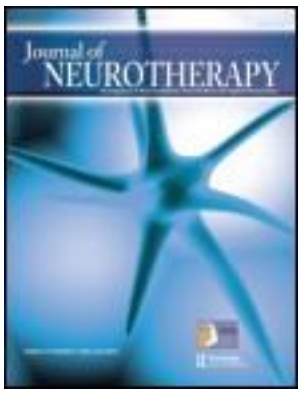

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A Comparison of EEG Biofeedback and Psychostimulants in Treating Attention Deficit/Hyperactivity Disorders

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A Comparison of EEG Biofeedback and Psychostimulants in Treating Attention Deficit/Hyperactivity Disorders

Thomas R. Rossiter, and Theodore J. La Vaque

The study compared treatment programs with EEG biofeedback or stimulants as their primary components. An EEG group (EEG) was matched with a stimulant group (MED) by age, IQ, gender and diagnosis. The Test of Variables of Attention (TOVA) was administered pre and posttreatment. EEG and MED groups improved ($p < .05$) on measures of inattention, impulsivity, information processing, and variability, but did not differ ($p > 0.3$) on TOVA change scores. The EEG biofeedback program is an effective alternative to stimulants and may be the treatment of choice when medication is ineffective, has side effects, or compliance is a problem.

The purpose of the study was to examine the efficacy of 20 sessions of EEG biofeedback in reducing AD/HD symptoms and to compare the results with those obtained with psychostimulant medication. Psychostimulants are the most widely used treatment for AD/HD (Barkley, 1990). In order to be a widely accepted alternative to medication, EEG biofeedback must be able to produce equivalent symptom reduction.

Reports documenting the use of EEG biofeedback in the treatment of attention deficit hyperactivity disorder (AD/HD) began to appear in the literature in the mid 1970's (Lubar & Shouse, 1976). In recent years the use of this treatment has become more widespread and has received increasing attention from the professional community and the public. The increased professional interest may be due to a number of factors including the reported effectiveness of the treatment, the availability of relatively inexpensive, high quality, quantitative EEG equipment, an expanding number of opportunities for training in the use of EEG biofeedback, and the emergence of scientific interest groups that have facilitated the promulgation of information in this area.

With increasing exposure, EEG biofeedback has been subject to greater scrutiny from the biofeedback community as well as professions dealing with the diagnosis and treatment of AD/HD. Barkley (1992, p. 10) concluded that "there is not enough evidence from well controlled scientific studies at this time to support the effectiveness of EEG biofeedback for AD/HD children." He criticized studies that used small numbers of subjects, lacked appropriate control groups, used diagnostic criteria that were unspecified or ambiguous, confounded treatment effects by using multiple interventions (e.g., academic tutoring, self control training, etc.), and employed outcome measures susceptible to practice and/or placebo effects. Some of Barkley's criticisms are valid (Lubar, 1993) and are being addressed by controlled studies using larger numbers of subjects.

Linden, Habib, & Radojevic (in press), using a waiting list control, demonstrated that 40 sessions of EEG biofeedback resulted in significant increases in IQ and reductions in parental reports of inattentiveness for the experimental, but not the control group. Cartozzo, Jacobs and Gevirtz (1995) found that 30 sessions of EEG biofeedback led to a significant reduction in theta (4-7 hz) amplitude, increased attention span on the Test of Variables of Attention (TOVA), and improved scores on the Freedom from Distractibility (FD) factor from the Wechsler Intelligence Scale for Children-Revised (WISC-R). A pseudo-treatment control group showed a significant increase in theta amplitude and no improvement on the TOVA or the WISC-R

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Freedom from Distractibility factor. Scheinbaum, Zecker, Newton and Rosenfeld (1995) compared an EEG biofeedback group to a "cognitive control therapy" group. Only the EEG biofeedback group showed significant improvement on the TOVA at post-treatment testing. More controlled experimental studies are necessary to demonstrate that EEG biofeedback has an independent effect in reducing the symptoms of AD/HD. However, clinical outcome studies that compare EEG biofeedback with other forms of treatment, particularly psychostimulants, are also needed to establish the relative effectiveness of EEG biofeedback as a treatment for AD/HD.

Treatment of AD/HD has traditionally involved use of psychostimulants and/or behavioral interventions. Among the psychostimulants, methlyphenidate, dextroamphetimine, and pemoline are the most commonly used medications, respectively. Between 70-80% of children with AD/HD appear to respond favorably to psychostimulants as compared to over 35% that improve with placebos (Barkley, 1990). The primary areas of improvement include attention span, impulse control and reduced motor activity. However, psychostimulants are not without their drawbacks. "To date research studies have not found any single treatment which provides for any long-lasting improvement in ADHD children, particularly once treatment is terminated, and that generalizes to other situations where the treatment wasn't given" (Barkley, 1992, p. 8). This is perhaps the most serious shortcoming of psychostimulants in treating AD/HD. The benefits are temporary unless the patient is willing to take the medication indefinitely (Barkley, 1990). In addition, side effects including decreased appetite, insomnia, anxiety, irritability, stomach aches and headaches occur in 20-50% of children treated with psychostimulants (S. Goldstein & M. Goldstein, 1990). In most cases, the side effects are mild and short term (Barkley, 1990). A potentially more serious, but infrequent, side effect involves the possible development or increase in tics produced by psychostimulants (Denckla, Bemporad, & MacKay, 1976).

Noncompliance with taking medication is a major factor limiting the effectiveness of psychostimulant medication. Long term compliance rates are typically poor and may be especially problematic among families of low socioeconomic status (Barkley, 1990). Many adolescents actively resist taking psychostimulants whether the medication has been helpful to them in the past or not. This might not be a serious problem if AD/HD children outgrew the disorder when they reached puberty as was previously believed. However, it is now estimated that only 30-40% of children with AD/HD have no residual symptoms of the disorder by their late adolescent or early adult years (Weiss & Hechtman, 1993). The remaining 60-70% continue to experience significant AD/HD symptoms that impair their emotional, social, academic and/or vocational functioning. The unwillingness of many adolescents to continue treatment with psychostimulants severely limits their treatment options.

Decisions regarding various treatments for AD/HD, including EEG biofeedback, are usually made in the context of limited health care resources. An informed decision requires information regarding the efficacy of EEG biofeedback compared to medication and other forms of treatment, the expected duration and cost of EEG biofeedback, how quickly response to treatment can be assessed, and what long term outcome(s) can be expected with the competing forms of treatment. The present study may help address some of these issues.

The present study uses a clinical trials methodology to compare the efficacy of two treatment programs which have EEG biofeedback and psychostimulents as their primary components. Kazdin (1986) views analogue studies and clinical trials as being at the opposite ends of a continuum of research methodologies in assessing treatment. Analogue studies refer to investigations of treatment procedures in the context of highly controlled laboratory conditions that only approximate the clinical situation. Analogue research is best suited to investigate specific aspects of treatment, the mechanisms responsible for change,

factors that influence treatment efficacy and similar issues requiring precise experimental control. Clinical trials are the most appropriate method for examining the effectiveness of alternative treatments under clinical conditions. Clinical trials utilize patients who have come to a clinic seeking services as opposed to college students or recruited volunteers. Because the research is conducted in a clinic setting, some compromises in research methodology and experimental controls often have to be made for practical and ethical reasons. Treatment is tailored to the individual and is determined on the basis of the patient's problems. Furthermore, it is the patient, rather than the clinician, who is ultimately responsible for choosing the treatment. In essence, a clinical trial provides treatment under many of the conditions where it would be applied in clinical practice. Thus, the results have the potential for broad applicability.

Since patients were drawn from a clinic population rather than being randomly assigned to treatment groups, they were matched on relevant demographic and treatment variables. Treatment(s) provided to each patient were based on the needs of the patient and were not limited to EEG biofeedback or medication. A multimodal approach to the treatment of AD/HD is generally considered preferable to reliance on any single intervention (Barkley, 1991; S. Goldstein & M. Goldstein, 1991; Lubar, 1995). Longitudinal studies of AD/HD suggest that the best long term outcomes are obtained with multiple interventions which change over time, but are based on the current needs of the patient (Weiss & Hechtman, 1993). By designing individualized treatment programs for both the EEG and MED patients, the results obtained are more likely representative of the outcomes that can be expected in clinical practice.

The Test of Variables of Attention (TOVA) was chosen as the instrument with which to compare matched groups of EEG biofeedback and medication treated patients because it is sensitive to the effects of both psychostimulants (Crosby, Corman, & Greenberg, 1992) and EEG biofeedback (S. F. Othmer & S. Othmer, 1992). The TOVA has the further advantage that, being computer administered and scored, it provides objective data that is relatively free of human bias. The same cannot necessarily be said of patient, parent, or teacher reports of behavioral changes whether obtained via interview or standardized questionnaires.

The purpose of the study was to: (1) demonstrate that 20 sessions of an EEG biofeedback program significantly reduce the cognitive and behavioral symptoms of AD/HD; (2) compare the results obtained with the EEG biofeedback program to those obtained with the psychostimulant medication program.

Method

Participants

The participants were 46 patients seen at two outpatient mental health clinics on a fee for service basis. They were referred by their parent(s), physician, school, or were self referred. The patients were evaluated by the first author and received a primary DSM-III-R (American Psychiatric Association, 1987) diagnosis of Attention Deficit Hyperactivity Disorder (ADHD) or Undifferentiated Attention Deficit Disorder (UADD). They included patients between 8 and 21 years of age, with IQ's between 80 and 120, who were administered the Test of Variables of Attention (TOVA) pre and posttreatment. Two treatment groups of 23 patients each were formed. The first group included all patients who received EEG biofeedback (EEG) as part of their treatment. The second group included patients who were treated with psychostimulants and did not receive EEG biofeedback (MED). The MED group was drawn from a larger pool of patients (N = 39) ages five to 45 and matched with the EEG group by age. Baseline evaluations were completed for both groups of patients before decisions regarding treatment(s) were made. The options of EEG biofeedback and/or a trial on psychostimulant medication were discussed with all patients regardless of their history of prior treatment with medication and/or expressed desire to receive EEG biofeedback. In some cases the

choice of treatment was dictated by the availability of insurance coverage for EEG biofeedback and/or whether the patient's schedule could accommodate the three treatment sessions per week considered optimal. Among the EEG patients with a history of treatment with psychostimulants, failure to respond to medication, limited symptom reduction, unacceptable side effects, or an unwillingness to continue use of medication were cited as reasons for seeking an alternative to medication.

Instruments

Intelligence data were obtained using the Kaufman Brief Intelligence Test (KBIT) or the age appropriate Wechsler Scale (WISC-R or III, WAIS-R). In some cases, results obtained during a school evaluation during the previous year were used. The IQ data were needed because intelligence is a factor in interpreting the TOVA performance of children and younger adolescents (Greenberg and Dupuy, 1993).

The TOVA is a 22.5 minute fixed interval visual continuous performance test (CPT) that is not language based and requires no left-right discrimination. One of two easily discriminated visual stimuli is presented for 100 ms every two seconds. The TOVA was standardized on over 1500 individuals ranging from 4 to 90 years of age and provides separate norms for males and females. The TOVA yields four outcome measures used in assessing AD/HD: errors of omission, errors of commission, average response time for the correct responses, and the standard deviation of the response time for correct responses. These four variables are interpreted as measures of inattentiveness, impulsivity or failure to inhibit response, speed of information processing and variability in attention, respectively. Two additional variables, anticipatory responses and excessive commission errors are used to determine if the TOVA results are valid.

The TOVA pattern consistent with AD/HD changes from childhood through the adolescent years. For example, excessive omission errors are a sensitive measure for younger children, but it is unusual to find deviant omission errors in adolescents and adults. In contrast, commission errors are often the only deviant finding for adults with AD/HD. These developmental trends necessitated that subjects be matched by TOVA normative age group. TOVA norms are in two year increments from ages four through nineteen and in ten year intervals for ages twenty and beyond. The TOVA has been shown to differentiate between ADHD, UADD, Conduct Disorder and normals (Waldman & Greenberg, 1992), be unaffected by the presence of a comorbid reading disorder (Dupuy & Greenberg, 1993), be sensitive to different dosage levels of psychostimulant medication (Crosby, Corman & Greenberg, 1992) and to the effects of EEG biofeedback (S. S. Othmer & S. Othmer, 1992). The test is computer administered and scored, which reduces the likelihood of human bias with respect to both the testing and outcome data. The TOVA thus avoids some of the potential difficulties inherent in relying on parent, teacher and patient reports as the primary basis for both diagnosing AD/HD and assessing treatment effects.

The Behavior Assessment System for Children (BASC) is used to evaluate children and adolescents from four to eighteen years of age. It provides teacher, parent, and self reports plus direct classroom observations and a structured developmental history. The parent and teacher questionnaires are parallel forms and permit direct comparisons on a number of scales including anxiety, aggression, attention problems, atypicality, conduct problems, depression, hyperactivity, social skills, somatization, and withdrawal.

Although a combination of the BASC instruments were used clinically, only the 6 to 11 (138 items) and 12 to 18 (126 items) year old Parent Rating Scales completed by mothers were included in the study. They were available for the largest number of EEG subjects both pre and posttreatment. The parent rates items on a four point scale indicating whether it never, sometimes, often, or almost always occurs. In addition to the clinical scales noted above, the BASC also utilizes three validity scales. The BASC provides separate scales for

measuring hyperactivity and impulsivity (Hyperactivity) and inattentiveness and distractibility (Attention Problems). This is an advantage in the differential diagnosis of ADHD and UADD. Several broader composite scales were also used in the study. The Externalizing Problems composite is characterized by disruptive behavior problems such as aggression, hyperactivity, and delinquency. The Internalizing Problems composite includes scales that measure depression, anxiety, somatization, and similar problems that are not marked by acting out behavior. The Behavior Symptoms Index provides a global measure of psychopathology derived from the other clinical scales. Over 50% of children and adolescents with AD/HD are comorbid for other disorders. The rate of comorbidity is in the range of 30-50% for Conduct Disorder, 35-60% for Oppositional Defiant Disorder, 20-30% for Anxiety Disorders, 30% for Mood Disorders, and 20-25% for learning disabilities (Weiss & Hechtmann, 1993). It was expected that changes would occur on the broader measures of psychopathology as well as the scales directly related to AD/HD (S. Othmer, S. F. Othmer & Marks, 1991).

Evaluation

The baseline evaluation for the EEG and MED subjects included the TOVA and intelligence testing if current IQ data were not available from another source. The BASC was administered for 14 of the EEG group. The remaining 10 members of the EEG group were evaluated using the Personality Inventory for Children or the MMPI-2 with patients over 18 years of age

A number of subjects in both the EEG (n = 5) and the Med (n = 4) groups were being treated with psychostimulants at the time of the baseline evaluation. With the exception of two EEG patients being treated with pemoline, all of the patients were taking methlyphenidate or dextroamphetimine. Medication was discontinued two days prior to baseline testing. This was considered sufficient to produce results not contaminated by medication effects. Methylphenidate and dextroamphetimine have half-lives and produce behavioral effects for 12 hours or less (Barkley, 1990). Pemoline has a more variable half-life and may be effective for as long as 12-18 hours (Wender, 1987). Personality and behavioral assessment was completed at the same time as the TOVA testing. After baseline testing, medication was reinstated for the five EEG patients being treated with psychostimulants and continued at maintenance levels through the 20 EEG biofeedback sessions.

Posttreatment administration of the TOVA for the EEG group was carried out after 20 EEG biofeedback sessions had been completed. This occurred from four to seven weeks after biofeedback began. Among the EEG group, five of 23 patients were still being treated with psychostimulants. For those patients, medication was discontinued two days before post treatment TOVA's were administered.

The MED group was retested while medicated from one to five weeks after starting medication. The TOVA was re-administered 90 minutes after taking the short acting form of methylphenidate or dextroamphetimine or 2.5 hours after taking the long acting forms of the medications. At that point, the medications are at peak effectiveness (Greenberg & Dupuy, 1993).

Treatment

EEG biofeedback was provided by both authors. EEG treatment protocols varied and depended on the age, presenting symptoms, and the baseline test results obtained from each patient. EEG protocols were sometimes changed during the course of treatment as targets for intervention changed, e.g., from improving attention span to reducing impulsivity. The protocols used were patterned after those of J. O. Lubar and J. F. Lubar (1984) and S. F. Othmer and S. Othmer (1992). The Lubar protocols emphasize suppressing activity in the theta range (4-8 Hz) with children and adolescents through the age of fourteen, increasing beta (16-20Hz) or sensorimotor rhythm (SMR) output (12-15 Hz) with adults twenty and older, and a combination of theta suppression and beta or SMR enhancement in the fourteen to twenty age range. The goal of

the Othmer protocols is to enhance beta (15-18Hz) or SMR (12-15Hz) production for all ages. Suppression of theta (4-7Hz) and high beta (22-30Hz) is of secondary importance.

NRS-24, NRS-1620, and NRS-2A digitizing EEG systems (Lexicor Medical Technology, Boulder, CO) were used to provide EEG biofeedback. These instruments differ primarily in the number of EEG channels available. They utilize data acquisition and patient feedback software (BioLex Version 2.0 or 2.2) that is functionally identical. EEG data were acquired using two bipolar electrodes, a forehead ground, and linked ear reference electrodes with the Lubar protocols. The Othmer protocols employed a single referential electrode, a reference electrode on the left ear, and a ground electrode on the right ear. The active electrode(s) was placed at Cz (Othmer protocols) or midway between Cz and Fz and midway between Cz and Pz (Lubar protocols) using the 10-20 International System. Skin preparation was conducted according to recommendations by the equipment manufacturer. Skin impedance during training sessions was less than 5K ohms (Lubar protocols) or less than 10K ohms (Othmer protocols).

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

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

Patients in the MED group were started or restarted on methylphenidate (n=16) or dextroamphetimine (n=7) prescribed by their personal physicians following the baseline evaluation. After the patient had been on medication for a minimum of three days with no significant side effects, the TOVA was readministered. The response to medication was determined by re-testing the patient 90 minutes after taking the medication and comparing the results with the pre-treatment TOVA. When the response to the initial dose of medication did not appear to be optimal, patients were re-evaluated using 2.5 mg or 5.0 mg increases or decreases in medication to determine the most effective maintenance dose.

Treatment was not limited to EEG biofeedback for the EEG patients or psychostimulants for the MED patients. Additional interventions were provided based on the needs of the individual patient. Ancillary treatments included school behavior modification programs aimed at improving the quality and consistency of behavior and/or schoolwork. Teachers completed behavioral and academic rating forms which were sent home daily or weekly and linked to from four to six privileges dispensed by the parents. If patients were experiencing behavior problems at home, the parents were seen as needed to develop effective behavior management strategies. These included the use of Time Out, Corrective Practice, and other behavior modification techniques. During the time period that the study was conducted, no patients were involved in individual psychotherapy or family

therapy. No academic tutoring programs or special education placements were implemented or terminated.

Results

EEG and MED patients were initially matched by TOVA age group. Analysis of relevant pretreatment demographic and treatment variables indicates that age matching produced treatment groups that were equivalent in most respects (Table 1). They did not differ in age (t = 0.19, $df = 44$, $p = .85$), gender distribution ($\chi^2 = 1.23$, $df = 1$, $p = .26$), intelligence ($t = 0.06$, $df = 44$, $p = .95$), frequency of ADHD vs UADD as the primary diagnosis ($\chi^2 = 0.11$, $df = 1$, $p = .74$), frequency of secondary/tertiary diagnoses ($\chi^2 = 1.04$, $df = 44$, $p = .31$), or frequency of Learning Disability and/or Emotionally Disturbed placements ($\chi^2 = 1.04$, $df = 1$, $p = .31$). The EEG and MED groups were not significantly different on baseline TOVA measures of attentiveness ($t = 1.02$, $df = 44$, $p = .31$), impulsivity ($t = .28$, $df = 44$, $p = .78$), processing speed ($t = .03$, $df = 44$, $p = .97$) or variability in attention ($t = .60$, $df = 44$, $p = .55$). However, more of the EEG (n = 17) than MED (n = 10) patients had previously been treated with psychostimulents ($\chi^2 = 4.39$, $df = 1$, $p = .04$).

The EEG (2/23) and MED (4/23) groups did not differ in the frequency of parents receiving behavior management training ($\chi^2 = 0.77$, $df = 1$, $p = .38$). However, patients in the MED group (13/23) were more likely than those in the EEG group (5/23) to be involved in a school behavior modification program ($\chi^2 = 5.84$, $df = 1$, $p = .02$) during treatment. The relatively low frequency of school behavior modification for the EEG group is due to the fact that many of the EEG patients were treated during the summer months when school

Table 1
EEG and Medication Group Demographic Variables

Variable	EEG	MED
Age (years)		
M	12.9	12.7
SD	2.9	3.2
Gender (n)		
Male	17	20
Female	6	3
Intelligence		
M	102.4	102.6
SD	9.9	9.4
Primary Diagnosis (n)		
ADHD	17	16
UADD	6	7
Secondary Diagnosis (n)	14	12
Treatment History (n)		
Special Education	8	7
Psychostimulents	17	10

Note. n = 23 for EEG and MED groups

was not in session.

The first purpose of the study was to demonstrate improvement in TOVA outcome variables following 20 sessions of the EEG program. Means and standard deviations for the pre and posttreatment TOVA variables are presented in Table 2. The TOVA data for the EEG group were analyzed using a one tailed t-test for dependent measures. It was predicted a priori that all four TOVA variables would demonstrate significant improvement following treatment. These predictions were confirmed. The EEG group showed increased attentiveness (t = 3.01, df = 22, p = .003), reduced impulsivity (t = 2.47, df = 22, p = .01), increased processing speed (t = 1.85, df = 22, p = .04), and decreased variability in attention (t = 4.67, df = 22, p = .0001). It was also predicted a priori that the EEG group would show significant behavioral changes on five BASC scales (Table 3). The prediction was confirmed. A one tailed t-test for dependent measures indicated significant reductions on the Hyperactivity (t = 2.84, df = 13, p = .007), Attention Problems (t = 2.81, df = 13, p = .007), Externalizing Problems (t = 4.21, df = 13, p = .0005), Internalizing Problems (t = 5.01, df = 13, p = .0001), and Behavior Symptoms Index (t = 4.41, df = 13, p = .0004) scales.

The second purpose of the study was to compare the effectiveness of the EEG biofeedback program with that of a medication pro-

Table 2
TOVA Results For EEG And Medication Groups

TOVA Variables	EEG		MED	
	Mean	SD	Mean	SD
Omission				
Pre	86.96	24.21	93.30	17.39
Post	102.91	5.86	103.13	11.92
Change	15.96	25.42	9.83	18.86
Commission				
Pre	95.43	16.12	94.17	14.15
Post	104.78	13.42	103.65	13.27
Change	9.35	18.13	9.48	12.00
Response Time				
Pre	84.35	18.37	84.52	17.35
Post	89.52	19.27	92.48	14.68
Change	5.17	13.43	7.96	10.27
Variability				
Pre	84.09	16.12	87.26	19.33
Post	97.30	16.90	102.30	15.88
Change	13.22	13.57	15.04	17.70

Note. Test Of Variables of Attention scores are standard scores with M = 100, S D = 15. n = 23 for EEG and MED groups.

Table 3
EEG Group BASC Data.

BASC Scales	Pre Treatment Mean	Pre Treatment SD	Post Treatment Mean	Post Treatment SD
Hyperactivity	63.43	15.02	54.62	11.00
Attention Problems	71.29	8.65	64.69	11.28
Externalizing Problems	62.71	12.07	55.53	10.10
Internalizing Problems	61.50	13.57	51.23	10.92
Behavior Symptoms Index	67.14	12.20	56.15	10.87

Note. Behavior Assessment System for Children scores are T scores with M = 50, S D = 10. n = 14.

gram in reducing the symptoms of AD/HD. It was predicted a priori that both treatment programs would result in significant improvement on TOVA outcome measures. This hypothesis was confirmed. The MED group (Table 2) showed improved attention ($t = 2.50$, $df = 22$, $p = .01$), reduced impulsivity ($t = 3.79$, $df = 22$, $p = .0005$), improved processing speed ($t = 3.72$, $df = 22$, $p = .0006$), and reduced variability in attention ($t = 4.08$, $df = 22$, $p = .0003$). It was further predicted that there would be no significant differences between the EEG and MED groups in the degree of improvement shown. The results confirmed this hypothesis (two tailed t-test for independent measures). There were no significant differences between the EEG and MED groups on change scores (posttest score minus pretest score) for errors of omission ($t = 0.93$, $df = 44$, $p = 0.36$), errors of commission ($t = 0.03$, $df = 44$, $p = 0.98$), average response time ($t = 0.79$, $df = 44$, $p = 0.43$), standard deviation of response time ($t = 0.39$, $df = 44$, $p = 0.70$), or the sum of the change scores on the four TOVA variables ($t = 0.11$, $df = 44$, $p = 0.91$).

When the data were analyzed on the basis of the outcomes for individual patients rather than treatment group means, there was no difference between the EEG (19/23) and MED (20/23) groups in the number of patients who showed significant improvement on the TOVA ($\chi^2 = 0.17$, $df = 1$, $p = 0.68$).

Discussion

The study demonstrated that a treatment program with EEG biofeedback as the major component led to significant reduction in both cognitive and behavioral symptoms of AD/HD after 20 treatment sessions completed over a period of four to seven weeks. The EEG group manifested significant improvement in attention, impulse control, speed of information processing and consistency of attention on the

TOVA. BASC questionnaires completed by mothers confirmed the reduction in AD/HD symptoms and also indicated a decline in internalizing and externalizing psychopathology. In every case where parents and/or teachers reported significant improvement in behavior or school performance, corresponding improvement in the TOVA performance was observed. This confirms that improvement was not limited to TOVA test scores, but had generalized beyond the clinic and was observed as symptom reduction in the patients' daily lives. More importantly, the EEG biofeedback program led to improvement on all four TOVA outcome variables that was equivalent to that obtained with the medication program. The EEG program is an effective treatment for AD/HD and a viable alternative to the use of psychostimulant medication. The results indicating significant reduction of AD/HD symptoms with EEG biofeedback are consistent with those reported by Lubar (1991), S. F. Othmer and S. Othmer (1992), Linden, Habib & Radojevic (in press), Cartozzo, Jacobs & Gevirtz (1995) and Scheinbaum, Zecker, Newton & Rosenfeld (1995). Moreover, the improvement was evident in far fewer than the 40-80 sessions sometimes cited as the expected course of treatment (Barkley, 1992). This allows for conservation of health care resources by identifying patients who are not responding to treatment earlier in the treatment process.

The EEG biofeedback program is an effective treatment for AD/HD and may be the treatment of choice in cases where medication is ineffective, only partially effective, has unacceptable side effects, or where compliance with taking medication is low. In addition, 60-70% of children with AD/HD continue to have symptoms of the disorder into their adolescent and adult years (Weiss & Hechtman, 1994). Since psychostimulants do not result in any lasting reduction of AD/HD symptoms, their use must be continued indefinitely if the symptoms are to be controlled. By the time many children reach adolescence, they are no longer willing to take psychostimulants whether they had responded favorably in the past or not. For this reason, there is a substantial population of AD/HD adolescents and young adults for whom medication is not an acceptable treatment option. The EEG biofeedback program provides an alternative for this group of patients.

Among patients who have a good response to medication, the choice between EEG biofeedback and medication is not as clear cut. The EEG program is more expensive in the short run than the medication program. However, the cost differential may be declining due to better pretreatment assessment and more efficient treatment protocols . S. Othmer (1994) reports that training is successfully completed in 20 sessions for at least 30% of AD/HD patients. The EEG biofeedback program is a cost effective alternative to the long term use of medication if it results in lasting symptom reduction, particularly if the patient is one of the 60-70% who will not "outgrow" the disorder. One to ten year follow-up of successfully treated patients suggests that EEG biofeedback leads to long term symptom reduction (Othmer, S., Othmer, S. F., & Marks, 1991; Lubar, 1995; Tansey, 1993). These reports are encouraging but need to be confirmed by systematic follow-up studies with larger samples of patients using objective assessment procedures such as the TOVA, standardized academic achievement tests, etc.

EEG biofeedback is not a "cure" for AD/HD. Nevertheless, there is an increasing body of evidence to support Lubar's (1995) conclusion that EEG biofeedback, often delivered in the context of a multimodal treatment program, leads to "normalization" of behavior and can enhance the long-term academic performance, social functioning, and overall life adjustment of the AD/HD patient.

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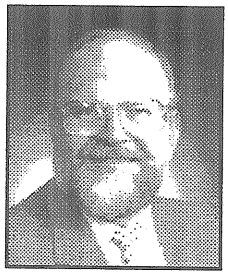

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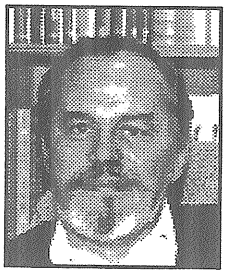

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