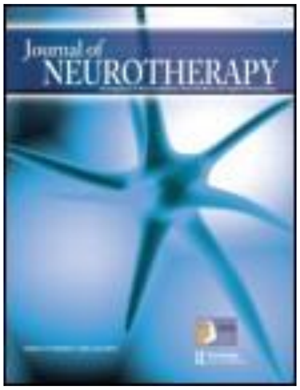

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Neurofeedback with Juvenile Offenders: A Pilot Study in the Use of QEEG-Based and Analog-Based Remedial Neurofeedback Training

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SUMMARY. *Introduction.* Atypical EEG and neuropsychological indicators have been observed among offenders. Dangerous offenders treated with a combined program that included neurofeedback (EEG biofeedback) and galvanic skin response (GSR) biofeedback demonstrated reduction in recidivism (Quirk, 1995). This study was designed to further evaluate the EEG findings of youth offenders and to provide an initial report on the effectiveness of a task-oriented analog/QEEG-based remedial neurofeedback training approach.

Method. Five offenders with significant psychopathology were referred for treatment. The group was evaluated with attentional testing and analog/QEEG assessment prior to and following neurotherapy. Treatment consisted of 20 or 40 sessions of a task-activated analog/QEEG-based approach. Another group of thirteen offenders were as-

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sessed with attentional testing and provided with neurotherapy following QEEG assessment.

Results. For all of the youth trained, in the analog/QEEG group, pre- vs. post-audio and visual attention testing demonstrated significant improvement within 20 remedial sessions. Three of the five youth showed rapid advancement in a residential grading system. Staff observational ratings suggested behavioral improvement in the QEEG group who in general were in training for a longer period of time.

Conclusion. EEG abnormalities and deficits in neuropsychological testing were found among offenders. Neurotherapy as an adjunctive treatment appears to hold promise for improvement in cognitive performance as well as recidivism. It is anticipated that different neurofeedback protocols may enhance outcomes.

KEYWORDS. Juvenile offenders, prison, neurotherapy, neurofeedback, QEEG-based neurofeedback, analog-based neurofeedback, remedial neurofeedback training

INTRODUCTION

Quirk (1995) demonstrated a reduction in recidivism in an adult offender population with a combined protocol of neurofeedback (EEG biofeedback) and galvanic skin response (GSR) training. While Quirk's work focused on adults, another clinician studied the effects of neurofeedback on incarcerated adolescent felons (Martin, 2002). This younger population also demonstrated benefit from neurofeedback intervention, with enhanced learning capacity and improved behavior.

The benefit of neurofeedback in remediating problems with attention, performance, and behavior is well known. It is therefore surprising that studies with offenders have been so slow in coming. The positive outcomes in the Quirk and Martin studies, combined with the need to address known psychological and neurological issues of those in the prison population, suggest a more extensive evaluation of neurofeedback should be undertaken.

The purpose of this study is to expand the current research in the use of neurofeedback in those convicted of criminal activity, with emphasis on the juvenile population. The authors also compared traditional neurofeedback protocols with techniques developed by the co-author.

Basis of Study

Juvenile offenders are often compromised neurologically. For example, Attention Deficit Hyperactivity Disorder (ADHD), addictive disorders, and impaired neuropsychological functioning are known to be widespread in the offender population. Hyperactive youth, especially those exhibiting antisocial behaviors, are at significant risk for criminal behavior (Satterfield & Schell, 1997; Mannuzza & Klein, 2000). As neurofeedback has demonstrated the ability to reduce hyperkinesis and impulsivity in those with ADHD (e.g., Lubar & Shouse, 1976, 1977; Shouse & Lubar, 1979; Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Lubar, 2003; Tansey & Bruner, 1983; Tansey, 1993), the question follows: Would decreasing hyperactivity and impulsivity in the criminal population reduce recidivism? Additionally, since the younger the subject at first arrest, the greater the likelihood of chronic and accelerating offenses, would neurofeedback deter future criminal activity in youthful offenders?

Research demonstrating the effectiveness of neurofeedback in addictive disorders includes the work of Peniston and Kulkosky (1989, 1991) and Saxby and Peniston (1995). While the authors know of few studies specifically evaluating the possible benefit of neurofeedback in addicted youth offenders, many in the juvenile corrections population have addictions and therefore should be good candidates for such intervention.

Studies in men convicted of violent crimes have found abnormal electroencephalographic (EEG) activity and impaired neuropsychological functioning. In one study (Evans & Park, 1997) indications of frontal and right hemisphere dysfunction were found in 20 men convicted of murder. Abnormalities noted were those associated with coherence, phase and amplitude asymmetries using an EEG normative reference database. In a study with a similar population (Evans & Claycomb, 1999), the presence of paroxysmal delta waves (primarily right lateral frontal) and/or excessive relative power in alpha frequencies at frontal or lateral frontal sites was associated with a history of dissociative experiences or out-of-character behavior that sometimes involved violence. In still another quantitative EEG (QEEG) study, reduced EEG comodulation was found in a sample of death penalty cases which, according to the author, suggests brain dysfunction (Weinstein, 2002). Other research confirms that neuropsychological brain dysfunction and structural irregularities in the prefrontal cortex are highly correlated with violence and psychopathic behaviors (Raine, 1993).

Overwhelming evidence that cerebral dysfunction can produce disturbed, often criminal behavior is offered in a treatise by Flor-Henry (1983). Temporal lobe epilepsy, in particular, can produce psychic aberrations, fugue states, and unusual behavior. Traumatic brain injury is associated with memory difficulties, problems with attention and concentration, lassitude, disturbance of sleep, irritability, depression, and headache (Kwentis, Hart, Peck, & Kornstein, 1985; Gennarelli, 1986; Prigatano & Pepping, 1987).

Many clinicians utilize neurofeedback training to remediate such neurological and clinical issues. For example, alleviating the symptoms of head injury (see Hoffman, Stockdale, & Van Egren, 1996), reducing seizure activity (a sequela of brain injury and other major types of genetic and acquired brain disease; Sterman & Friar,1972; Sterman, 2000), and learning disabilities (Thornton & Carmody, 2005; Tansey, 1993).

Study Objectives

The present study investigates whether certain specific neurofeedback interventions impact neurological and behavioral measures in adolescent offenders. In a previously reported study performed with an eating disordered population (Sams & Smith, 2004), the authors compared clinical outcomes with three different approaches to neurofeedback training: symptom-based, quantitative EEG-based, and a combined analog and quantitative EEG-based training that included task-activated neurofeedback protocols, heart rate variability biofeedback, and cortical blood flow training. The present investigation was designed to further evaluate outcomes with two of those three previously used neurofeedback methods–the quantitative EEG-based and analog/quantitative EEG-based approaches. Since Quirk (1995) reported that increasing the number of sessions enhances outcome effectiveness, we also sought to test this.

METHODS

Group One

Participants. Thirteen incarcerated youthful offenders were referred for neurofeedback training to a program carried out by trained correctional staff and supervised by the first author, a licensed clinical psychologist with training and experience in neurotherapy. The group ranged from 13 to 17 years of age. All participants had a history of multiple criminal offenses and drug abuse/dependence. Some had committed actual crimes while under the influence of drugs. The group consisted of eleven males and two females, with the predominant ethnicity being Hispanic (11 Hispanics vs. 2 Caucasians). The majority of male subjects had a background of mixed substance abuse, while the females were self-reported as addicted to methamphetamines. No information was available regarding socio-economic status.

Procedure. Each participant and/or guardian reviewed and signed informed consent forms and received both a written and verbal overview of the training process. The correctional staff completed weekly behavioral forms rating cooperation and completion of assignments and chores on 8 of the 13 subjects. (Five participants were housed at a facility that used a different rating system so their ratings were not considered in data analysis.) In the rating system, youth progress from the lowest level (one) in half steps depending upon cooperative behavior (no adverse behavioral incidents, and completion of chores and assignments) to the top level of seven. A minimum score of five must be achieved before the youth is eligible to be discharged from the facility, a seven being even more desirable.

A TOVA continuous performance test (Greenburg & Waldman, 1993) that evaluates visual attention was administered before training commenced and after session 20. An appropriately sized ECI Electrode-Cap (Electrode-Cap International, Eaton, OH) was placed on the participant's head, and adjusted for symmetry and proper electrode placement. The electrodes were filled with conductive gel using a blunted needle, and impedances reduced to 5 K ohms or below by gently abrading the scalp at the electrode site. EEG data were recorded with a Lexicor 24-channel digital EEG recording device using Neurolex™ software. Two conditions, eyes-open and eyes-closed, were recorded for approximately five minutes each. A sampling rate of 128 samples per second was used, with the high pass filter in the off position.

The recorded data were transferred to Lexicor Medical Technology, Inc., Boulder, CO via e-mail attachment for interpretation and training recommendations. Training protocol selection was based on statistical deviations from a proprietary database (DataLex™). Priority was assigned to adjusting inappropriate amplitudes, followed by asymmetry, coherence, and phase training. Training recommendations were specific for the eyes-open and eyes-closed conditions.

Training sessions were conducted by trained correctional staff supervised by a licensed psychologist certified in biofeedback. All training sessions were done on Lexicor equipment using Biolex™ software. Electrode impedances were reduced to 10 K ohms or less for all biofeedback sessions. Participants were allowed to choose displays for visual feedback and to adjust audio controls to a comfortable level. Adjustments were made to baseline threshold settings after a two-minute baseline recording. Individual training session times ranged from 30 to 40 minutes, depending on the specified protocol. EEG data were collected at the end of each training session.

Group Two

Participants. Five male juvenile offenders were referred for neurofeedback training. The group ranged in age from 13 to 17 years. All had multiple arrests (range of three to nine). Three of the five had gang affiliation, and four had backgrounds of substance abuse or dependence. Two had criminal offenses connected to sexual exploitation and assault. The participant with no substance abuse history had symptoms of ADHD and multiple arrests for larceny. Ethnic background was mixed, with three participants of Hispanic origin, one Caucasian and one African-American. Four had been incarcerated previously. One participant from Group One was later transferred to Group Two. He received ten treatment sessions according to Group Two procedures, after receiving 24 sessions using methods as described for Group One.

Procedure. As in Group One, each participant and/or guardian signed consent forms and received both a written and verbal overview of the training process. An IVA Continuous Performance Test (BrainTrain, Inc., Richmond, VA), a test of ability to sustain auditory and visual response control and attention over a 15-minute period (Sandford, 1995; Seckler, Burns, Montgomery, & Sandford, 1995), was administered before neurofeedback training.

For the initial EEG data collection, an appropriate sized ECI Electrode-Cap was placed symmetrically on the head; the electrodes cavities were filled with electrode gel and impedances reduced to 5 K ohms or less by gently abrading the scalp with a blunted needle.

As in Group One, a Lexicor 24-channel digital EEG recording device with NeuroLex™ software was used to collect data. A sampling rate of 128 samples per second, with the high pass filter off, was used for three conditions: eyes-open, eyes-closed, and task activation. The task activation process required the playing of Tetris, a visual-spatial video game, on a Game Boy, a hand-held video game system. The analog EEG data for the three conditions were visually analyzed for disturbances in background activity and to determine if transient focal, asymmetric, epileptiform, or inappropriate generalized activity were present. All data were reformatted to include at least one sequential (scalp-to-scalp recording) montage to visually enhance possible transient focal data. The EEG was then visually edited for artifacts, and all possible artifacts deleted prior to statistical analysis. EEG and QEEG analysis and training recommendations were provided using clinical strategies created around neurological inefficiencies.

Training priority was given to the inefficiencies found in the analog EEG patterning (for example, unstable background activity, paroxysmal activity, significant asymmetries, focal slow waves, spike activity). Next, priority was assigned to inefficient cortical circuits, specifically, coherence and phase deviations found in a lifespan normative reference database (NeuroRep).

Each participant wore an appropriately sized ECI Electrode-Cap for training. A minimum of eleven electrodes (Cz, Fp1, Fp2, F3, F4, P3, P4, F7, F8, T3, T4, and ground) were filled with electrode gel. Other electrode sites were filled as necessary for the specific training protocol. Impedances were reduced to 5 K ohms or less before the baseline data were collected.

A baseline condition preceded all neurofeedback sessions to compare current with previous sessions. An 11-channel, task activated (playing Tetris on Game Boy) baseline was recorded in Neurolex™, using a sampling rate of 128, for a minimum of 80 (two second) epochs. No audio tones were used during the baseline condition.

After the no-audio baseline recording, the trainer adjusted the volume of headphones and placed the headphone pads comfortably over the participant's ears. The participant continued playing the video game as high-pitched tones provided the audio-based neurofeedback training information.

Each session consisted of two or three five-minute, synergistically compatible training protocols (as determined from research by the co-author with other persons with a variety of neurological and psychological symptoms). The training segments were always at the same electrode site(s), using a specific scalp electrode to a combined ear reference linkage, a sequential ("bipolar," or scalp-to-scalp) montage, or a Linear Channel Combination (LLC) montage incorporating the sum of four to seven electrode sites. Each five-minute protocol was a different training band, utilizing a group of frequencies in the 0.5 to 120 Hz range.

The training protocols selected were those shown to decrease delta (0.5-3 Hz), theta (3-6 Hz), alpha_a (8-10 Hz) and/or alpha_f (8-12 Hz), while increasing 13Hz (11.5-14.5 Hz), alpha_b (10-12 Hz), beta1 (15-20 Hz), and/or beta2 (20-28 Hz). These were protocols that had clinically demonstrated the ability to stabilize ongoing background activity (reduce paroxysmal activity and unstable patterning), and remediate inefficiencies found in normative EEG reference database reports. These included: Increase magnitude difference between a pair of scalp electrodes or a scalp to combined ear reference; decrease magnitude difference between two scalp electrodes or a scalp to combined ear reference; increase or decrease synchrony (synchrony defined as 50% coherence and 50% phase) between two scalp sites or multi-electrode sites simultaneously; decrease peak amplitude + synchrony (a mathematical expression of first selecting the peak amplitude of a frequency band, then decreasing the synchrony between two or several electrodes sites simultaneously); appropriate coherence and phase training [the "opposite" of the deviation(s) reported on an age appropriate normative EEG reference database] between electrode pairs shown on the database report, or more diffusely, using multi-site training (if larger areas of deviations are found). Neurofeedback reinforcement was provided by magnitude regulated, high pitched tones (created by the trainer adjusting the y-axis for maximum high pitch) as the subject processed and responded to the complex task (playing Tetris).

Immediately following each neurofeedback training session, the subject completed five minutes of heart rate variability training (Heart Math, Boulder Creek, CA) using diaphragmatic breathing techniques with visual feedback only. This, in turn, was followed by five minutes of frontal (mid-forehead placement) cortical blood flow training (Bio-Comp Research, Los Angeles, CA) under task (playing Tetris) with auditory feedback.

Each participant received either 20 or 40 training sessions as described. The youth who transferred into Group Two from Group One received 10 additional training sessions according to Group Two methods. The IVA visual-auditory continuous performance testing was repeated near the time of the last session and compared to the pre-training data. Pre- and post-EEG data were collected and compared, including an analysis using the Excel statistical program to compare magnitude changes in eight frequency bands at 19 electrode sites. A weekly log and behavioral rating scores were kept by the staff on each participant as described for Group One.

RESULTS

Pre- to post-training scores were compared. Paired sample T-tests were performed to assess changes in pre- and post-training scores from the TOVA and IVA tests, and from behavioral rating scales as applicable for each group. Scores based on invalid test administration and other invalid scores were dropped from the comparisons, so the total sample size was reduced in Group One from 13 to 8 and one of the 8 subjects provided little valid TOVA data. Results are shown in Tables 1 and 2.

The only significant difference for Group One was change in behavior level from pre-training (mean = 2.9) to session 20 (mean = 6.7). Behavior Level ratings performed by staff range from 1 (least cooperative) to 7 (most cooperative). For Group Two significant differences were found for Auditory Attention Quotients (AAQ) and Visual Attention Quotients (VAQ). The difference was nearly significant for Visual Response Control Quotient (VRCQ) and not significant for the Auditory Response Control Quotient (ARCQ).

Post-training status of Group Two members was followed for a period of six months. Three of the original five participants received 34 or 40 treatment sessions, and successfully completed probation with no arrests. Two of the five received 20 training sessions. While these two offenders showed improvement on attention-related cognitive tests, behavioral ratings did not improve. As a result, probation was not com-

TABLE 1. TOVA and Behavioral Scores, Pre-Training vs. Post-Session 20 for Group One.

	Pre-Training	Post-Training	p value
Omission errors	107.3	94.7	.219
Commission errors	105.1	107.1	.506
Response time	111.3	106.7	.557
RT Variability	103.3	102.3	.928
Post-Commission errors	5.8	4.9	.474
Behavioral levels	2.9	6.7	.003*

*indicates significant difference

TABLE 2. IVA and Behavior Scores Pre-Training vs. Post-Session 20 for Group Two.

	Pre-Training	Post-Training	p value
ARCQ	75.0	85.4	.123
VRCQ	76.8	94.8	.051
AAQ	79.6	96.2	.049*
VAQ	74.2	91.2	.043*
Hyper-activity	7.4	2.8	.172
Behavioral level	1.2	2.8	.099

*indicates significant difference

pleted within the six months of the study. There was no opportunity to follow the outcome of Group One participants after cessation of training.

DISCUSSION

This investigation has a number of shortcomings. The small number of subjects in each group severely restricted statistical treatment of the pre/post training and group comparisons. The lack of matched control groups, the variable training times both within and across groups, and the failure to control for large differences in pre-training test and behavioral rating scores among participants are factors that need to be considered in future research of this type. Furthermore, factors such as determining whether observed behavioral and cognitive changes are causally related to neurofeedback training alone, to a combination with other concurrent treatment, or to other behavioral modification training within participants' institutional settings must be considered. The provision of more extensive and detailed information on the long-term social/psychological adjustment of participants is also a missing factor and should be considered in future research.

These shortcomings considered, neurofeedback training did seem to show favorable impact on cognitive functioning and behavior in these two groups of juvenile offenders. This investigation of two neurofeedback training approaches for juvenile offenders suggests different outcomes that appear to depend on the methods employed. Group One training was based on QEEG results, whereas Group Two training

(a) used protocols that addressed patterns found in both the analog EEG and QEEG analysis, (b) used protocols shown to reduce slow activity (below 10 Hz) and increase fast activity (above 10 Hz) or to reduce magnitude globally at all electrode sites, (c) trained during a task-activation condition, and (d) supplemented neurofeedback training with heart rate variability biofeedback and cortical blood flow training.

Findings of this pilot study provide some suggestions to guide future research. First, there is some evidence that the combined analog and QEEG-based training protocols of Group Two may be more effective for facilitating cognitive changes (decreases in impulsiveness and improvement in sustained attention) than protocols based on QEEG data alone. Giving further weight to the analog/QEEG-based approach are the similar results the authors found in an eating disordered population (Sams & Smith, 2004).

Secondly, there was support for earlier findings that more training sessions lead to greater improvement in behavior, and thus potentially less recidivism. Quirk (1995) observed that effectiveness of neurofeedback with incarcerated persons increased as a function of the number of training sessions done. At least as far as behavioral ratings are concerned, the data from both groups of the present study lend support to this idea. Group One participants (21-57 sessions) who had behavioral rating data available showed ratings improvement over the course of treatment and the three participants in Group Two who had more than 20 sessions improved while the two who had 20 sessions did not.

Group One participants' training extended over an average of 20.6 weeks versus just 7.6 weeks for participants of Group Two. It is not known if the lower behavioral ratings for the two Group Two participants with only 20 sessions were more a function of number of sessions or of time. Follow up was not possible to help determine which was more likely. These issues of combined analog and QEEG-based training as superior, and number of sessions versus duration of training should be addressed in greater depth by future research.

Several studies have shown that a high percentage of incarcerated persons suffer from brain damage or dysfunction, with related problems in behavioral control, attention, and learning. This clinical research study and growing numbers of research results and clinical reports suggest that neurofeedback is useful in facilitating recovery from many such conditions (Walker, 2004). For the benefit of those at high risk to commit crimes, and of their potential victims in society, there is a pressing need for well-designed research studies to explore the use of neurofeedback (and other biofeedback procedures) with both adult and juvenile offenders. Hopefully, the present study will encourage others to explore the possible benefit of neurofeedback in preventing recidivism and rehabilitating some of society's most troubled individuals.

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