EEG Biofeedback for the Enhancement of Attentional Processing in Normal College Students

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College students diagnosed as free of any neurological or attention deficit disorder received EEG biofeedback to enhance beta (16-22 hertz) activity while simultaneously inhibiting high theta and low alpha (6-10 hertz) activity in order to evaluate improvements in attentional measures. *Following short-term treatment (mean number of sessions=20), subjects were evaluated as either learners or non-learners based upon standard pre- versus post-treatment neurofeedback measures. Attention quotients taken from pre and post-treatment measurements using the Intermediate Visual and Auditory (IVA) Continuous Performance Test identified significant improvements in attentional measures in learners, while non-learners showed no significant improvements. Results suggest that some "normal" young adults can learn to increase EEG activity associated with improved attention. Twenty sessions, however, even for this population may represent the lower limit for achieving significant improvement.*

Over the past two decades, the use of electroencephalographic (EEG) biofeedback has been shown to be beneficial for the enhancement of attentional processes in children and adults with attention-deficit disorder (ADD) and attention-deficit hyperactivity disorder (ADHD). For these two groups the EEG biofeedback procedure has been used to help individuals normalize neurological functioning, thereby enabling them to process information and deal with sensory stimulation more effectively (Lubar, 1985, 1991, 1995a, 1995b; Lubar & Lubar, 1984; Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992; Senf, 1988; Tansey, 1984, 1990).

Given the effectiveness of using EEG biofeedback for enhancing performance in individuals with ADHD and ADD, the next research question that needs to be answered is whether this EEG training can be used for the enhancement of attentional processing in normal individuals. The objective of this study was to determine whether the EEG biofeedback techniques effectively used to improve attentional processing for individuals with ADHD and ADD will have similar benefits for normal subjects.

Method

Subjects

Seven subjects were recruited from the undergraduate population at the University of Tennessee for participation in this project. Subjects were required to meet the following inclusion criteria: 1) between the ages of 1845, 2) classified as a freshman or sophomore, 3) cumulative grade point average between 2.0 and 2.'5 (on a 4.0 point scale), 4) free from any diagnosed learning disorder, and 5) no previous history of EEG biofeedback training. All subjects signed a consent form that had been approved by the Committee on Research Participation at the University of Tennessee. Three of the initial subjects failed to complete participation. The final sample of four included two men and two women.

Procedure

Following an initial evaluation meeting with one of the researchers to determine subject appropriateness based upon inclusion criteria, pre-treatment evaluations were conducted over a one week span. These evaluations included the following: Intermediate Visual and Auditory (IVA) Attention 7bst, Autogen A620 Neurofeedback Assessment, Quantitative Monopolar 19 channel EEG, and the Wechsler Adult Intelligence Scale-Revised (WAIS-R).

The IVA attention test is a computerized, continuous performance test designed for individuals ages eight through adult, combining visual and auditory stimuli using various computer displayed patterns. This evaluation yielded the following scores: full attention quotient, auditory attention quotient, visual attention quotient, mean response time for auditory stimuli, and mean response time for visual stimuli. Subjects were scheduled individually for the administration of this test and given general instructions concerning testing procedures. Because all test instructions and procedures for this test were automated and provided directly by the computer both in spoken and written form, the experimenter initiated the procedure for the subject and left the room.

The Autogen A620 (Stoelting-Autogenics Corp.) neurofeedback assessment was used to determine power spectrum and ratio information within various electroencephalographic (EEG) domains. This assessment was conducted using a dual sensor placement at locations FCZ and CPZ of the International 10-20 system for electrode placement. These locations are 10 percent of the Nasion-Inion distance measured from CZ anteriorly and posteriorly The sites were physically prepared using Omniprep solution to cleanse the surface and provide improved conductance. A quarter-inch high mound of Elefix (Weaver and Company) conductive cream was placed at each site with electrodes pushed through this mound to the scalp surface at their respective locations. The electrodes (Gram Instrument Co.), gold-plated silver with a central hole for the paste to extrude, were held in place using a medium-sized cotton ball. A single earclip electrode, using Electrogel to improve conduction, was placed on the left ear of the subject following a cleansing using Oniniprep solution. Following this preparation procedure, subjects were instructed to fixate on a location approximately 36 inches directly ahead of them for a period of one and one-half minutes during which data were collected.

A quantitative monopolar 19-channel EEG or "Brain Map" was used to provide percentage and power information within the following encephalographic domains: beta, alpha, theta, and delta. Information concerning the relationship between these domains was also obtained. The quantitative EEG was administered following the International 10-20 system for electrode placement and included the central locations. Prior to Electro Cap placement, an earclip electrode was placed on each ear using Electrogel to improve conductance following a preparation using Omniprep solution. Connections were made using an electrode cap (Electro Cap Company) and Electrogel was applied to each sensor using a small blunt hypodermic tube inserted through the sensor in order to improve conductance. Following preparation, data were collected under the following conditions: eyes open baseline, eyes closed baseline, a reading condition, a drawing condition, while completing the Raven's Progressive Matrices, and a listening condition.

The Wechsler Adult Intelligence ScaleRevised (WAIS-R) was used to obtain intelligence quotient and subscale scores for all subjects. It was hypothesized that through an analysis of subscale scores, specific trends relating to performance on neurofeedback parameters and attentional improvements could be identified.

Following the pre-treatment evaluations, subjects received EEG biofeedback training (mean number of sessions=20) using the Autogen A620 Neurofeedback System to increase beta (16-22 hertz) activity while simultaneously inhibiting high theta and low alpha (6-10 hertz) activity (theta-alpha). Feedback was provided individually using a dual sensor placement (bipolar placement) at location PCZ and CPZ of the International 10-20 system for electrode placement. Following the physical preparation of the scalp using Ornniprep solution a quarter-inch high mound of Elefix (Weaver and Company) conductive cream was placed at each site. Each sensor was placed into its respective mound and held in place using a medium sized cotton ball. A single earclip electrode, using Electrogel to improve conduction, was placed on the left ear following a preparation using Omniprep solution. Measures of impedance remained below 5 ohms throughout training sessions.

All feedback sessions used the following training protocol: baseline-two minutes, feedback-seven minutes, reading plus feedback-seven minutes, feedback-seven minutes, and listening plus feedback-five minutes. During baseline, subjects were asked to sit quietly and focus their attention on a picture placed approximately two feet in front of them at eye level. Subjects received no feedback concerning their performance during baseline. During both feedback only conditions, subjects were provided with both visual and auditory feedback contingent upon the production of beta EEG while simultaneously inhibiting the production of theta-alpha EEG activity. The Autogen A620 criterion for reward was set at 50 samples occurring in 0.5 seconds and the EEG was sampled at 128 samples per second. During the reading condition, subjects read to themselves passages from Fiction 100: An Anthology of Short Stories (fifth edition) or other college level material. During the listening condition, subjects listened to the experimenter read passages similar to those used during the reading condition. For both the reading and listening conditions subjects received only auditory feedback. Following the completion of each session, sensors were removed and all pastes and gels were cleaned.

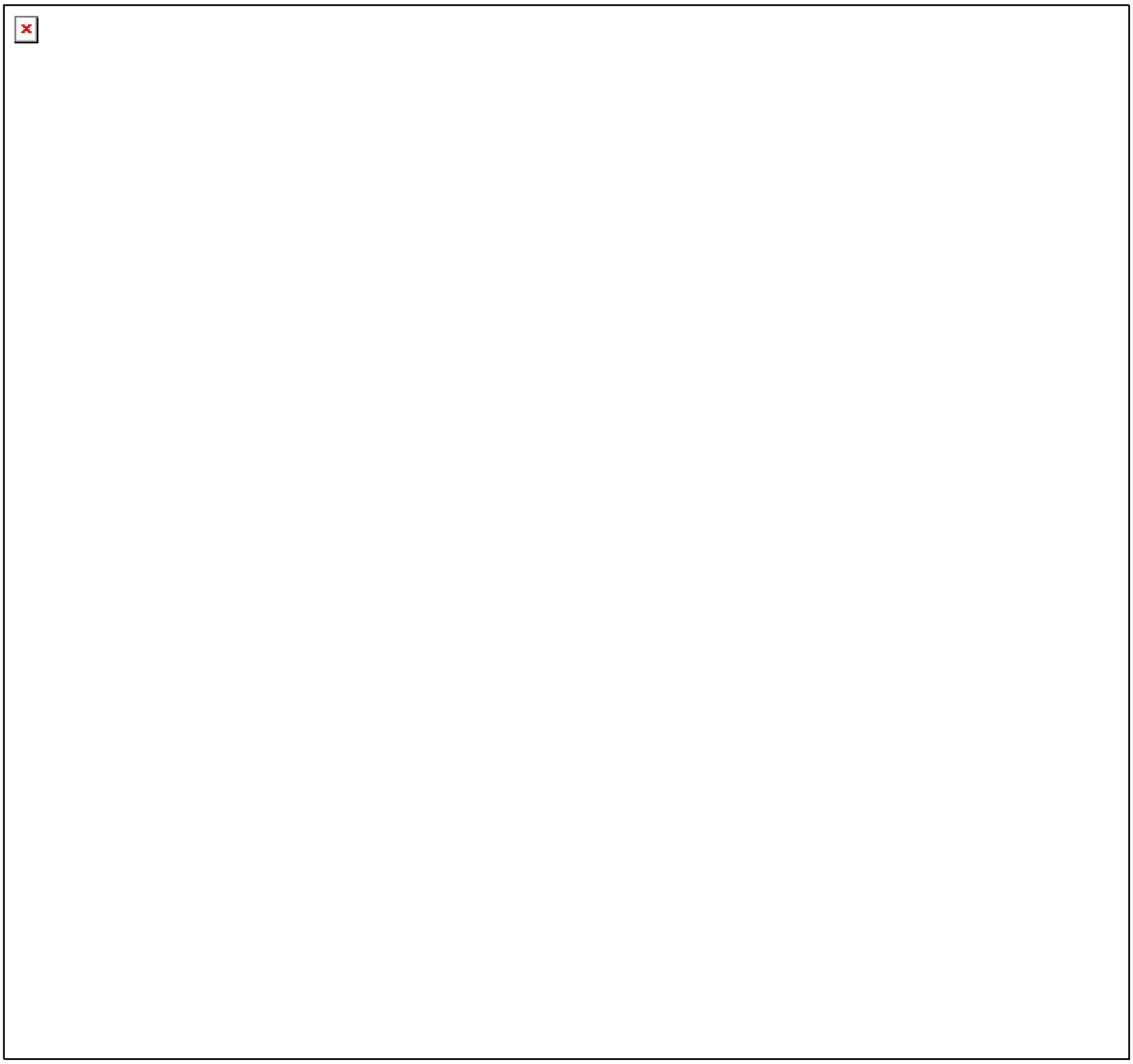
Following the treatment phase subjects were once again administered the tests utilized during pre-treatment. These tests were once again completed over a period of two weeks. All post-tests were administered at approximately the same time of day as the pre-tests in an attempt to limit any differences among scores due to daily fluctuations in EEG and other effects of circadian rhythm.

Results

Results were calculated using four of the original seven subjects. It was necessary to remove three subjects from the analysis due to non-compliance issues in one or more of the following areas: failure to regularly attend neurofeedback sessions, failure to complete required number of sessions, and failure to complete post-training assessments.

In order to assess the effects of neurotherapy for those subjects who were exposed to all procedures, Sperman RHO Correlations were obtained based upon changes from baseline in the following Autogen A620 parameters: % of EEG thetaalpha (IEEG%), % of EEG beta (REEG%), [tV levels of EEG theta-alpha (IEEG [N), [tV levels of EEG beta (REEG VV), and thetaalpha/beta ratios (I/R). Subject I (SI) obtained the following Sperman RHO Correlations: IEEG%=-0.467, REEG%= -0.078, IEEG [LV=-0.183, REEG [tV=0.037, and I/R=-0.332. For subject 2 (S2) the Sperman RHO Correlations were -0.450, 0.497, -0.344, -0.282, and -0.149 respectively. For subject 3 (S3) the

Sperman RHO Correlations were 0.214, -0-233, 0.088, -0.032, and 0.193 respectively For subject 4 (S4) the Sperman RHO Correlations were 0.419, -0.324, 0.429, 0.355, and 0.305 respectively All correlations are summarized per subject in Figure 1.



Among the parameters documented, learning is indicated by negative correlations in % of EEG theta-alpha, theta-alpha uV levels, and theta/beta ratios, and positive correlations in % of EEG beta and beta [tV levels. Based upon these observations, S1 and S2 demonstrated learning in four out of five parameters. S3 demonstrated no learning using these parameters, and S4 demonstrated learning in only one out of the five parameters.

Improvements in attentional processing were directly assessed using the Intermediate Visual and Auditory (IVA) Attention Test. Based upon a standard deviation equal to 15 points as signifying improvement between pre- and post-tests, S1 and S2 achieved Full Attention Quotient (FAQ) deviation scores of 2.2 and 3.73 respectively, while S3 and S4 achieved FAQ scores of -.93 and .13

respectively. In order to provide more specific analysis, the FAQ was divided into two sub-quotients, the Auditory Attention Quotient (AAQ) and the Visual Attention Quotient (VAQ), both of which yielded deviation scores. S1 and S2 achieved AAQ deviation scores of 1.33 and 1.67 and VAQ deviation scores of 2.0 and 1.33, all respectively S3 and S4 achieved AAQ deviation scores of -2.0 and -.13 and VAQ deviation scores of .60 and .26, all respectively

An additional IVA measurement that provides further information related to attentional processes is mean reaction time. This measurement was divided into two portions: mean auditory reaction time (MNA) and mean visual reaction time (MNV). Comparing the difference between pre- and post-test administration, S1 and S2 demonstrated MNA improvements of 74 and 52 milliseconds respectively. For S3 and S4, MNA difference scores were -68 and -33 milliseconds respectively. The difference measurements between pre- and post-tests for MN`V were 75, 68, and 44 milliseconds for S1, S2, and S4 respectively and -23 for S3.

For the purpose of WAIS-R analysis, subjects were classified as either "Learners" or "Non-Learners" based upon the results from the Sperman RHO Correlations for

neurofeedback parameters, improvements in **attentional processing measured by scores obtained from the IVA, and improvements** in mean reaction time from the IVA. Using these results, S1 and S2 were labeled as Learners and S3 and S4 were labeled as Non-Learners.

Results from WAIS-R administration revealed that all four subjects had Full Scale IQ scores in the average or above average range (98-117), and all four subjects manifested significant scatter among subscale scores. None manifested a pattern of scatter that **would suggest** a processing anomaly of a nature likely to be associated with either a specific learning disability, an Attention Deficit Disorder, or unwillingness to exert effort in response to at least circumscribed task demands. It would appear, then, that all were intellectually capable of succeeding at college level work, but that psycho-social factors reflected in scatter differences between the two groups might be related to their successes or failures as learners.

Differences between Learners'and NonLearners' scatter on WAIS-R subtests were explored. First the subtests on which each subject's observed performance differed from that expected from his or her Full Scale IQ score were identifled. A difference was considered to have been manifested when the subject's performance was three or more scaled scores less or greater than his or her mean scaled score for the eleven subtests. Then subtests on which Learners and Non-Learners consistently differed from each other in terms of expected or unexpected performance could be identified.

There was no consistent difference between Learners and Non-Learners in terms of number of subtests on which observed performances differed from expected performances. There was only one subtest in which differences were associated with learning status: Vocabulary. Here both Learners showed poorer observed than expected performances whereas the observed performance of the Non-Learners

did not differ from those which were expected for them. In fact, the scaled scores (6 and 7) on Vocabulary for both Learners were at levels that suggest impairment.

Initial results from the Autogen A620 neurofeedback assessment and the quantitative monopolar 19-channel EEG revealed no indications of attentional or neurological abnormalities for any of the subjects. Comparing pre- and post-treatment measurements, no distinct pattern of change was observed for either assessment. Distinct patterns of change were also not observed in pre- versus post-treatment WAIS-R scores. Because no distinct patterns were observed, data are not included.

Discussion

Based upon the results of the neurofeedback parameters which demonstrated that S1 and S2 improved in four out of the five measurements, and S3 and S4 improved in zero and one measurement, respectively, subjects were classified as "Learner" or "Non-Learner." Based upon the improvements in attentional performance among Learners, the results suggest that some college students can learn to increase EEG activity assessed by objective measures.

The first possible explanation for why Non-Learners were unable to perform as well as Learners may have to do with the relatively low number (mean=20) of EEG biofeedback sessions all participants received. The number of sessions required to show significant improvements has been consistently shown to be between 30 and 50 (Lubar, 1995a, 1995b; Lubar & Lubar, 1984). The mean of 20 feedback sessions received by these subjects may represent, even for a college population, the lower limit for any non-handicapped student achieving significant improvements.

Scores obtained by Learners and NonLearners on the WAIS-R Vocabulary subtest are suggestive of potential differences existing between these groups that may have led to their ability or inability to perform successfully during neurofeedback training. Ordinarily scaled scores on Vocabulary are regarded as the single best estimate of overall intellectual ability because of their high correlation with Full Scale IQ and the fact that they are relatively robust to interference from functional psychopathologies. When impaired performance is seen specifically on this subtest, it usually reflects a history of social deprivation with regard to spoken language. That is, there has usually been a marked impoverishment in the language used in the individual's familial and personal social environments. It would appear likely then, that the Learners came to college from markedly language impoverished environments. Their underdeveloped vocabularies would be specific handicaps for college achievement commensurate with their general intellectual abilities. The fact that they are in college, however, suggests that they have been ambitious to achieve more academically than their social environments might ordinarily support. The inferred high ambition to learn may account for their accomplishment during neurofeedback in a very circumscribed number of trials.

Based upon this evaluation, further investigations assessing the role of motivation and level of ambition on EEG biofeedback performance seems warranted. The important relationship between psychological factors and learning in a neurofeedback paradigm needs to be investigated because it may lead to the development of predictive measures for success. It may be that there are some individuals with normal intelligence for whom neurofeedback is not an appropriate intervention wherein for others it may be the most effective way to enhance peak academic performance. Finally, based on these preliminary results we strongly suggest that at least 30 sessions of training are necessary, even for "normal" populations, to enhance attention for complex tasks.

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