The Boys Totem Town Neurofeedback Project: A Pilot Study of EEG Biofeedback with Incarcerated Juvenile Felons

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SUMMARY. Seven male adolescents, ages 14 to 17 who were in a juvenile detention residential treatment program and diagnosed with the combined type of Attention Deficit Hyperactivity Disorder (ADHD-C) or with Conduct Disorder, participated in a study examining the effects of electroencephalographic (EEG) neurofeedback on sustained attention, response inhibition, executive functions, intellectual ability, and memory. All of the participants received 20 sessions of EEG biofeedback therapy in conjunction with treatment received in a residential program.

Pre- and post-treatment measures were collected within one week of treatment, and data were analyzed using an adapted model of Jacobson and Truax's method of clinically significant change (Jacobson & Truax, 1991) which allows criterion scores to be set and 95 percent confidence intervals determined at the level of individual performance on the collected measures. Sixty-four percent experienced improved performance

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after EEG neurofeedback on one or more measures. Clinically significant and reliable improvements were observed on teacher ratings of the Global Executive Composite from the Behavior Rating Inventory of Executive Function (average improvement = .22 mean item raw score points; Gioia, Isquith, Guy, & Kenworthy, 2000). Normal range performance was enhanced on the Composite IQ measure of the Kaufman Brief Intelligence Test (average gain = 9 points; Kaufman & Kaufman, 1990), on the Omissions subscale from the Conners' Continuous Performance Test (average decrease = 13 errors; Conners, 1994) and on the four subtest screening measures from the Wide Range Assessment of Memory and Learning (Sheslow & Adams, 1990), with average gains ranging from 2.0 to 3.67 scaled score points across the four subtests. The results are consistent with previous findings, and suggest that the methodology used for data analysis is a useful tool to assess individual levels of change, and indicate that EEG biofeedback may be a useful adjunct in the treatment of juvenile offenders.

KEYWORDS. Juvenile corrections, neurofeedback, ADHD, adolescents

INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is among the most common disorders of childhood, affecting between three and seven percent of the school age population (American Psychiatric Association, 2000). A practical definition of the disorder includes impairment in five areas: impulsivity, inattention, over-arousal, difficulty with gratification, along with emotional lability and external locus of control (Goldstein, 1999). These impaired areas of functioning currently are included in one or more of the three subtypes of the disorder, as defined by the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders-Text Revision (American Psychiatric Association, 2000): predominantly inattentive, predominantly hyperactive-impulsive, and combined types. ADHD and conduct disorders frequently are co-morbid, with a high incidence of both among persons convicted of crimes.

Over the years, numerous studies have been conducted to determine the neurobiological underpinnings of ADHD, with the primary focus being the frontal regions of the brain. There has also been a growing body of research supporting the use of electroencephalographic (EEG) neurofeedback as a primary treatment for ADHD.

ADHD, Conduct Disorders and the Frontal Regions of the Brain

The frontal lobe theory of ADHD was introduced in the 1930s, when similarities were observed between patients with lesions in the frontal lobe and children with ADHD symptoms (Aman, Roberts, & Pennington, 1998). Both groups were noted to display deficits in response inhibition, inattention, excessive restlessness and distractibility. Since that time, there has been a continuing effort to better understand the functions of the frontal lobe system and how abnormalities in these functions lead to these symptoms.

Other findings of interest regarding frontal lobe function and behavioral disorders in adolescents and children have been found. Of special relevance here are findings regarding brain electrical activity (EEG) in the frontal areas of the cortex. High absolute delta power has been seen in adolescents with oppositional and explosive behaviors (Bauving, Laucht & Schmidt, 2000). Bars, Hevrend, Simpson, and Munger (2001) found atypical frontal brain activation in children diagnosed with oppositional defiant disorder. They noted greater right than left frontal alpha power. A common finding in children with ADHD has been excessive power in slower wave (theta and alpha) portions of the EEG at frontal and central sites, often in combination with abnormally decreased power at higher frequencies.

Since there is evidence that there are deficiencies in attention, impulse control and other executive functions in many persons convicted of crimes, and since these deficiencies are known to be related to brain damage/dysfunction and EEG abnormalities, any treatment with a potential to modify brain function should prove especially useful in correctional settings. The authors conducted an investigation in which incarcerated youths with evidence of problems with attention and impulse control had their residential treatment enhanced with EEG biofeedback (neurofeedback) training designed to help improve regulation of brain function.

METHOD

This study was conducted using a within subjects, quasi-experimental design, with pre- and post-measures that assessed treatment related change in executive functions. These functions included sustained attention, response inhibition and working memory.

Participants

The sample included seven male adolescents, ages 14 to 17 years, involved with a correction-based, residential treatment program in Ramsey County, Minnesota. Participants were referred for the EEG treatment if they had a current diagnosis of ADHD, or if a screening completed by the staff psychologist indicated a diagnosis of ADHD or significant problems with impulse control. Table 1 provides information about age and diagnoses of each participant. Individuals with the combined type of ADHD are identified by the abbreviation ADHD-C. Two individuals with a primary diagnosis of Conduct Disorder were included in the sample, due to the high rate of comorbidity with ADHD, and the increased impulsivity individuals with Conduct Disorder display (American Psychiatric Association, 2000).

Participants were briefed about confidentiality and other ethical aspects of participation in this treatment, and signed permission was obtained from parents or legal guardians prior to initiation of the treatment. Participants completed pre- and post-treatment testing, which occurred in a quiet room at the residential facility.

Measures

Conners' Continuous Performance Test 3.0 (CPT; Conners, 1994): The CPT is a computer-based measure, where respondents are required to press the computer keyboard space bar when any letter, except the letter "X," appears on the computer monitor. There are 360 trials pre-

TABLE 1. Participant Characteristics

Client	Age	Primary Diagnosis	Secondary Diagnosis
1	16	Conduct Disorder	None
2	15	Conduct Disorder	None
3	17	ADHD-C	Cannabis Dependence
4	15	ADHD-C	None
5	14	ADHD-C	Major Depression
6	15	ADHD-C	Cannabis Dependence
7	17	ADHD-C	Cannabis Dependence

sented in 18 consecutive blocks of 20 trials (letter presentations). The 18 blocks are presented with three different inter-stimulus intervals (ISIs). The ISIs are one, two and four seconds, with display times of 250 milliseconds. The order in which the different ISIs are presented varies between blocks. The CPT takes 14 minutes to complete. The scores include 11 measures that reflect attention and impulse control, in addition to an overall index score. These are reported in terms of T-scores and percentiles. The number of omissions (missed targets) an individual makes is the primary measure of sustained attention, while impulsivity is measured by the number of commissions (false hits) made.

Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990): This test is designed as a clinical instrument to assess memory and learning functions across the school years. The entire battery consists of nine subtests, yielding three main scales (Verbal Memory Index, Visual Memory Index and Learning Index). These index scores are summed to create a General Memory Index. A Screening Form comprised of four subtests (Picture Memory, Design Memory, Verbal Learning and Story Memory) was used in this study. The correlations between the Screening Form and the complete WRAML standard form are .846 (ages 8 and older) and .864 (ages 9 and older). The Screening Form requires approximately 10 to 15 minutes to complete.

Behavior Rating of Executive Function (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000): This is a rating scale for parents and teachers to complete regarding the executive function-related behaviors of children, ages 5 to 18 years. Both forms contain 86 items, with eight clinical scales assessing the following executive functions: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan and Organize Materials, and Monitor. Two validity scales are included which assess inconsistency of responses and negativity. The eight clinical scales are used in computing scores on two broader indexes, Behavioral Regulation and Metacognition. These indexes provide summary information about a child's ability to shift cognitive set and modulate emotions and behavior, along with the ability to cognitively self-manage tasks and monitor performance. The Global Executive Composite is a summary score also derived from the clinical scales.

Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990): This is a brief, individually administered measure of verbal and nonverbal intelligence. It contains two subtests: Vocabulary (including Part A, Expressive Vocabulary and Part B, Definitions), and Matrices. Age-normed standard scores with a mean of 100 and a standard deviation of 15 are provided for the K-Bit IQ Composite score. This composite score has been shown to correlate well with the Wechsler Intelligence Scale for Children-Revised Full Scale IQ score ($r = .8$), supporting the construct validity of the K-Bit IQ Composite score.

Variables

Variables included: (a) changes in performance on the CPT using the measures of Omissions and Commissions and the overall Index score, (b) changes in scores on the four subtest screening form of the WRAML, (c) changes in teacher ratings on three summary scales of the BRIEF including Behavioral Regulation, Metacognition, and the Global Executive Composite, and (d) changes in the K-BIT Composite score.

EEG Apparatus

The EEG neurofeedback was provided using a Pentium II laptop computer, a 14-inch active matrix screen and Windows 98, 2nd edition as the operating system. The visual and auditory stimuli for the neurofeedback training were provided using a BrainMaster System Type 2E (BrainMaster Technologies, 2000b) and Brainwave Animation Pro software version 2.00.05 (BrainMaster Technologies, 2000c). The BrainMaster hardware samples at a rate of 120 samples per second, with an input impedance of 10 mega ohms. The amplifier has a bandwidth of .5 to 40 Hz, with a common mode rejection of 90 db.

The Brainwave Animation Pro software filters the EEG data stream into its component bandwidths using third order Butterworth filters, and displays both raw and filtered wave forms on screen. Feedback is provided by means of computer animations that play or pause, and the playing of a single tone. The animations play (progress) and the sound plays when all designated thresholds are being met, playback of the animation and play of the sound pause when the thresholds are not met. A midi tune (user selectable) begins to play after 100 points have been scored within a three-minute period. If the score for any three-minute period is higher than the score for the immediately preceding period a special animation plays.

Procedure

Seven participants completed both pre- and post-testing using the BRIEF, Conners' CPT, K-BIT and WRAML, and 20 neurofeedback sessions. The pre-testing was completed one week prior to the initiation of neurofeedback training and the post-testing was completed within one week after completion of the training. The training sessions lasted approximately 30 minutes each and occurred two to three times per week. The same training protocol was used with each client. An F3-F4 electrode placement was used with wide band amplitude reduction (2-36Hz), and C3-C4 was used in wide band amplitude reduction (2-30 Hz) and in SMR augmentation (12-15 Hz), coupled with reduction of theta (2-7Hz) and hi-beta (20-36Hz).

Training took place in three 10-minute segments during each training session. The first segment of each session utilized wide band amplitude reduction (2-30Hz) at F3-F4. The second portion included wide band reduction at C3-C4. The third portion included theta (2-7Hz) and high beta (20-36Hz) reduction and SMR (12-15Hz) enhancement at C3-C4. The wideband amplitude reduction thresholds were set so a reward could be given 85% of the time. The SMR protocol thresholds were set so that the total reward percent was approximately 80%.

Electrode Placement

Electrode placement sites were established using the international 10-20 locations described by Lubar (1995). To place electrodes, the participant's skin surface was cleaned and prepared using NuPrep, a mild abrasive gel. A gold-plated clip electrode prepared with 10-20 Conductive Paste was placed on the ear and used for the ground site. A headband with two, gold-plated electrodes, set in sponges and soaked in saline solution, was used on the active (F3, C3) and reference (F4, C4) sites on the scalp. Proper electrode connections were verified by visually examining the waveform display, as outlined in the BrainMaster General Manuals and Technical Information (BrainMaster Technologies, 2000a, p. U-19). Electrodes with poor connections were removed and the preparation process was repeated.

Data Collection

During EEG biofeedback training, participants were taken to a room separate from classroom and school activity. Each client was seated in a chair, approximately two feet in front of a laptop computer screen. Each session was conducted in an identical manner across participants. Each session involved the presentation of visual (flying through a landscape scene) and auditory (tone) stimuli that responded to desired changes in EEG, as described above. As each client met the reward criteria, they moved faster through the landscaped scene and heard a pleasant tone to indicate success.

RESULTS

Statistical Procedures

The differences obtained between the pre- and post-test scores on the dependent measures provided information about the effectiveness of EEG neurofeedback in modifying the identified executive functions of the participants. Jacobson and Truax's (1991) model of clinically significant change was employed. This model is based on the concept of normative assessment, where an individual client's functioning is compared to that of the normative group employed for that particular assessment instrument. Based on the determination of cut-off scores, one can identify if a client's functioning has improved, deteriorated or remained the same, as a result of the treatment. According to Wiger and Solberg (2001), the additional use of a reliable change index (RCI) serves to determine if the differences between an individual's pre- and post-treatment scores are due to measurement error or the treatment. They outlined the calculation of a RCI, based on a 95% confidence interval, using a formula adapted from Jacobson and Truax's (1991) model. This model is based on the concept of normative assessment, where an individual client's functioning is compared to that of a normative group. Based on the determination of cut-off scores, one can identify if a client's functioning has improved, deteriorated or remained the same, as a result of the treatment. The calculation of a RCI, uses the formula: $\text{RCI} = 1.96 \sqrt{2S^2 (1 - r_{tt})}$.

The Z score value of 1.96 represents the 95% confidence interval. The S value is the standard deviation of the scores of the test, and the reliability coefficient is represented by r_{tt}. The 95% confidence interval for the RCI is determined by setting cut-off scores that are two standard deviations on either side of the mean of the normative sample scores.

In this study changes in the participants' executive function behaviors, as measured by the BRIEF, Conners' CPT, K-Bit and the screening version of the WRAML, were determined by calculating cut-off scores and RCIs on each test.

Reliable Change Index/Clinical Significance

Clinically significant change is any change that meets the established confidence level. An RCI was calculated where a minimum number of points of change in the test score was set, based on the reliability coefficient and standard deviation of the test. This established a 95% confidence interval around the cut-off score.

Results Summary

The results from the data analyses are summarized for the sample in Figures 1 and 2. Figure 2 reflects the total number of participants who showed clinically significant change on each particular measure. Results were viewed in this fashion to illustrate which measures were most sensitive to the changes brought about by neurofeedback.

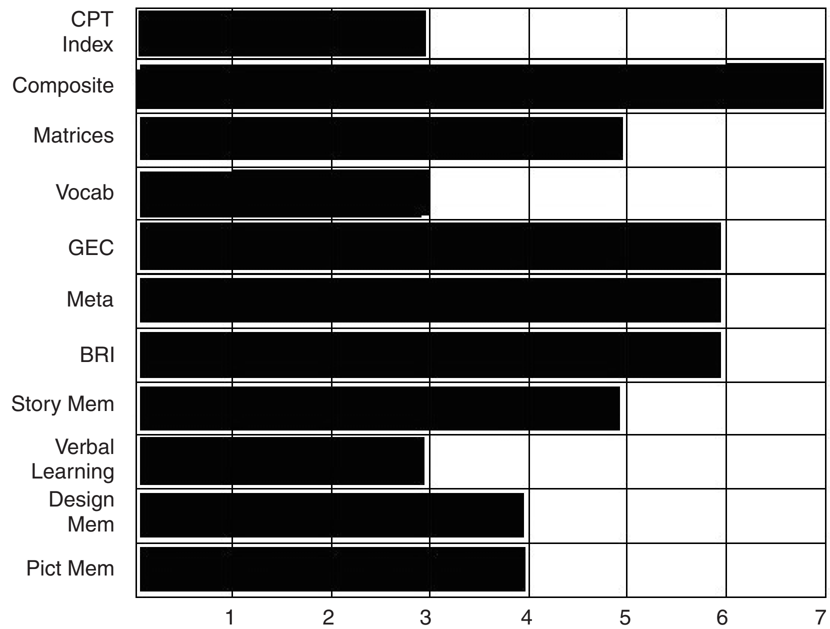
Conners' CPT: The results for one client were not included in the analysis because his performance on the pre-test was invalid. Four individuals decreased the number of omission errors they produced from pre-test to post-test, although only two of these participants scored in the clinical range at pre-test and below this level at post-test. The changes for these latter two participants after EEG neurofeedback reflected a change to normal functioning (RCI = .90). The remaining two individuals' post-test scores indicate normal functioning as well, although they also had performed in the normal range initially (criterion < 17.15). One individual did not show a change in performance, but this must be viewed in light of the fact that he produced no omission errors during either time period. One client produced more omission errors after treatment compared to before treatment, representing clinically significant and reliable deterioration (RCI = .90) although his post-test

FIGURE 1. Results on All Scales

	BRI	MC	GEC	CPT Index	Pict Mem	Design Mem	Verbal Learn	Story Mem	Vocab	Matrices	Comp IQ
#1	ns	Δ	Δ	0	ns	Δ	Δ	Δ	Δ	Δ	Δ
#2	Δ	Δ	Δ	Δ	ns	ns	ns	Δ	Δ	Δ	Δ
#3	Δ	Δ	Δ	invalid	Δ	Δ	ns	Δ	ns	Δ	Δ
#4	Δ	Δ	Δ	ns	ns	ns	ns	Δ	Δ	Δ	Δ
#5	ns	−Δ	−Δ	Δ	Δ	Δ	ns	Δ	ns	ns	Δ
#6	ns	Δ	ns	Δ	Δ	Δ	Δ	ns	ns	ns	Δ
#7	Δ	Δ	ns	Δ	Δ	Δ	Δ	ns	ns	Δ	Δ

ns = no significant change
−Δ = significant negative change
Δ = significant positive change
0 = pre- and post-test scores were 0

FIGURE 2. Total Changes Per Scale



score remained well below the criterion for ADHD. Overall, the participants demonstrated an average decrease of 13 errors from pre-treatment to post-treatment.

The results from the CPT Commissions Scale did not demonstrate reliable change because the standard error of measure (SEM) used to calculate the RCI was quite large (mean SEM = 12.56). As a result, it was difficult for participants to obtain scores outside the band of measurement error (RCI = 14.35).

Five of the seven participants produced usable Conners' CPT Index scores. One produced invalid results, and one achieved a score of 0 on both pre- and post-tests. Of the remaining five, three showed clinically significant positive change, one showed clinically significant negative change and one showed no significant change in either direction. Two of the participants improved their scores from the abnormal to normal range.

BRIEF: The Global Executive Composite from the BRIEF, a summary of all changes on that instrument, was believed to provide the best measure of treatment change of the three BRIEF indices analyzed. Four participants scored within the normal range on the Global Executive Composite (RCI = .17) as rated by their teachers, while another individual demonstrated significant change although not achieving a normal result. One client displayed mild deterioration and another failed to show clinically significant change. These results of the BRIEF indicate that five out of seven participants demonstrated a clinically significant and reliable, positive response to the treatment on at least one of the scales.

WRAML: Performance on the Verbal Learning subtest was characterized by no change for four participants. The remaining three participants displayed gains averaging 3.67 scaled score points, with one individual improving his performance from below average before treatment to scoring within the normal range after treatment. These results indicate three of the seven participants were able to learn and recall significantly more individual words over a series of trials after treatment, while four participants demonstrated no change.

The Story Memory subtest required participants to listen to a paragraph-length story and repeat it immediately afterward. Four individuals were better able to recall details of the story after treatment, performing in the average range at the time of the post-test (RCI = 1.0). Three of these participants had scored in the average range during the pre-test period; therefore, they improved their already solid abilities. The remaining participant of these four increased his performance from below average prior to treatment to scoring within the normal range after treatment. In addition, another client improved his performance, although he did not reach the criterion level. Finally, two participants did not demonstrate any change on this measure. These results suggest 71% of the sample received a positive benefit in memory for verbal discourse after completion of EEG neurofeedback, averaging 2.0 scaled score points improvement.

Forty-three percent of the sample did not produce meaningful change on the WRAML Picture Memory subtest, a measure of visual memory. Four individuals were able to improve upon their already average range performance after treatment.

The Design Memory subtest of the WRAML provides a measure of visual memory for abstract geometric designs. All participants performed well within the normal range during both measurement periods. Four participants demonstrated clinically significant and reliable improvements in performance (RCI = 1.06), while an additional client was slightly below the RCI cutoff level. The remaining two participants did not produce reliable changes, although one displayed a non-significant trend toward decreased performance after treatment. These results indicate the majority of the sample experienced improved visual memory performance after treatment, with an average increase of 3.5 scaled score points.

K-BIT: The Composite IQ measure from the K-Bit provides an estimate of an individual's level of intellectual functioning. Five participants performed within the normal range prior to treatment, and experienced clinically significant and reliable gains in intellectual functioning after treatment (RCI = 2.51). The remaining two participants scored below average on the pre-test results and received scores in the average range after treatment. The gains for all seven participants averaged 9.14 standard score points and ranged from 4 to 18 standard score points. The results indicate that significant improvements in intellectual functioning were consistently observed in the sample.

DISCUSSION AND CONCLUSION

All of the participants experienced improved performance after EEG neurofeedback on at least one of the dependent variables. Significant gains averaging nine standard score points on the K-BIT IQ Composite were obtained over all seven participants These results are consistent with previous studies, which have reported improved performance on measures of intellectual functioning after neurofeedback (Linden, Habib, & Radojevic, 1996; Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Tansey, 1991). Thompson and Thompson (1998) found an average 12-point gain on the Full Scale IQ index of the Wechsler Intelligence Scales following neurofeedback training.

The teacher ratings on the BRIEF showed consistent improvements across most of the participants. The Global Executive Composite indicated clinically significant improvements for five of seven participants. The improvements reflected gains in aspects of flexible problem-solving, improved regulation of emotional reactions and behavior, and inhibition of inappropriate responses. Six of the participants received scores similar to the instrument's ADHD-C group norm prior to treatment, while only two received such scores after treatment. This suggests that in the residential treatment setting, those participants displayed fewer aggressive behaviors, were able to make better decisions about how to handle problems or conflicts, were able to maintain attention to a greater degree, and had increased awareness of their behaviors after they received EEG neurofeedback.

Results from the WRAML indicated the participants displayed improved performance on various aspects of verbal and nonverbal memory, with five of the individuals who scored in the abnormal range on the pre-test scoring in the normal range on the post-test. In general, all participants improved their scores on at least one subtest of the WRAML, with scores increasing by 1.0 to 7.0 scaled score points. Thus, it seems that neurofeedback training such as that of this study can have positive effects on several types of memory.

Three participants improved their scores on measures from the Conners' CPT and one showed significant decline. The latter's scores, however, were well below the ADHD cutoff level at both assessment periods. Of the four who improved, two had scored at the ADHD level initially. Both of these appeared to respond positively to the neurofeedback, and their scores were at normal levels at post-testing. On average, participants produced 13 fewer CPT Omission errors after treatment, suggesting improved ability to sustain attention.

Overall, the results from the current study demonstrated improved cognitive and executive functioning after EEG neurofeedback. Teacher ratings of the participants' behaviors indicated the most change, and suggest the participants experienced increased behavioral regulation (i.e., they were less impulsive and disruptive). This is an especially important finding inasmuch as problems with behavioral regulation obviously are common in forensic settings.

Changes in CPT performance were not as striking as some of the other measures in the current study. This may have been because Omission errors (reflecting inattention) were not the best measure of the participants' main deficits, and the Commissions subscale from the CPT (reflecting impulsivity) contained too much variability to be useful. It is possible the participants would have experienced greater impairment on other measures of response inhibition, which might have provided more room for improvement after neurofeedback. Given the participants' histories of legal involvement, it is reasonable to assume they demonstrated impulse control problems in everyday life. This is consistent with Barkley's argument that ADHD is primarily a disorder of response inhibition (Barkley, 1997) rather than attention issues. It may have been useful to include reaction time and response variability in the analyses to better explore this possibility.

The mild gains produced in memory and the larger gains in intellectual functioning are interesting (and not necessarily expected), because these areas are not inherently associated with ADHD symptomatology. According to Othmer, Othmer, and Kaiser (1999), however, there is a reasonable explanation for these types of general cognitive improvements that also have been documented by others. These authors suggest the core issue of ADHD "is a disruption or discontinuity in the processes by which different brain regions maintain communication and continuity of mental processing" (p. 299). They note the disruption is global, and not limited to a specific brain region or neurotransmitter system. Because neurofeedback serves to improve the brain's ability to maintain homeostasis and leads to improved stability of the brain's regulatory functions, it may impact brain functioning on a global level and contribute to more efficient cortical communication and processing. Therefore, if neurofeedback influences very basic neurological processes and, as a result, every level of cognitive function is impacted, individuals who perform within normal limits on various IQ measures yet experience significant gains after neurofeedback (as was the case in the current study), may simply be processing information more efficiently. Therefore they are more able to access skills that have developed, but previously were not consistently available.

In the current study, individual levels of improvement or deterioration were assessed using the Reliable Change Index as a measure of clinical significance. This allowed statements to be made regarding the clinical significance and reliability of these changes with 95% confidence. As a result, previous critiques of EEG neurofeedback efficacy research, such as the lack of statistical power, were not relevant for the current study. The use of this methodology demonstrated its sensitivity to neurofeedback treatment-related changes in areas associated with executive and general cognitive functioning. The present findings are consistent with some previous research and suggest that EEG neurofeedback may be a helpful adjunct in the treatment of juvenile offenders. Hopefully this study will serve as a basis for further research in adolescent corrections. Future research using larger samples and control groups should help validate EEG neurofeedback as an effective intervention for adolescent offenders.

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