Efficacy of Neurofeedback on Adults with Attentional Deficit and Related Disorders

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INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a lifelong disorder that affects as many as one in every twenty adults. Whereas ADHD in childhood is commonly associated with poor school performance and academic achievement, in adulthood this disorder can be especially disruptive to social and vocational relationships. Many adults with ADHD experience a form of thought disorder in which multiple tracks of thought are experienced simultaneously and sometimes in rapid succession, switching between two or more different topics. To an external observer this state may appear as internal distractibility or difficulty maintaining focus on a topic in conversation (Jerome, 1997). Other problems can plague ADHD adults. Compared to normals, adults with ADHD seek out novelty (Downey, Stelson, Pomerleau, & Giordani, 1997), exhibit abnormal (lower) emotional reactions to punishment situations (Braaten & Rosen, 1997) and are impaired on mental flexibility and psychomotor speed (Silverstein et al., 1995). Adult ADHD has high comorbidity with depression, antisocial personality disorder, and alcohol and drug abuse/dependence (Downey et al., 1997; Nixon, Tivis, & Parsons, 1995). Even the onset of smoking is found to be earlier in individuals with ADHD than those without (Downey, Pomerleau, & Pomerleau, 1996).

ADHD appears to be a disorder of multifactorial etiology, involving both electrophysiological and neuroanatomical abnormalities (Zametkin et al, 1990; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1991). Neurophysiological and electrophysiological differences between ADHD children and controls suggest a possible regulatory dysfunction of arousal mechanisms may underlie the impulsive, inattentive, and hyperactive symptomatology that characterizes this disorder (Abarbanel, 1995; Othmer, 1998). Neurofeedback training is an operant conditioning technique used to reinforce or inhibit specific forms of EEG activity (Sterman, McDonald, & Stone, 1974) that impacts self-regulatory systems (Sterman, 1996) and it has been used to improve cognitive and psychophysiological functioning (Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Sterman, 1982). In one of the earliest reports on the effectiveness of neurofeedback in treating attention deficit disorder, Lubar & Lubar (1984) trained six children on SMR neurofeedback. After 10 to 27 mo of training, every child demonstrated considerable improvement in their schoolwork. Lubar's success with neurofeedback on ADHD has since been replicated many times in both outcomes studies and controlled research (e.g., Tansey, 1991; Rossiter & LaVaque, 1994; Linden, Habib, & Radojevic, 1996). Neurofeedback training also produces significant improvement on the Test of Variables of Attention, a continuous performance task which asseses sustained attention and impulse control. (Cartozzo, Jacobs, & Gevirtz, 1995).

Numerous studies have assessed the effect of neurofeedback training in children with ADHD. The purpose of the present study is to evaluate the efficacy of neurofeedback for ADHD adults seen in the clinical practice of EEG Spectrum and its affiliated offices as measured by the Test of Variables of Attention (TOVA).

METHOD

Subject population

One hundred and forty-two adults (age 19 to 79 years, mean 40.8 years) participated in this study. Females comprised almost exactly one-half of the sample (n=73). Subjects were obtained at 10 clinical settings affiliated with EEG Spectrum, Inc. and were selected based on the availability of pre- and post-training data for the TOVA. None of these subjects were on any stimulant or antidepressant medications during the test. Although most subjects suffered from ADD or ADHD, many also exhibited comorbid conditions such as Tourette's Syndrome, minor traumatic brain injury, epilepsy, anxiety disorders, and depression. The subjects also included some who were referred for ADHD but may not have met the classical diagnostic criteria for the condition.

Materials

Neurofeedback training was performed on Neurocybernetics 2-Channel EEG systems. All subjects were evaluated with the Test of Variables of Attention (TOVA) (Greenberg, 1987), a continuous performance task (CPT) that presents to a subject a geometric target or non-target. The use of a single non-target allows this test to be conceptualized as a Go/No-Go task, a form of test which is associated with frontal lobe function (e.g., Levin et al., 1991). Results from the TOVA include measures of omission errors (inattention), commission errors (impulsivity), response time (speed of information processing), and response time variability (consistency of response). This test was administered on a PC computer and used a single switch for response. This test consists of only two non-verbal stimuli which requires a subject to pay attention for 22.5 min without prolonged rest. Presentation probabilities for targets and non-targets are mixed between test halves in order to evaluate high-likelihood and low-likelihood response conditions (i.e., 20% targets first half of test, 80% targets second half), and thereby provide measures of impulsivity and inattention, respectively. Normative age-based data is available for each gender in 10- year age groups (Greenberg & Waldman, 1993).

Procedure

The training protocol consisted of rewarding enhanced EEG amplitudes in the 12-18 Hz frequency regime, while simultaneously inhibiting excessive amplitudes in the low frequency (4-7 Hz) and high-frequency (22-30 Hz) regimes. Electrode placement always included one electrode site on the sensorimotor strip (at either C3 or C4 in the standard 10-20 system) and less commonly one electrode with either frontal or parietal placement. If training was done solely at C3 and C4, then the montage was referential to the proximate ear. If training involved frontal or parietal placement, the montage was bipolar with either C3-Fpz or C4-Pz. Left-side (C3) and right-side (C4) training involved rewarding activity in the 15-18 Hz and 12-15 Hz, respectively. Occasionally, these two protocols were used in succession during a single training session with the respective duration (e.g., 10 min SMR, 20 min Beta) of the two protocols titrated on the basis of changing symptomatology and TOVA results (Greenberg, 1987). Left-hemisphere training (e.g., C3) involved Beta reward only whereas right-hemisphere training involved SMR reward only.

Training consisted of 30 min of visual and auditory feedback on the instrument, within a 45-min contact hour. Visual feedback was provided by a variety of means which map the EEG amplitude in the reward and inhibit bands into the brightness, size, and/or velocity of objects on a computer monitor. Most commonly, information about the amplitude of signals in each of the bands was given independently. Alternatively, the subject was simply be notified that an inhibit threshold was exceeded by the withholding of the conventional reward. When all reward conditions were satisfied for a minimum of 0.5 s, an auditory beep and visual incentive (e.g., highway stripe, star in sky) was provided as reinforcement. The visual feedback signal was occasionally complemented with direct tactile and auditory feedback of EEG amplitude in the reward band. Subjects were evaluated prior to and at completion of training (a minimum of 20 sessions).

A Huynh-Feldt correction for degrees of freedom was applied to the task by measure interaction to counter potential nonsphericity of the four dependent measures. Planned comparison t-tests were used to evaluate differences for each dependent measure, applying the Bonferroni correction for multiple tests.

RESULTS

Repeated measures univariate analyses of variance (ANOVA) were used to evaluate the effect of neurofeedback training on four dependent measures of the TOVA: Inattention (percent omission), Impulsivity (percent commission), Response Time, and Response Variability. Low scores were truncated at four standard deviations below normal (i.e., 40 points). Mean pre- and post-training TOVA scores are presented in Table 1.

Table 1. Mean standard scores for TOVA subtests before and after 20 or more neurofeedback sessions for 142 adults with attention problems.

	Pre-Training	Post-Training	Change
Inattention	85.9	96.1	+10.2
Impulsivity	85.4	98.7	+13.2
Response Time	103.1	103.0	-0.1
Resp. Variability	86.7	95.7	+ 9.0

A significant interaction of treatment and TOVA measure was found, F(2,231)=11.780, p < .001. As shown in Figure 1, neurofeedback training produced significant improvement in inattention scores; F(1,141)= 17.273, p < .001; impulsivity scores, F(1,141)= 85.760, p < .001; and variability of response time, F(1,141)= 26.570, p < .001. No effect of response time was found, F < 1.

Results are even more dramatic when individual data are observed. As can be seen in Figure 2, only a handful of subjects demonstrated declines in impulsivity scores while the majority improved greatly and in proportion to pre-treatment values. Improvement extended above and beyond the normal range for many individuals.

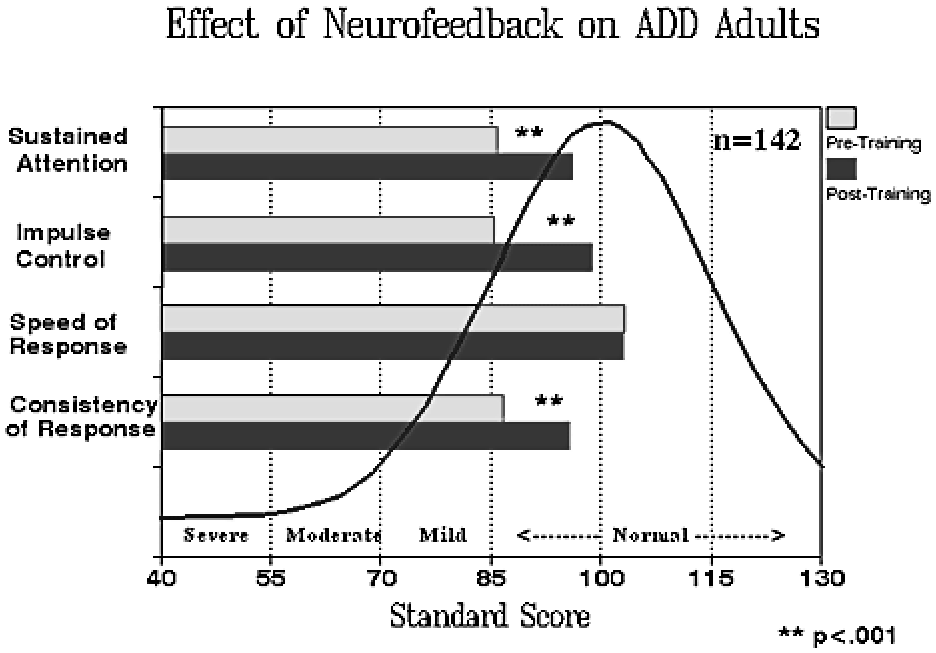

Figure 1. Pre- and post-treatment TOVA standard scores for all four dependent measures in 142 adults with attentional deficits and related disorders.

There is a systematic tendency toward improvement in attention, with the most significant improvements occurring where the pre-test scores are in most severe deficit (e.g., pre-treatment scores below 70). As can be seen, only a handful of subjects demonstrated marginal declines in impulsivity scores while the majority improved greatly and in proportion to pre-treatment values. Statistical analysis of this phenomenon supports this perception ($p < .05$). Those subjects with pre-treatment impulsivity scores greater than two standard deviations below the mean (i.e., scores of 70 and below) improved more than 27.2 points. Response variability improved 25.9 points and inattention scores improved by 40.4 points for those with pre-training scores of 70 or below.

In all, neurofeedback training produced clinically significant improvement (i.e., half a standard deviation increase or more on one or more measures), in 83 % of all subjects, a result superior to the 70% response rate of psychostimulants (Cantwell, 1994; Barkley, 1990).

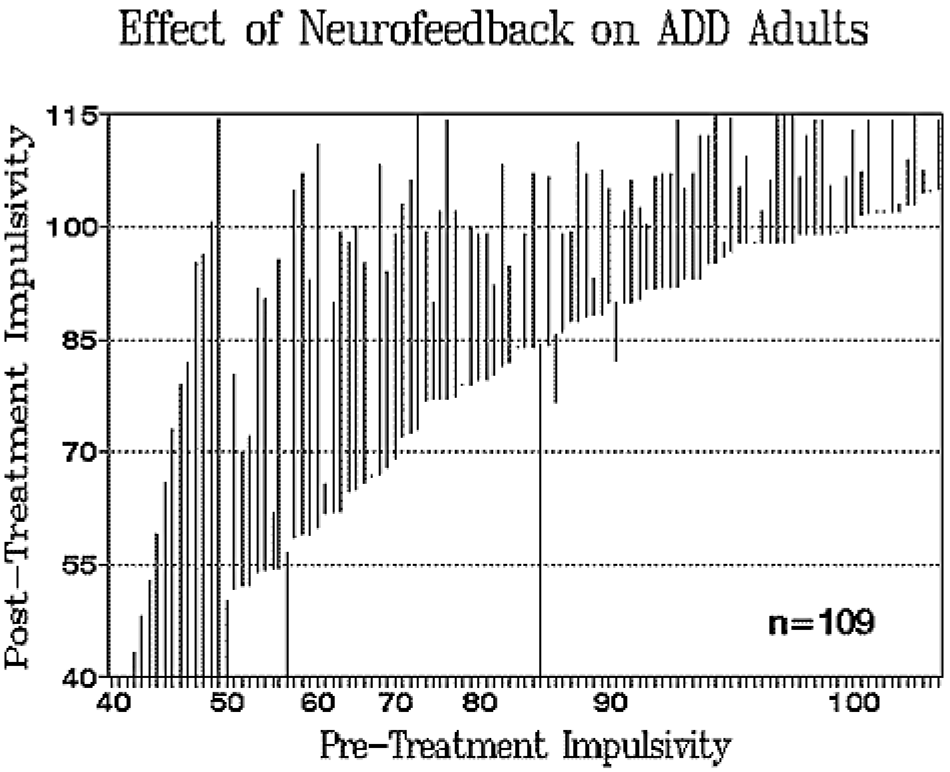

Figure 2. Pre- and post-treatment TOVA impulsivity standard scores for 109 adults. Only adults with pre-treatment scores of 105 or below were included. Each line segment represents a single subject's change from pre-training to post-training scores. The data are sorted by pre-training score. Improvement is indicated when the line segment rises above the pre-training value.

Discussion

The present study demonstrated the efficacy of neurofeedback in treating attentional deficits in adults using an outcome study. Significant improvement was found for inattention, impulsivity, and variability of response after 20 or more sessions of neurofeedback. On average, neurofeedback restored these properties of attention to nearly the population mean (i.e., value of 100).

The effectiveness of neurofeedback is all the more impressive given the fact that many of these subjects were þdifficultþ patients who had already undergone numerous prior treatments including stimulant medication with little or no success and a variety of settings and clinicians were involved in this study. Some of the adults had suffered from attentional and cognitive disorders for 20 to 30 years. All of these obstacles were overcome, indicating the robustness of this intervention. The extraordinary success rate of neurofeedback in remediating attentional problems, in the present and previous studies, at rates higher than stimulant medications in the present study, implies that profound effects on neurobiological mechanisms may be responsible for these results (Sterman, 1996; Othmer, 1998).

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