of thrill-seeking), e.g., runs into street without looking

Note: The above items are listed in descending order of discriminating power based on data from a national field trial of the DSM-III-R criteria for Disruptive Behavior Disorders.

B. Onset before the age of seven.

C. Does not meet the criteria for a Pervasive Developmental Disorder.

Criteria for severity of Attention-deficit Hyperactivity Disorder.

Mild: Few, if any, symptoms in excess of those required to make the diagnosis and only minimal or no impairment in school and social functioning.

Moderate: Symptoms or functional impairments intermediate between "mild" and "severe."

Severe: Many symptoms in excess of those required to make the diagnosis and significant and pervasive impairment in functioning at home and school and with peers (DSM III-R, 1987).

Historical Perspective of this Definition

The following discussion will include an historical perspective of the development of our view about ADHD .

Prior to the twentieth century, childhood disorders were not thought to be of importance or even recognized as problems. From a psychological perspective, children were treated as

little adults who must be trained in the appropriate behaviors and manners of the current age. The term, "Tabula Rasa", the white page (...that must be written upon) was first coined by John Locke in 1690. This viewpoint has influenced the interpretation of childhood learning and behavior theories for centuries. Another complication, and explanation, for the apparent lack of prior emphasis on childhood disorders can be traced to the prevailing socioeconomic perspectives of the given time period. Especially in the United States, the "great melting pot", many childhood learning and behavior problems were viewed and masked as cultural and/or language differences. Some prejudicial views may have also contributed to the lack of emphasis on these problems, assuming a lack of character or poor moral development as a reason for little or no success in performance of academic tasks. Thus, it was not until the twentieth century that any research or observation of the symptomatology associated with ADHD was even presented about this disorder.

The literature shows that an early discourse on hyperactivity was written in 1902 by Dr. G.F. Still, published in the Lancet. Dr. Still, an English pediatrician, noted a subgroup of children with "abnormal defects in moral control...and wanton mischievousness and destructiveness" (Still, 1902). This type of characterization of a childhood syndrome does not reappear

in the literature again until the early 1920's. It was noted by Holman (1922), Kennedy (1924), and Stryker (1925) that children who had had influenza-related encephalitis exhibited patterns of antisocial behavior, hyperactivity, impulsiveness and decreased attention. These early articles were the basis and beginning of the organic model, that some underlying brain dysfunction could explain the common characteristics of a syndrome. Then in 1938, Jasper, Solomon, and Bradley presented research that referred to children who exhibited excessive slowing in the EEG. This data was referred to as early indicators of what came to be known as MBD. Findings concerning any EEG abnormalities were considered part of the research that centered on finding some neurological markers to help clarify the diagnosis of minimal brain dysfunction syndrome.

In 1947, Strauss developed the term minimal brain dysfunction syndrome (MBD), also known as "Strauss Syndrome". In his research and review of the literature, Strauss found that an underlying theme of some MBD existed in many different cases outlined in the literature. Although the onset and initial occurrence of MBD varied, causalities were associated with toxic reactions, or with brain injury complicated by an association with mental retardation, and sometimes MBD seemed to involve genetic factors (Strauss and Lehtinen, 1947). Strauss did note that

in some cases there were neurological signs of perinatal complications, however, these did not preclude a suggestion of minor brain deviations. With "Strauss syndrome" defined, research began to focus on EEG abnormalities.

During this same time period, the 1940's and 1950's, psychometric tests were being developed and used to recognize and differentiate normal populations from MBD syndrome children. Meanwhile, research into EEG abnormalities continued. Evidence presented by Knott, Platt, Ashby, and Gottlieb (1953) indicated that both MBD-syndrome children, and children who later developed psychopathic personalities disorders, showed some type of EEG abnormalities. Again, in this research, excessive slowing of the EEG was found to be present as were the forms of epileptogenic activity. Research has also been presented that states that in approximately 50% or more of MBD groups tested, EEG abnormality exists (Capute, Niedermeyer, & Richardson, 1968; Burks, 1960). Other studies conducted in the late 1950's and into the 1960's continued to support the findings that EEG abnormalities were an integral part of the syndrome referred to as MBD (Cohn & Nardini, 1958; Werry, Delano & Douglas, 1965, Pavy & Metcalf, 1965; Klinkerfuss, Lange, Weinberg, O'Leary, 1965).

By the time the DSM II (1968) was written, a consensus definition of MBD had been established as follows:

This disorder is characterized by overactivity, restlessness, distractibility, and short attention span, especially in young children; the behavior usually diminishes in adolescence (DSM II, 1968).

However, there were no minimum criteria for symptomatology and diagnosis was inferred from behavioral observation. The diagnosis of MBD seemed to gain popularity and included a large grouping of various symptoms ranging from behavioral to neurological. One researcher, Paul Wender in his book The Minimal Brain Dysfunction in Children, wrote that perhaps as many as half the child psychiatric population being diagnosed were categorized as MBD (Wender, 1971). Other researchers observed the same phenomenon of excessive diagnosis (Gross and Wilson, 1974). While MBD was the primary diagnosis assigned, users of the DSM II could also choose a diagnosis of Hyperkinesis. According to Rosenthal and Allen (1974), hyperkinesis was considered more of a psychiatric diagnosis, as opposed to the more neurological origins associated with MBD. While the differences from MBD were subtle, diagnosis of hyperkinesis emphasized the symptomatology, the impact on the social sphere of the child (relations with peers and family), and the longevity of the disorder in terms of initial onset of the hyperkinetic behaviors of the child (DSM II, 1968).

When, in 1980, the DSM III was written, it was acknowledged that MBD had become somewhat of a "catch all" term for many differing childhood disorders. Accordingly,

the MBD syndrome was broken down into differentiated categories. With a new emphasis on behavioral criteria, the disorder was divided and labeled as: attention deficit disorder with and without hyperactivity, and ADD residual type (DSM III, 1980). Two other disorders were labeled and recognized as separate: oppositional disorder and conduct disorder. This more specific categorizing was in response to the realization that these disorders are separate entities.

Indeed, up to the 1980's, it was apparent that even more research was needed to fully differentiate ADD from all other disorders. In one book published in 1982, the authors mention that there is still the need to identify "universal and specific" factors of the various childhood disabilities and disorders (Ysseldyke and Algozzine, 1982). In an attempt to do so, authors Nichamin and Windell, arguing for a biologically-based diagnosis of ADD, state that it is not caused by "...faulty diet, preservatives in food, visual disorders, schizophrenia, childhood head injuries, inadequately trained teachers, air pollution, or poor parenting" (Nichamin & Windell 1984). Many researchers from varied professions continued to question the breakdown of these disorders as defined in the DSM III. For example, McGee, Williams and Silva wrote:

ADD may or may not be accompanied by hyperactive behavior, but the focus of the disorder has become attentional dysfunction rather than excessive motor activity. The

relations among attention deficit, hyperactive behavior and conduct problems or aggressive-antisocial behavior, however, are yet to be described (1984).

Some researchers suggested that a lack of rigorous evaluation was evident in the revised definitions in the DSM III (Rubinstein and Brown, 1984). These are but a few examples of the many articles and opinions rendered exhibiting dissatisfaction with the descriptions given in the DSM III. Therefore, when the DSM III-R was released there were changes once again in the diagnostic criteria for ADHD.

CHAPTER II

Common Treatment Modalities Available

Given the confusion and controversy surrounding the definition of ADHD, it is hardly surprising that the views of treatment modalities available are any less controversial. The different treatment modalities available are: the pharmacological, the behavioral, and neurofeedback.

By far the most common response to a diagnosis of ADHD is to begin some type of pharmacological treatment regime. The widespread success of a pharmacological approach to the treatment of ADHD has made drug therapy popular with pediatricians and psychiatrists. There is also a multitude of data and research available that attests to the efficacy of a pharmacological regime as a treatment for ADHD. As with most aspects of ADHD, pharmacology has its own controversy and detractors. Both sides of this issue will be addressed, with an emphasis on the most commonly prescribed medication, widely known as Ritalin.

Ritalin's pharmacologically correct classification is Methylphenidylacetate hydrochloride (MPH). Safer and Krager (1984) estimate that in the United States, 1% to 2% of the school-aged population is on some dosage of MPH. According to research, Dr. Charles Bradley was the first physician to treat the symptomatology associated with ADHD

pharmacologically. Dr. Bradley reported that although the effects were drug- and dosage-dependent, positive effects were observed in both attentiveness and school-related behaviors. Amphetamine sulfate (benzedrine) was the pharmacological compound that Dr. Bradley prescribed (Bradley, 1937). Since that first use of a pharmacological compound, there have been innumerable studies and articles considering the efficacy of this approach to the treatment of ADHD. As stated earlier, MPH is the current drug of choice. The progression over time from amphetamine sulfate to MPH is logical, in that it has been shown that MPH has structural, and pharmacological properties similar to amphetamines (Murray, 1987).

Support for the use of MPH (and other medications) as a treatment for ADHD is widespread. One source of support is from school personnel, especially concerning the management of the hyperactivity aspect of the disorder (Greenspoon & Singer, 1973). In their book, Dupaul and Barkley assert that, based on over four decades of field use and research, the positive pharmacological effects include increased control of motor activity level, decreased impulsiveness, and increased attention span (1990). Some reports indicate that the higher the dosage, the greater the improvements (Rapport and Kelly, 1991). It has been estimated that as many as 60% of the ADHD children treated with MPH show positive effects (Swanson and Kinsbourne,

1979). There is a great deal of support for the use of pharmacological treatment, in fact, one article cited 10 sources referring to positive effects of psychostimulant drugs (Brundage-Aguar, Forehand, & Ciminero, 1977).

Nonetheless, in spite of the great support for the use of MPH and other medications, there is still concern over their possible negative effects. As stated in one review of the literature, "Research suggests, however, that a wealth of inconclusive evidence regarding the use of psychostimulant medications is available, demonstrating the need for further study in this area" (Meents, 1989). Two other reviewers state that although classroom manageability is undeniably improved, serious questions remain concerning the positive effects of MPH on academic achievement and cognitive functioning (Barkley and Cunningham, 1978). Cognitive processing abilities may actually be diminished in some children according to one pair of researchers (Tannock and Schachar, 1992). Another criticism of MPH relates to side effects, which can include nausea, dizziness, anorexia, headache, palpitations; it has also been reported to suppress growth (weight and height) with long term use (CIBA, 1992). Sulzbacher found that in only 27.5% of the over 1300 studies he reviewed, ranging from 1937 to 1971, were there any utilization of control measures; for example, use of placebos. In some of the studies, multiple drugs were employed; in addition there was also a lack of adequate

control for subject or experimenter bias, and many studies were not done in a double-blind method (with or without multiple drugs or placebos involved)(1972). An additional criticism stems from a question of reliability of evaluation of drug effects. Researchers have found that the evaluation of drug effectiveness is usually based on rating scales completed by parents and teachers, and verbal reports. These evaluations are suspect because they can be influenced by rater biases and "halo" effects (Gittleman-Klein & Klein, 1975; Schleifer, Wiess, Cohen, Elman, Cvefic, & Kruger, 1975). Although the use of medications is seemingly the preferential choice of treatment modalities "methodological problems in drug studies, the problems of idiosyncratic responses to drug therapy, and the possibility of adverse side effects suggest caution in the use of this treatment (Brundage-Aguar, D., Forehand, R., & Cininero, A.R., 1977). These concerns have led professionals working with ADHD children to examine and develop other treatment strategies.

Another treatment strategy, second in prevalence after pharmacological treatment, is behavioral management. As with any other therapy or treatment, research can be found that both supports and detracts from the efficacy of behavior management. Behavior management has been categorized as actually including three different groups: behavior therapy, which uses operant conditioning; behavioral self-control therapy, which uses self-

monitoring,-reinforcement,-evaluations; and cognitive-behavioral therapy, which uses self-instruction, problem-solving, attribution retaining, and stress inoculation.

Many research studies suggest positive effects of behavior modification, as a treatment for ADHD. Documentation exists that shows positive effects (decreased behavioral problems such as out-of-seat behavior, talking excessively, etc.) in regular classrooms (Rooney, Hallahan, & Lloyd, 1984) and in special education classes (Hallahan, Marshall, & Lloyd, 1981). Barkley states that "certainly, in the improvement of classroom academic achievement, behavior modification approaches are in fact superior to other methods, including stimulant drug management" (1981). There are many and varied successful applications of this therapy in the literature. Modification of a five-year-old boy's aggressive and hyperactive behavior was accomplished by teacher attention to appropriate behavior, while the inappropriate behaviors were ignored (Vance, 1969). A controlled evaluation of hyperkinetic children, attending both normal and non-remedial classes, found behavioral methods useful as an alternative to drug therapy (O'leary, Pelham, Rosenthal, and Price, 1976). Use of modeling techniques combined with candy as a positive reinforcer was successful with elementary school-aged children in the reduction of hyperactive behavior (Nixon, 1969). Another article showed that monetary rewards were able to lower

significantly out-of-seat and restless behavior in medicated and non-medicated hyperactive boys (Christensin, D.E. & Sprauge, R.L., 1973). Doubras and Daniels (1966), in research conducted with a fixed schedule of reinforcement with tokens (exchanged later for candy), showed that "the disturbed, hyperactive behavior came under stimulus control with 'grasshopper' play decreasing significantly during the latter part of conditioning and extinction periods". In another, somewhat different research paradigm, children with hyperactivity were involved in a behavior management intervention that included group consequences as well as individual consequences. In either case, 0-4 pieces of candy could be rewarded dependent on the behavior of the target child, either to the target child privately or to the entire group of children. Teacher rating scales showed significant improvement in classroom and hyperactive behaviors in both circumstances, however results were slightly better for the child in the group circumstance (Rosenbaum, A., O'Leary, K.C., & Jacob, R.G., 1975).

Another example of a behavior management technique, that has been shown to be successful with a hyperactive child, is time-out. In this multiple-baseline study, with a 10-year-old boy diagnosed as hyperactive, the results showed control of inappropriate behavior was achieved. Time-out was shown to be a useful technique because "...the changes in inappropriate behaviors which, when reduced via time-out

procedures, increased attending behaviors" (Sachs, D.A., 1973). From this brief review of the literature, it is clear that there is much to be gained from the inclusion of behavior management in any treatment regime for ADHD.

Despite these successful experiences, there are several criticisms of behavior management as a treatment for ADHD. One argument against behavior management therapy is that contingent reinforcement procedures (a popular type of behavior management) are often thought to little more than bribery. To clarify, the difference between bribery and reinforcement procedures is that bribery is clearly an illegal act, and in defense of this critical suggestion Tymchuk (1974) states:

For most children the dependence on records, graphs, M&M's and so on is only temporary. Each child will start to do things, once he is trained, because he will receive good things in return, then he may do some because he wants to please you, then to please himself (p. 51).

There are other criticisms of behavior management therapy, that are more specific to the treatment of ADHD. Firestone and Douglas (1975) reported a significant increase in impulsivity in a reward reinforcement paradigm. Other researchers note that, although in a laboratory setting behavioral-cognitive therapy effects are positive, these effects are difficult for the inattentive child to generalize and use in real situations (Abikoff & Gittleman, 1975). Abikoff, in a later study, notes that there is no

attempt to assess whether any actual change in the children's self-statements occurs; instead, changes are inferred from performances on psychological tests (1991). Another investigator showed that there were no significant treatment effects in a study on self-verbalization commands during math performance and on activity levels after twenty, 30-minute training sessions (Burns, 1972). Another criticism of the use of behavior modification therapy is that for parents and teachers implementing the instructions to "... be consistent, provide structure and try not to have changes in the routine" (Silver, 1991) can be very difficult. In a review of the literature, Brundage-Aguar (1977) states that one glaring weakness in the research is that, although methodology is much better in this treatment approach, there are no follow-up measurements nor changes in academic performance shown (1977).

The last of the three treatment modalities to be examined is neurofeedback. As stated earlier, neurofeedback is a form of biofeedback dealing with the EEG patterns, or the brain's electrical activity patterns. This approach draws on knowledge accumulated from the fields of psychology and electronics. The primary psychological contribution to the development of neurofeedback is the theoretical perspective from which it has grown - namely, Behaviorism. The psychological field has also given us an abundance of research concerning EEGs. This research has centered around

defining what these brain activity patterns are, both subjectively and objectively, and what the potential is, or may be, for learning to control EEGs. The electronics field has given neurofeedback the incredible machinery needed to isolate the specific EEG activity targeted and feedback this information to the individual. Contributions from both of these fields have made neurofeedback possible.

When B.F. Skinner developed the school of thought known as Behaviorism, it is doubtful whether he would have considered a clinical application such as neurofeedback. Yet, from a theoretical perspective, neurofeedback cannot be associated with any other construct. More specifically, it is associated with a subcategory of Behaviorism, Thorndike's instrumental learning theory where "...the animal has to learn the relation between a response and reward: Given this response, there will be reinforcement" (Gleitman, 1981). Thorndike's S-R theory of learning has been adapted by neurofeedback quite successfully. To illustrate, with ADHD children, the stimulus (the need to attend in order to learn) is met with incorrect response of too much of one EEG activity (theta activity) and not enough of another EEG activity (beta activity), therefore no reward (audio and/or visual feedback). Yet when, by chance, the correct combination of EEG activity occurs the reward (feedback) is immediate. (Greater details and explanations of EEG activity terms will be provided later in this paper). Over time the

correct S-R bond is developed. Stimulus generalization is developed within a neurofeedback session by including academic tasks performance and listening tasks both paired with feedback. Extinction is discouraged by using a maintenance format that, in effect, becomes an intermittent schedule of reinforcement. Clearly, neurofeedback's theoretical ties are dedicated to operant conditioning, a major subcategory in the school of thought known as Behaviorism.

The idea of using EEG biofeedback (known now as neurofeedback) was first developed in the 1960's. This earliest research was done working in the alpha range (8-11 Hz) of the EEG. In a paper published in 1969, Kamiya presented data demonstrating that alpha production could be trained in subjects using auditory feedback. When the alpha activity was above a certain microvolt level, a tone would sound. The data showed that volitional control of alpha production was attained. In the first stage of the study, all 7 subjects were able to increase alpha from a baseline of 25% to 55%. In the second stage of the study, 6 of the 7 were then able to suppress alpha production, from an initial range of 40%-80% suppression to an ending range of 60%-95% suppression (Kamiya, 1969). Another early researcher working with alpha activity said "The most precise expression of the behavioral state most closely identified with alpha activity is relaxed wakefulness" (Brown, 1981).

The work of these early researchers was concerned with both suppression of alpha activity and increased activation of alpha activity; most of the work was done in an exploratory vein. These researchers were discovering whether, and how well, EEG biofeedback could be done.

While alpha activity received more attention, the other EEG frequencies were also being evaluated in relation to subjective associations. Theta activity, which has been defined as occurring somewhere between 4-10 Hz (depending on the researcher), has been associated with drowsiness, earliest sleep, day-dreaming, and imagery (Green, Green & Walters, 1970; Brown, 1971). Beta activity, which occurs in the 14 to 28 to 40 Hz range (again depending on the researcher), is the fastest of the EEG frequencies. Subjective adjectives associated with beta activity include: active, alert, energetic, excited, and exhilarated. (Bird, Newton, Sheere, & Ford, 1978). The last of the pertinent EEG frequencies is the sensorimotor rhythm (SMR), defined as 12-15 Hz. Although there are no subjective associations in the research concerning SMR activity, it is associated with absence of movement on the part of the subject. Early research done with cats indicated that after being "...trained to produce abundant quantities of this rhythm (they) became resistant to seizures induced by convulsant drugs" (Brown, 1981). This led to the inevitable question, can SMR training work similarly with humans? The early and

subsequent research indicated significant reduction of seizure activity or the complete absence of seizure activity in human subjects (Stermann & Friar, 1972; Lubar, Shabsin, Natelson, Holder, Whitsett, Pamplin and Krulikowski, 1981). This SMR training also included theta activity reduction, to decrease day-dreaming activity, as part of the paradigm.

One extra, positive side-effect of the SMR training paradigm for seizure disorders was that the subjects displayed a greater ability to concentrate and focus. This led to subsequent research to see whether EEG biofeedback might be helpful for hyperkinetic children (Lubar, 1991). This was the beginning of the development and the use of neurofeedback as a viable treatment for ADHD. What followed were several studies, and research into the use of SMR training with theta inhibition training as a powerful alternative and/or adjunctive therapy for the hyperkinetic disorder (Lubar & Shouse, 1976; Shouse & Lubar, 1978, 1979).

This successful research and clinical application led to another discovery by Dr. Lubar. He observed that while non-hyperkinetic children with attentional difficulties were reading or engaged in some academic task, they were producing extremely low beta activity and excessive theta activity. As stated by Lubar (1991):

Based on these early observations and my basic knowledge of the relation between higher frequency activity and activation in the nervous system, I hypothesized that perhaps children with attention difficulties,

especially if they had reading, spelling disorders, or other associated learning problems, might benefit from beta training as well as SMR training (p. 209).

This hypothesis was supported by a study that reported significantly less beta (14-32 Hz) production in hyperactive subjects (Grunewald-Luberbier, Grunewald, & Raske, 1975). Thus began intense research into this possibility (Lubar & Shouse, 1976; Lubar & Shouse, 1976; Lubar & Deering, 1981; Lubar, Bianchini, Calhoun, Lambert, Brody, and Shabsin, 1985; Lubar, Gross, Shively, & Mann, 1990; Lubar, J.O. & Lubar, J.F., 1984; Shouse & Lubar, 1978; Shouse & Lubar, 1979).

It was not until the 1980's that replications of Lubar's pioneering efforts began to surface and be published. The earliest and most prolific replicator of this work has been Michael Tansey (1984, 1985, 1990, 1991, Tansey & Bruner, 1983). Using a paradigm similar to Lubar's, Tansey has reported evidence of the viability of SMR and beta-wave training for helping children who have attentional problems, with and without hyperactivity. These similar paradigms essentially consisted of reinforcing fast brainwave activity, specifically SMR and/or beta activity (associated with motor control and attending behaviors, respectively), while at the same time inhibiting the production of theta activity (associated with day-dreaming). Greater attention to the details of this paradigm will be

addressed in the methods section of this paper. One of Tansey's first research efforts reported that a combination of SMR and EMG (electromyographic biofeedback for control of fine motor activity) showed some improvements in a 10-year-old boy with hyperactivity and a reading disorder. The research consisted of three sessions of EMG biofeedback followed by 20 sessions of SMR neurofeedback. The feedback modality used was auditory; the loudness of the tone indicated the amplitude of the SMR activity, and the number of beeps per minute indicated the frequency of the appropriate activity. The SMR activity was successfully increased at the end of training and the subject's grades had improved dramatically. The child's parent commented that the child had been unable to read or spell during the prior school year. The authors state that "with respect to EEG biofeedback training, conditioned increases in SMR, monitored as a 12 Hz to 14 Hz brain wave over the Rolandic cortex, resulted in clear reductions in hyperkinetic behavior..."(Tansey & Bruner, 1983). Tansey presented further supportive research in his articles on the effects of SMR training on the neurologic precursors of learning disabilities (Tansey, 1984, 1985). More specifically, in the 1984 study, Tansey presented research on 6 boys whose ages were 10 and 11. These boys received the same type of SMR training as described earlier and tangible reward at the end of each session of neurofeedback "if they made a lot of

beeps". Each of these subjects showed significant increases in frequency of production, and amplitude of SMR. All subjects also increased IQ scores at least one standard deviation (based on WISC-R profiles). The 1985 research was a replication of the 1984 study, with one additional subject. These individuals also exhibited significant improvements in SMR production (both amplitude and frequency) and in IQ scores. In 1990, he replicated his earlier works on a larger scale. Using essentially the same paradigm as before, he also included the 7 Hz theta inhibition, and visual feedback in addition to the auditory feedback. In this study there were 24 subjects. Results were that there was a 64% positive shift in the subjects' "brainwave signatures", and in 22 of the 24 subjects the WISC-R profile IQ scores were increased at least one standard deviation. Tansey's inclusion of theta inhibition (as well as Lubar's) is supported by research conducted earlier. Beatty and O'Hanlon (1979) demonstrated that training a subject to suppress or enhance theta activity can increase or decrease vigilance performance, respectively. The authors suggest that this technique, by simply learning to control theta production, may help subjects to be aware of the changes in their own arousal level and thus alert them to take corrective steps (Beatty and O'Hanlon, 1979). In 1991, Tansey published an article referring to the "brainwave signatures" of learning disabled children,

specifically, the overabundance of slow brainwave activity and the general lack of fast brainwave activity. As stated by Tansey (1991):

These research reports and reviews point to how EEG biofeedback data (brainwave signatures) plus WISC-R profiles can be used to maximize the diagnostic efficacy of the psychologist/biofeedback clinician's contribution to a truly comprehensive learning disability evaluation and effective treatment plan. (p.4)

The fact that few studies have been conducted to replicate Lubar's work is one of the strongest criticisms of neurofeedback as a viable treatment modality for ADHD. The primary reason for the lack of corroborative research is that the equipment has only recently become available to the professional community. Now, however, over the past two years the number of clinical centers and practitioners of neurofeedback has grown to over 125. There is an ongoing study attempting to compile data collected from most of these centers in order to evaluate the application of neurofeedback as a viable alternative and/or adjunctive treatment for ADHD.

Certainly, on an intuitive level neurofeedback has appeal. There has been research to indicate a significant lack of beta activity and an overabundance of theta activity in children who have been diagnosed as MBD, hyperkinetic, or ADHD (depending on the diagnostic criterion at the time of

the research). It does appear likely that training the child to increase fast brainwave activity (SMR and/or beta), while decreasing slow brainwave activity (theta), could have positive effects on ADHD. This general approach to the changing of the EEG patterns makes sense, when you take into account that:

The attention system that allows this change of concentration and distractibility does not represent a single group of neurons or a single microscopic, anatomical location. It projects to all areas of the brain and modulates change in state from intense concentration easy distractibility in normal subjects (Goldstein & Goldstein, 1990, p.44).

The present study seeks to contribute to the literature on neurofeedback by presenting two case studies, treated in a private clinical setting. A description, in detail, of the treatment process will be presented.

CHAPTER III

Methods

Subjects

The subjects for this study were two 11-year-old boys, medically diagnosed as ADHD. One boy had no hyperactivity (S1), the other boy was hyperactive and on a consistent dosage of MPH (Ritalin) throughout treatment (S2). There were no other complicating disorders (e.g. mental retardation, seizure disorder, conduct disorder, etc.) present in either child.

The subjects were referred for the study by a local pediatric neurologist. The parents were informed about the study, its' purpose, and asked if they would like their sons to participate.

Apparatus

The equipment used with these two case studies has only been developed within the last four years. This instrumentation is new and state-of-the-art; its tradename is Neurosearch-24, and was developed by the Lexicor Corporation of Boulder, Colorado. This equipment can collect data from 19 channels for topographical brain mapping and has neurofeedback capabilities. For the two subjects whose data are being presented, both of the machine's capabilities were utilized. For the pre- and post-brain mapping, the ECI Electro-cap was

used, which provides 19 channels configured according to the international 10-20 system. Also used were two ear-reference Grass electrodes. The actual neurofeedback sessions used the Biolex software, also developed by Lexicor. For neurofeedback, the electrodes were placed at FZ and PZ (also from the international 10-20 system, clinical research has shown these placements to be the most effective); there were also two ear-reference Grass electrodes and one regular Grass electrode used as a ground (placed on the forehead). The electrodes were attached with Nihon Khoden Elefix paste and were stabilized with a cotton ball. The placements were prepped using OMNIPREP. Throughout treatment all impedances were at 5 K ohms or less (10 K ohms or less is considered acceptable). The sampling rate of EEG activity with the Lexicor equipment is 128 samples/second.

The pre and post intelligence and achievement tests were performed by independent psychological examiners. The pre testing data was obtained from the parents, the testing had been done by the school systems the subjects attended. The post testing data collection was done by a different psychological examiner. The intelligence test data reported was from the Wechsler Intelligence Scale for Children-Revised (WISC-R). The achievement test data reported was from the Wide Range Achievement Test-Revised (WRAT-R).

The WISC-R is a standard battery of test that assesses

different aspects of intellectual functioning. The WISC-R consists of two scales, the Verbal Scale and the Performance Scale. For the purposes of this study the Performance Scale data and the Verbal Scale data were reported. Several indices, or scores, are obtained from the WISC-R. Composite scale scores (Verbal, Performance, and Full Scale IQs) provide general measures of verbal and performance skills and a measure of overall intellectual functioning (Full Scale). The Verbal Scale subtests measure comprehension and the ability to apply verbal skills to the solution of new problems. The Performance Scale subtests assess nonverbal problem solving ability, perceptual organization, and visual-motor proficiency of tasks such as puzzles, analysis of pictures, imitating designs with blocks, and copying.

According to the manual, written by Sarah Jastak and Gary S. Wilkinson, a general description of the WRAT-R is:

The WRAT(-R) was first standardized in 1936 (restandardization began in 1981) as a convenient tool for the study of the basic school codes of reading (word recognition and pronunciation), written spelling, and arithmetic computation. It was designed as an adjunct to test of intelligence and behavior adjustment...The method of measuring the basic codes was advisedly chosen to achieve the following ends: (1) to study the sensory-motor and coding skills involved in learning to read, spell, write, and figure, (2) to provide simple and homogeneous content, (3) to avoid duplication and overlapping with tests of comprehension judgement, reasoning and generalization studied by means

other than reading, spelling, and arithmetic tests, (4) to free diagnostic inferences from common confusions due to operational semantics, and (5) to permit validity analysis by the method of internal consistency (1984, p.ii).

The reported data also includes results from a questionnaire consisting of five questions concerned with the parents stress, relative to the subjects' schoolwork and homework. The questions asked were as follows: "During the your child's sixth grade school year, on a scale of 1 - 5, please rate your stress level while in the following situations: (1) getting your child to start/complete homework assignments, (2) attending parent-teacher conferences, (3) enforcing study habits and behaviors on your child, (4) getting your child to turn in completed assignments, and (5) getting your child to bring home essential items (e.g. books, xeroxes, etc.)". The parents were asked to rate the same questions for the seventh grade year. Report cards were obtained from the parents of both subjects for the sixth and seventh grades to calculate pre and post training GPAs.

Procedures

Using the Biolex software, thresholds were established for each subject from baseline amplitudes of theta and beta activity. In this study, theta is defined as 4-8 Hz, and beta is defined as 16-20 Hz. These criteria were set to

inhibit the theta activity approximately 60% of the time; while rewarding non-inhibited beta approximately 25% to 30% of the time. These criteria were strict and were not changed over the course of the treatment sessions. Learning curves can be presented based on the reduction of theta activity, while increasing beta activity.

The treatment sessions were twice a week, for 50 minutes. Over time the sessions were reduced to once a week, then to every other week, then to once a month, then to every other month, and a follow-up session after three months. The sessions were subdivided into a 2 minute baseline (no visual feedback), two 5 minute feedback only conditions (audio and visual feedback), one 5 minute reading condition with both modalities of feedback available, and one 5 minute listening condition with both modalities of feedback available. As already stated the feedback modalities were both visual and auditory, and were provided through the computer software. For subject 1 there were a total of 38 sessions, for subject 2 there were a total of 31 sessions.

Whenever theta activity exceeded parameter setting, a redlight would come on and no positive auditory feedback was possible. For beta activity the visual feedback was presented in the form of a green circle that would enlarge in diameter dependent on the amplitude of the beta activity; the auditory feedback also reflected amplitude increases and

decreases by presenting a higher or lower frequency.

Verbal intermittent positive reinforcement was provided by the therapist throughout treatment. Key terms and words used were: "good job," "concentrate," "focus," "comeback, there's too much theta," "you're doing super, keep it up," etc. No tangible rewards were given and verbal reinforcements were decreased over time, thus creating an opportunity for intrinsic self-control and self-reinforcement to develop. It is also important to note that, while there were no formal behavior management techniques taught to the parents of the subjects, there were some informal suggestions given. For example, parents were informed that, typically, ADHD children tend to be influenced by consequences and rewards that are not delayed, but are immediately administered. The subjects and their parents were also encouraged to develop assignment sheets to be used on a daily basis and initialed by their teachers to avoid confusion and forgetfulness. Another suggestion given was for the subjects to create a place for completed assignments in their notebooks, to avoid lost assignments. By developing these types of behaviors the parents and the subjects could promote a more structured and organized approach to schoolwork and homework.

Design and Analysis

The results section will include a table presenting the

Spearman statistical analysis of correlations of the EEG activity (beta and theta) by the number of sessions, to assess changes in the EEG activity over time. This statistical analysis will be offered in conjunction with graphic representation of the percentage of time inhibited theta activity occurred over sessions for both subjects and the percentage of time non-inhibited beta activity occurred over sessions for both subjects as well. In addition, WRAT-R and WISC-R profiles, pre- and post- neurofeedback training will be presented in a bar-graph form for both subjects. Also for both subjects, a line-graph representation of the topographic analysis, pre- and post-training, of the microvolts of theta/beta ratios will be presented. School records, GPAs and behavioral comments, from both subjects for the school year during which neurofeedback occurred and the school year after training will be presented as well. To further assess the potential success of the treatment, the parents of the subjects were asked to determine if their stress level, related to parenting, had changed any from the subjects' sixth grade year to their seventh grade year. The results of this questionnaire will also be presented.

CHAPTER IV

Results

Outlined in table 1, the beta and theta activity over all conditions of neurofeedback training showed strong correlations between the number of sessions and the EEG activity recorded of both subjects. This significant statistical analysis supports the graphic representations presented in Figures 1-4. Figure 1 shows that the amount of inhibited theta activity, produced by S1, started at approximately 60% and ended at approximately 15%. Figure 2 shows that the amount of non-inhibited beta activity, produced by S1, started at approximately 30% and ended at 80%. The reader will also note when viewing Figures 1 and 2, that from session #20 to session #23 there is a reversal in the trends. This reversal is explained by the fact that the subject was taking an antihistamine during that period, and when he came off the drug the trends reversed again, and there was no loss in learning. Figure 3 shows that the amount of inhibited theta activity, produced by S2 (who is the hyperactive child and on Ritalin), started at approximately 60% and ended at 10%. Figure 4 shows that the amount of non-inhibited beta activity, produced by S2, started at approximately 25% and ended at 85%. These graphs show distinct learning curves in the reduction of inhibited theta activity of both subjects, and in the increase of the

non-inhibited beta activity of both subjects.

Figures 5 and 6 are bar-graph representations of WISC-R and WRAT-R scores for both subjects. Subject 1 showed highly improved scores on all 3 WISC-R scales. The verbal category was +25 points post-training, the performance category was +23 points post-training, and the full scale category was +26 points post-training. For subject 1, the WRAT-R profile showed increases of +21 points on reading, +6 points on arithmetic, and the only negative result was -10 points drop on spelling. Subject 2 showed improved scores on the WISC-R as well. The verbal category was +10 points post-training, the performance category was slightly worse at -7 points post-training, and the full scale category had a slight improvement of +1 points post-training. However, for subject 2, the WRAT-R profile showed increases of 5 to 7 points on all categories. Figures 7 and 8 are line-graph representations of the microvolts of the theta/beta ratios from the topographic analysis of the brain mapping procedure for both subjects. These topographic analyses represent the microvolt level (or size) of the theta activity relative to the microvolt level of the beta activity in the form of ratios. The data suggests that the neurofeedback training may have had an effect on these ratios at the points of placement of the electrodes, specifically FZ and PZ. The lowering of the ratio at CZ indicates that there may have been a generalization of learning between the two specific

placements.

Table 2 is a representation of the GPAs of both subjects from the sixth grade (during treatment) and the seventh grade (after treatment). Teacher comments on the subjects' behavior from both school years, taken from the same report cards, are as follows. For subject 1, in the sixth grade, comments were typically satisfactory. In the seventh grade, teacher comments had remained the same, satisfactory. For subject 2, in the sixth grade, comments were not satisfactory. In the seventh grade, the comments were now satisfactory. The results of the stress-related questions for the parents of both subjects were in keeping with the results previously presented. The parents of subject 1, on a scale of 1-5 (1- not stressful and 5- most stressful), indicated that, in terms of completing homework assignments, parent-teacher conferences, enforcing study habits and behaviors, turning-in completed work, and bringing home essential items (books, xeroxes, etc.) questionnaire responses had gone from 4s to 2s during the sixth grade to the seventh grade. For the parents of subject 2, asked the same questions, the results were 5s during the sixth grade, down to 4s during the seventh grade.

CHAPTER V

Discussion

The title of this thesis indirectly poses the question, is neurofeedback a viable alternative and/or adjunctive treatment for ADHD? One of the strengths of neurofeedback is that it is a coping device that will allow people with ADHD to learn to recognize when they are producing beta and/or theta. Once a person can become aware of a behavior or activity they may then be able to correct the inappropriate behavior or activity. Although this is only a dual case study, the results are consistent with the possibility that there are many positive effects which suggest that the neurofeedback treatment for ADHD is viable. Clearly, subject 1 had the greater benefits from the treatment, but subject 2 showed benefits as well, although the results were less dramatic. The primary differences between the two boys are: (1) that one of the subjects is hyperactive and on Ritalin (refer back to the criticisms section on pharmacological treatments of ADHD and the possibility that cognitive functioning may actually be impaired by the drug), and (2) it may well be that the parents of subject 1 followed through with the informal suggestions about behavior management techniques and the development of better habits for handling schoolwork and

homework, while the parents of subject 2 did not. Also, the need for family counseling to help deal with the special difficulties associated with raising an extremely hyperactive child was not entertained by the parents of subject 2. Therefore, the fact that some success was seen for subject 2 may well be attributed to his successful application of learning acquired during his neurofeedback training. The results clearly showed some degree of success for both subjects.

As stated previously in the text, criticisms of neurofeedback include a lack of research to either confirm or deny the usefulness of this treatment modality. The reason for the lack of research has been explained as well previously in the text. Another criticism of neurofeedback that may arise is a lack of any type of controls in the research. I think this issue must be addressed from an ethical point-of-view. When doing neurofeedback, the researcher is literally giving the subject information about how the subject's brain is functioning. If one were to give that subject bogus or even random rewards, there is no way to know what brainwave activity is actually being reinforced. What if, for instance, the subject was producing epileptic activity at that moment? How could anyone chance reinforcing something that could potentially have detrimental effects on the subject? Perhaps the software could be developed to avoid this potential problem,

however, at this point such software is not on the market. One possible answer, I believe, would have to be a waiting list type of control group. Another possible control study could be to compare neurofeedback with the other types of treatments available. Another possibility would be to add to this study two more subjects, one that is equally hyperactive but not being treated pharmacologically and one that would receive no neurofeedback but would receive all the other therapist interactions within a session. Lack of long term follow-up data is another frequently seen criticism in the literature for the other forms of treatment for ADHD. It could conceivably be used in the criticism of neurofeedback as well. The current and future researchers into this subject will need to be aware of this problem and need to address it.

Another possible criticism is that, as with any therapeutic approach, the person's motivation to achieve and the therapist's ability to establish rapport and encourage success will influence the results. Yet the same could be said about the more traditional behavior management techniques; and to some degree, the pharmacological approach as well (the person must believe in the prescriber and take the medication to benefit).

One last criticism found in the literature about treatments of ADHD is that there is no evidence to support that the treatment crosses over into the life of the ADHD

child. However with neurofeedback, as explained in the methods section, every effort is made to encourage the child to use and develop strategies to control their brainwave activity while engaged in academic tasks. And the maintenance approach to termination also discourages extinction of the operantly conditioned responses learned to enhance attending behaviors and decrease the day-dreaming behaviors. Neurofeedback is not a panacea, or some type of cure for ADHD. What neurofeedback is, however, is a strong coping device that will allow people with ADHD to learn to become more aware of what it is that they are doing that interferes with their ability to attend and what it is like when they are daydreaming too much. Once a person can learn to be aware, then they can learn to recognize and correct the inappropriate behaviors.

There is one other issue I would like to address in this discussion. In my review of the literature there seemed to be an overwhelming sense of one approach to treatment vs. another type of treatment approach. There were a few articles that seemed to advocate a combination of treatments, but that appeared to be the exception rather than the rule. The Us vs. Them mentality seems to be present in a large portion of the literature. Surely, it must be recognized by the professionals that work with ADHD that this is a very complex and difficult disorder and can be treated best by utilizing all our resources available.

The newest and very promising resource available is neurofeedback, which may be used as a valuable alternative and/or adjunctive treatment for ADHD in addition to the traditional methods of treatment.

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APPENDIX

Table 1

SPEARMAN'S RANK CORRELATION COEFFICIENTCorrelation of Sessions by EEG Activity

Conditions	Beta		Theta	
	Subject 1	Subject 2	Subject 1	Subject 2
Baseline	.706*	.723	-.743	-.781
Feedback	.740	.801	-.799	-.742
Listening	.816	.801	-.803	-.842
Reading	.832	.802	-.841	-.783

* All correlations significant at the .005 level.

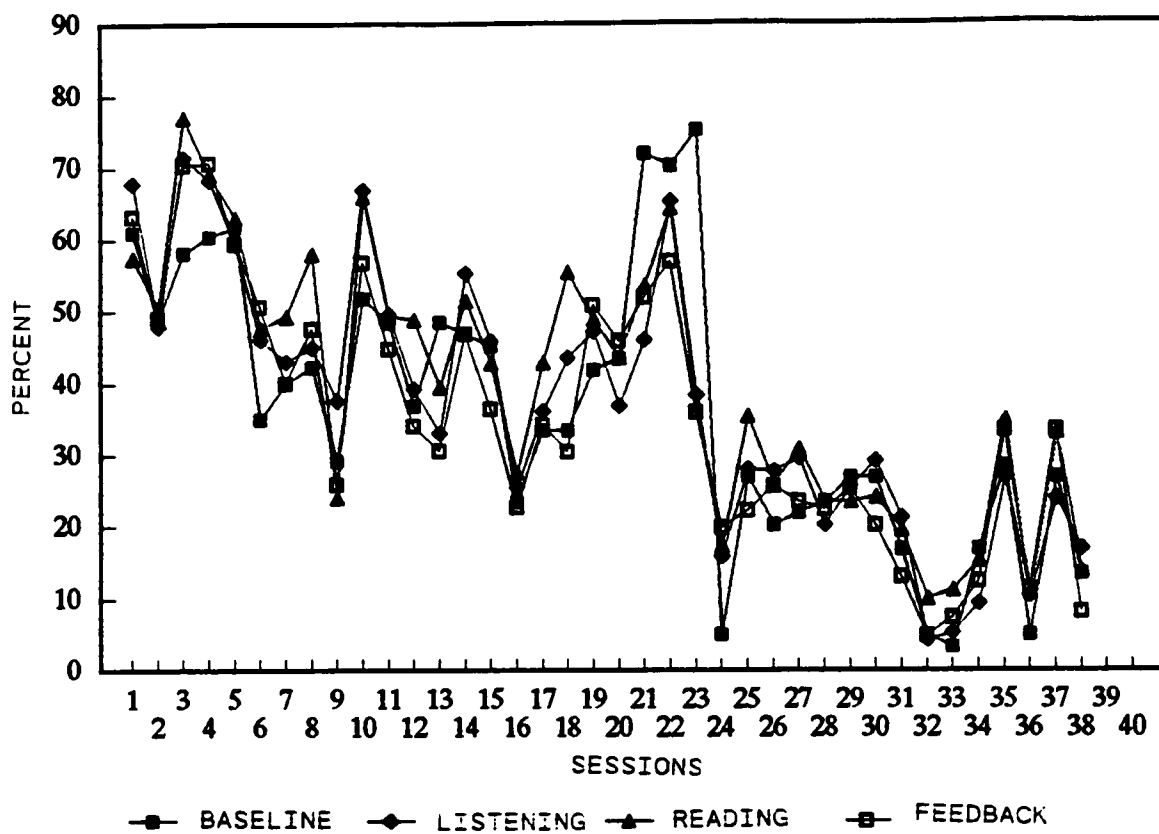


Figure 1. Percentage of theta for all conditions, subject 1

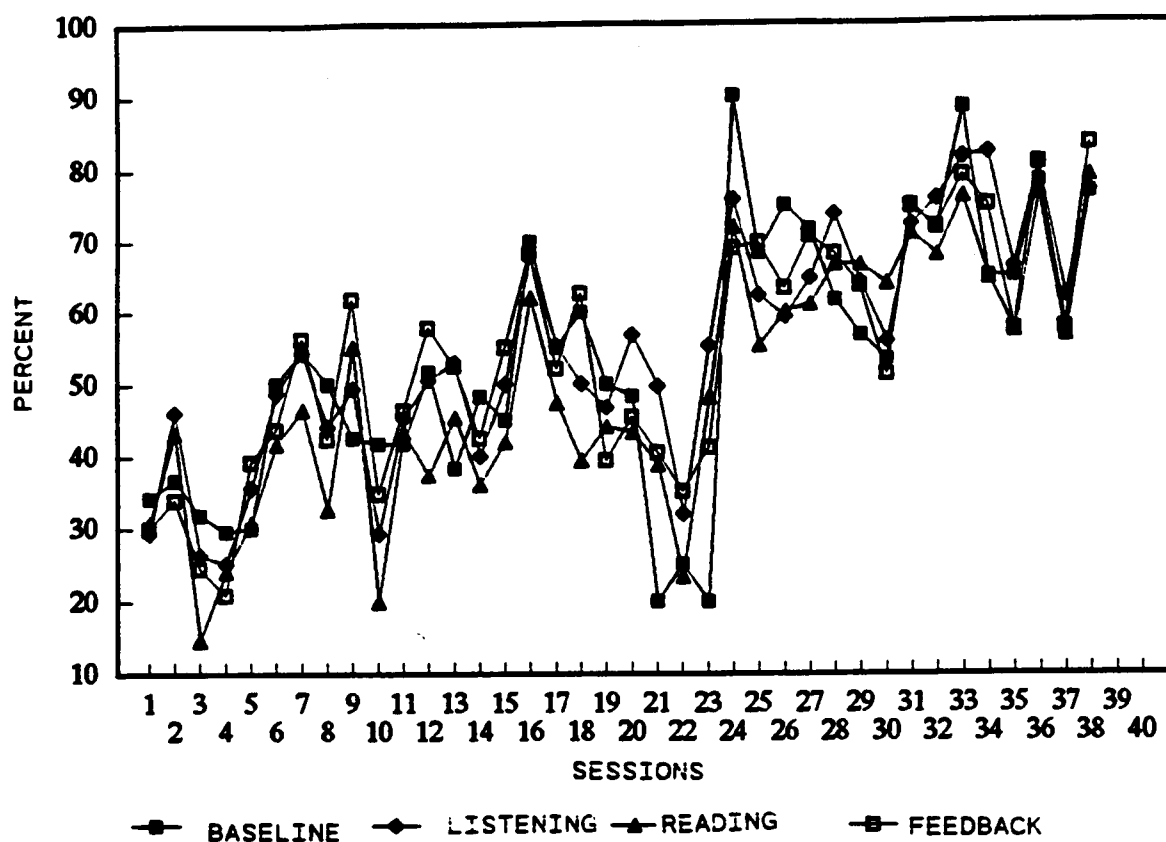


Figure 2. Percentage of beta for all conditions. subject 1

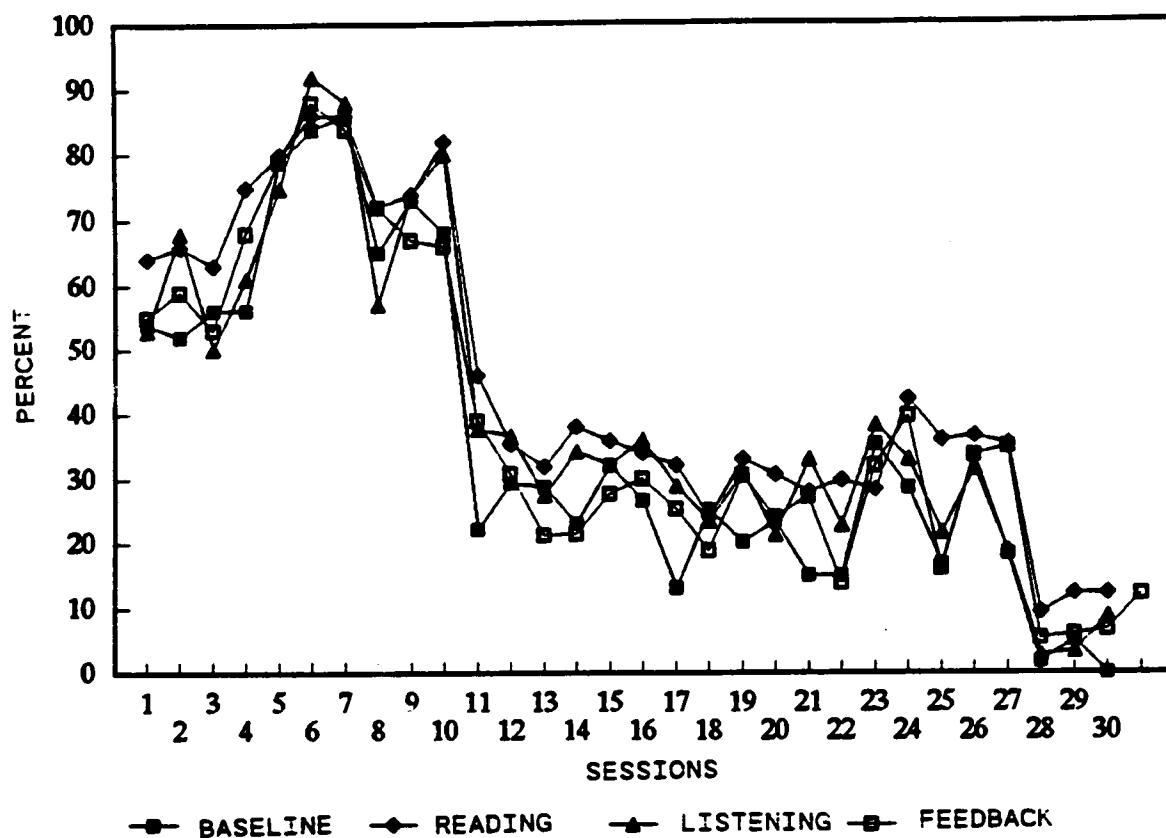


Figure 3.* Percentage of theta for all conditions, subject 2 (*Hyperactive and taking Ritalin)

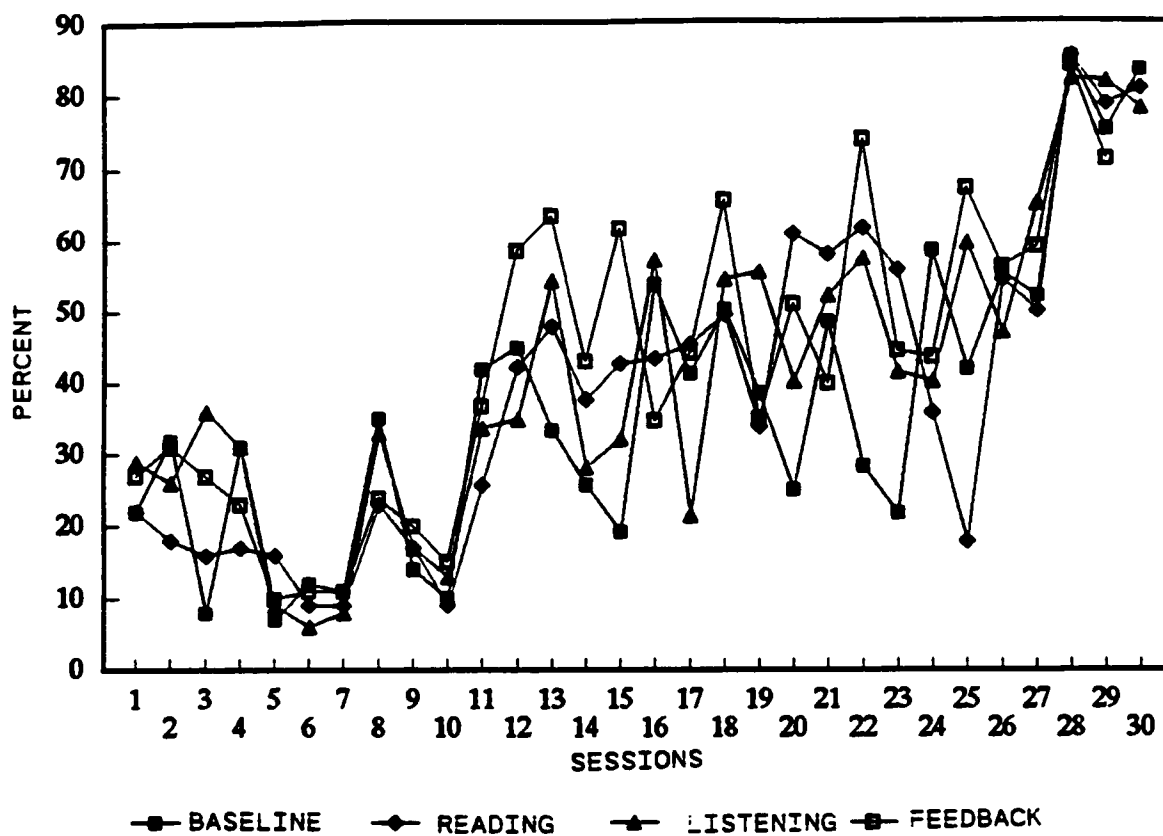


Figure 4.* Percentage of beta for all conditions, subject 2 (*Hyperactive and taking Ritalin)

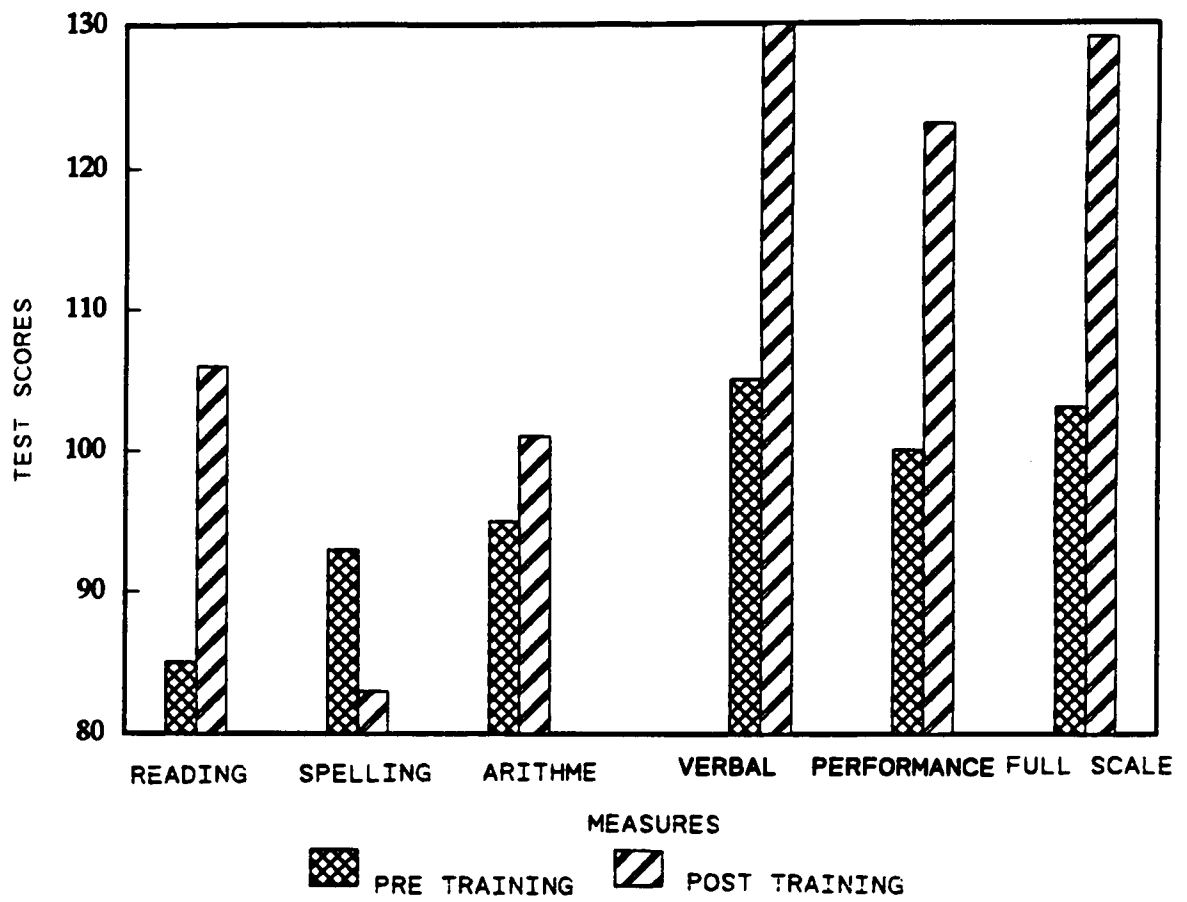


Figure 5. Pre-Post Training WRAT-R and WISC-R scores, subject 1

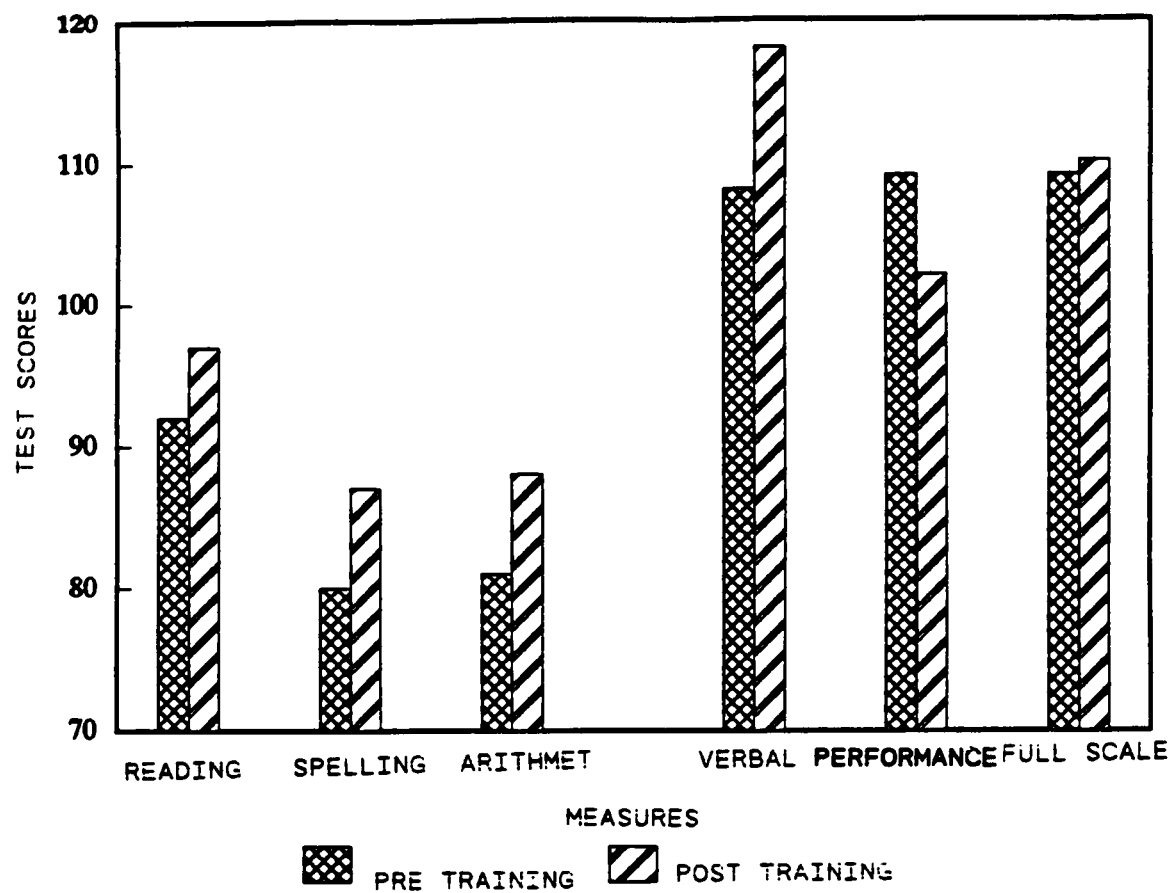


Figure 8. Pre-Post Training WRAT-R and WISC-R scores, subject 2

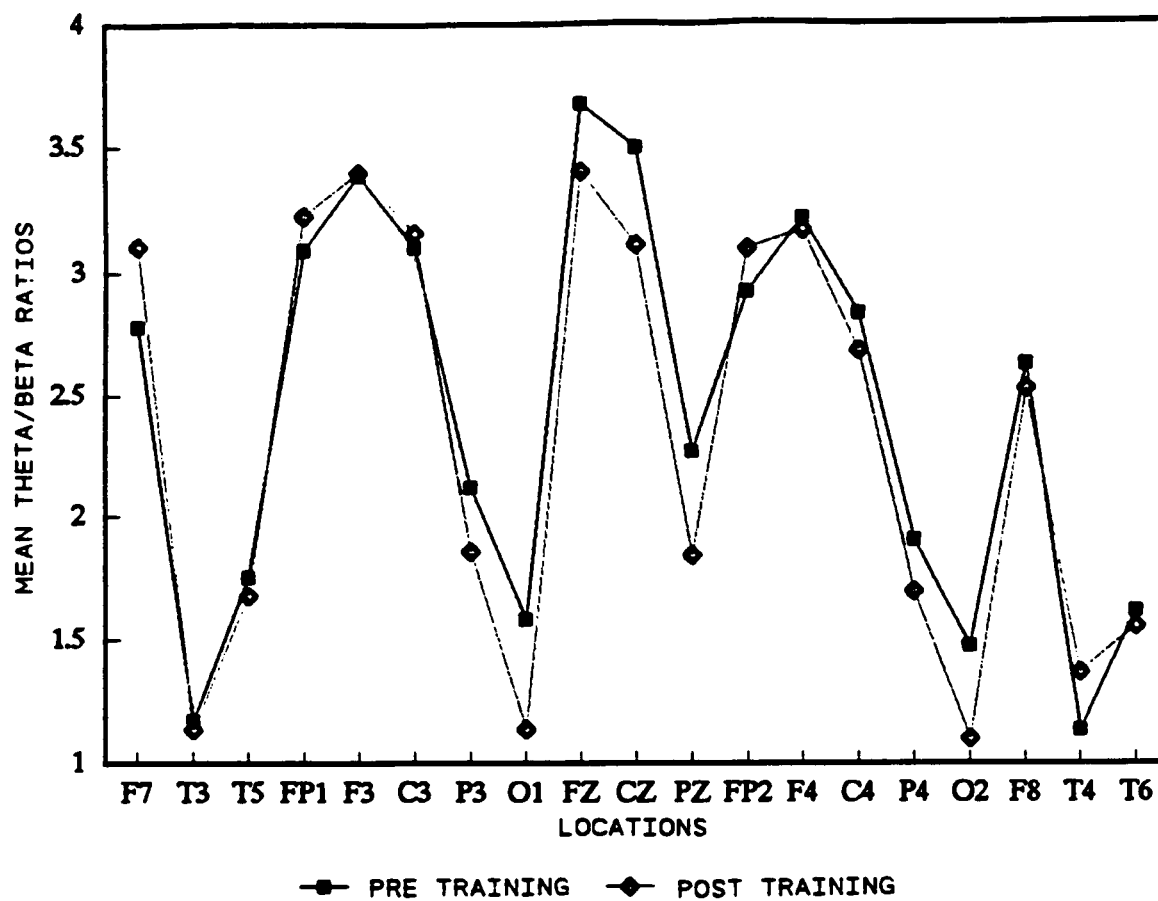


Figure 7. Theta-Beta Ratios (Microvolts) Pre and Post Training, subject 1

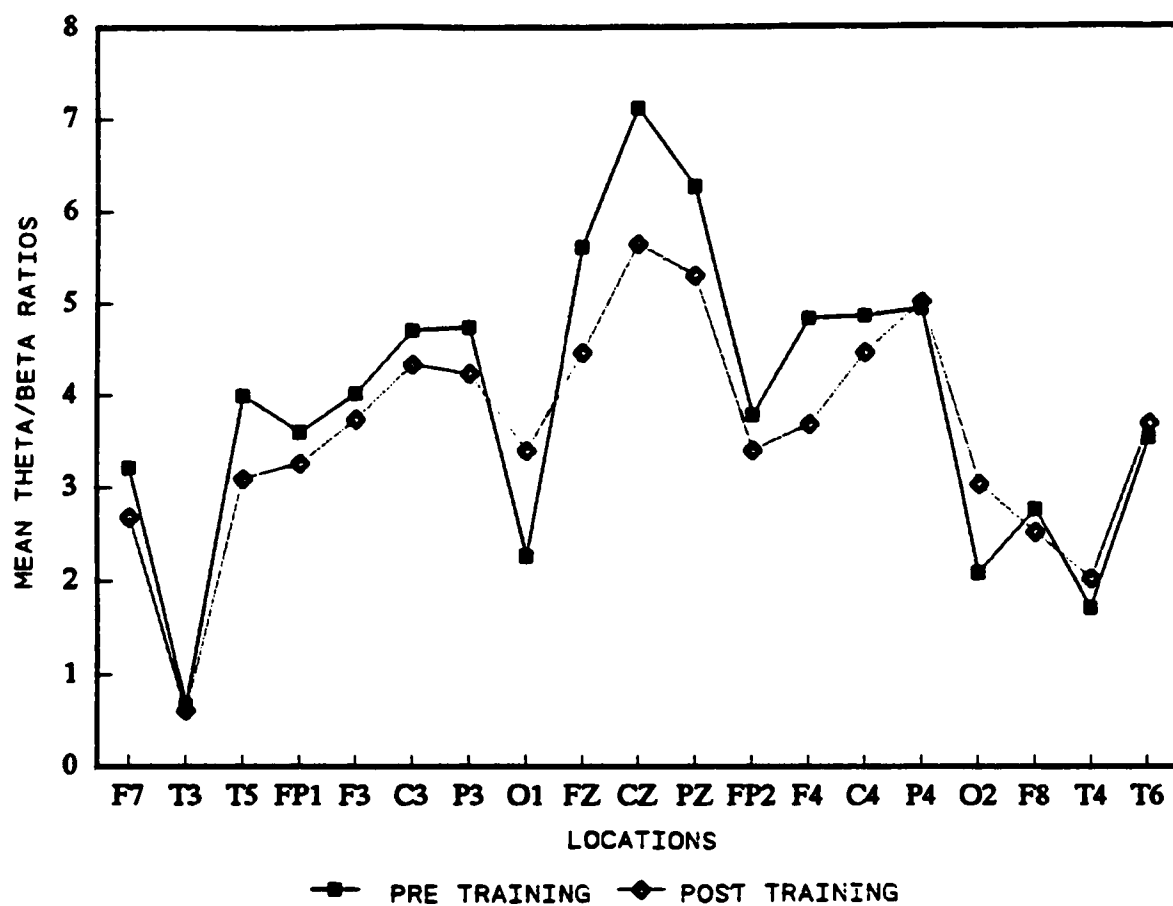


Figure 8. Theta-Beta Ratios (Microvolts) Pre and Post Training, subject 2

Table 2

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Subjects' GPAs Pre and Post Training

	PRE TRAINING GPA	POST TRAINING GPA
SUBJECT 1	2.33	3.00
SUBJECT 2	2.33	2.50

PARENT'S STRESS QUESTIONNAIRE

During the your child's sixth grade school year and seventh grade school year, on a scale of 1 - 5, (1-no stress, and 5-most stress) please rate your stress level while in the following situations:

(1) getting your child to start/complete homework assignments:

6th grade:

7th grade:

(2) attending parent-teacher conferences:

6th grade:

7th grade:

(3) enforcing study habits and behaviors on your child:

6th grade:

7th grade:

(4) getting your child to turn in completed assignments:

6th grade:

7th grade:

(5) getting your child to bring home essential items (e.g. books, xeroxes, etc.):

6th grade:

7th grade:

VITA

Jennifer Pauline Samples was born in Chicapee, Massachusetts on July 8, 1960. She attended elementary schools on Clark Air Force Base, Philippines; in Camp Springs, Maryland; and on Maxwell Air Force Base, Alabama. She graduated from Homewood High School in June, 1978. The following September she entered the University of Tennessee, Knoxville and in December, 1982 she received the degree of Bachelor of Arts in Liberal Arts with a major of Psychology. She reentered the University of Tennessee in the Fall of 1984 and in August, 1993 she received a Master of Arts in Liberal Arts with a major of Psychology.

She is now presently employed as a practitioner of biofeedback/neurofeedback at SouthEastern Biofeedback & Neurobehavioral Institute, in Knoxville, Tennessee.