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Applicability of brain wave biofeedback to substance use disorder in adolescents

David L. Trudeau, MD*

Department of Family Practice and Community Health, Medical School, University of Minnesota, 420 Delaware Street Southeast, Minneapolis, MN 55455-0392, USA

Attempting a review paper on the use of neurofeedback in adolescent addictions is difficult. There is practically no literature on the use of neurofeedback in adolescent addictions, and the only information available comes from studies published on adult addiction treatment. Brain wave biofeedback (sometimes called neurofeedback or neurotherapy) has been studied as a method for treatment of addictive disorders in adults over the past 15 years or so, with a slowly accumulating body of evidence supporting its use in different circumstances. Several recent reviews [1,2] have detailed the literature regarding its use and development of neurotherapy for addictive disorders and are not repeated here, except in a general way to introduce the reader to the technique and specifically discuss its applicability to child and adolescent psychiatry. Although neurofeedback is an attractive technique for treating addictive disorders because it is medication free and compatible with other therapies, it also appeals to persons interested in alternative treatments. It has applicability in difficult-to-treat groups, such as stimulant abusers [3–5], incarcerated felons [6], and chronic treatment-resistant alcoholics [7,8]. Neurotherapy for addictions has several disadvantages in that it is labor intensive (20 to 30 half-hour sessions), requires special equipment ($2,000–$5,000 cost) and training, and lacks large randomized clinical trials for validation. Most authors describe enduring effects, and in the case of addictions treatment, long-term follow-ups have been done.

Brain wave biofeedback techniques for psychoactive substance use disorder (PSUD) may be of special interest for adolescent medicine because of the high comorbidity of PSUD and attention deficit hyperactivity disorder (ADHD) in

* 20385 Siskiwit Shores Drive, Cornucopia WI, 54827.
E-mail address: trude003@tc.umn.edu

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adolescents [9]. The techniques that are described in this article that combine classic ADHD neurofeedback approaches with addiction neurofeedback approaches hold special interest for adolescents with PSUD. They are medication free and minimize opportunities for medication abuse, by inappropriate self-overdose and by trading medication for other substances. Hyperactive ADHD is clinically significant because it is an antecedent for PSUD, conduct disorder, and antisocial personality disorder [10–12]. Neurofeedback techniques may have special applicability in attempting to treat the constellation of conduct disorder, non-alcohol PSUD, and ADHD in teens who are already abusing stimulants. The author reported on the high incidence of childhood ADHD in a sample of adults with chronic PSUD and found that childhood ADHD status in this population predicted adult stimulant abuse [13]. This research sample supports other literature that finds significant overrepresentation of adults and adolescents with comorbid ADHD and PSUD and among children with ADHD who develop PSUD over time [14–16]. By providing low-risk and medication-free therapy for ADHD and PSUD, neurotherapy becomes another treatment option open to practitioners who are reluctant to prescribe controlled substances to children with ADHD and adolescents at risk for or with PSUD.

This article briefly reviews the techniques of brain wave biofeedback that began with meditational, hypnogogic models and their evolution to models that also address ADHD and drug-induced neuroelectrophysiologic abnormalities. The relationship between ADHD status, drug status, and electroencephalographic (EEG) abnormalities is discussed, because EEG biofeedback protocols may be selected specifically to address EEG abnormalities. Some attention is given to the potential use of neurotherapy in prevention of substance abuse. Finally, suggestions are made regarding future research considerations for neurotherapy in the treatment and prevention of PSUD in children and adolescents.

Brain wave biofeedback techniques used in addictions

Most addiction protocols involve the use of alpha-theta biofeedback. This technique involves the simultaneous measurement of occipital alpha (8–13 Hz) and theta (4–8 Hz) and feedback by separate auditory tones for each band for amplitudes more than preset thresholds. Alpha, the dominant resting eyes-closed frequency (8–12 Hz) of the EEG is pronounced in an eyes-closed awake resting state in normal individuals, and theta (4–8 Hz) becomes more pronounced in deeply relaxed states. The training is done eyes closed with auditory feedback. The subject is encouraged to relax and increase the amount of time signal heard, that is, to increase the amount of time that amplitude of each defined bandwidth exceeds the threshold. Various equipment and software have been used to acquire, process, and filter signal, and there are differences in technique inherent with equipment and software.

More recent modifications entail training at higher frequency bands before the use of alpha-theta training. The beta band (12–30 Hz) usually is divided into

several frequencies: the sensorimotor rhythm band (12–16 Hz), the low beta band (16–21 Hz), and the high beta band (22–30 Hz). Sensorimotor rhythm and low beta bands have been used for training, especially in stimulant abusers. The effect of this feedback is to increase the amount of time that the defined bandwidth amplitudes exceed the training threshold. Training at these bands is a technique similar to that commonly used for ADHD and is purported to increase attention and concentration and possibly to reduce hyperactivity. Beta training is done eyes opened as the subject intensively concentrates on increasing visual and auditory signals associated with meeting training parameters (an increase in amplitude of the selected portion of the beta band above threshold values).

Alpha-theta feedback training was first used and described by Green et al [17] in 1975 at the Menninger Clinic. This method was based on Green's observations of single-lead EEG during meditative states in practiced meditators. When the separate and independent auditory feedback of alpha and theta signal was given to subjects in eyes-closed seated or semi-recumbent relaxed condition, states of profound relaxation and reverie were reported to occur. As meditational states progressed, increased theta amplitude was observed after initial increased alpha amplitude, then drop off of alpha amplitude (theta-alpha crossover). Whereas the EEG changes produced are similar to stage 1 sleep [18], the subjects were maintained in a relaxed yet focused condition, subjectively similar to a hypnotic trance with reverie and a sense of timelessness. Those effects may be nonspecific to the alpha-theta brain wave biofeedback method and may be achievable with other biofeedback techniques that use relaxation [19] or with meditational techniques alone [20,21]. Alpha-theta brain wave biofeedback was seen as useful in augmenting psychotherapy and individual insight by Green and colleagues. It could be seen as a use of brain wave signal feedback to enable a subject to maintain a particular state of consciousness similar to a meditative or hypnotic relaxed state over a 30- or 40-minute feedback session.

The first studies of alpha-theta biofeedback for addictions focused on augmenting therapy experience in alcoholics engaged in psychotherapy and 12-step model programs in a Veterans Administration hospital setting. Daily 20-minute alpha-theta EEG biofeedback sessions (integrated with EMG biofeedback and temperature control biofeedback) were done over 6 weeks and resulted in free, loose associations, heightened sensitivity, and increased suggestibility [22]. Patients discussed their insights and experiences associated with biofeedback in therapy groups several times a week, which augmented expressive psychotherapy. Twemlow and Bowen [23] found that ''religiousness'' as a predictor of ''self-actualization'' may have increased as a result of imagery experienced in theta states. This was seen as positive to the program goal of augmenting Alcoholics Anonymous as a recovery philosophy. The high suggestibility of the method was acknowledged: ''treatments such as brain wave training, which use abstract, ill understood techniques are potential repositories of magical projection and fantasy and would logically be more acceptable to alcoholics who are able to have faith (devoutly or moderately religious)'' [23].

In another uncontrolled study at Topeka Veterans Administration hospital, 21 alcoholics were reported to exhibit within and across session increases in raw theta amplitudes at occipital areas bilaterally measured by single lead EEG during the course of alpha-theta training, becoming more able to achieve deep states as manifested by EEG [24,25]. These initial studies advanced the use of biofeedback-induced theta states in promoting insight and attitude change in alcoholics, with the assumptions that biofeedback-induced theta states are associated with heightened awareness and suggestibility and that this heightened awareness and suggestibility would enhance recovery.

Peniston and Kulkosky [8,26] reported a randomized and controlled study of adult chronic treatment resistant alcoholics treated with alpha-theta EEG biofeedback. Compared with a traditionally treated alcoholic control group (n = 10) and nonalcoholic controls (n = 10), alcoholics who received brain wave and temperature biofeedback (n = 10) showed significant increases in percentages of EEG record in alpha and theta rhythms and increased alpha rhythm amplitudes (single lead measurements at international site O1). The experimentally treated subjects showed reductions in Beck Depression Inventory scores compared with the control groups. Control subjects who received standard treatment alone showed increased levels of circulating beta endorphin, an index of stress, whereas the brain wave biofeedback group did not. Thirteen-month follow-up data indicated significantly more sustained prevention of relapse and substantial changes in personality test results in the experimental group compared with the controls.

The protocol (described as follows) has become known as the ‘‘Peniston Protocol’’ and has become the focus of research in subsequent studies. Subjects are first taught deep relaxation by skin temperature biofeedback using autogenic phrases and have at least five sessions of temperature feedback. They are instructed in brain wave biofeedback, and while they are in an eyes-closed and relaxed condition, they receive auditory signals from EEG apparatus using an international site O1 single electrode and linked ears. A standard induction script that uses suggestions to relax and ‘‘sink down’’ into reverie is read [8]. When alpha (8–12 Hz) brain waves exceed a preset threshold, a pleasant tone is heard, and by learning to voluntarily produce this tone, the subject becomes progressively relaxed. When theta brain waves (4–8 Hz) are produced at sufficiently high amplitude, a second tone is heard, and the subject becomes more relaxed and, according to Peniston, enters a hypnagogic state of free reverie and high suggestibility.

After the session, with the subject in a relaxed and suggestible state, a therapy session is conducted between subject and therapist in which the contents of the imagery experienced are explored and ‘‘abreactive’’ experiences are explored. This technique also was used in the treatment of combat posttraumatic stress disorder by the authors, with reported recall and resolution of incomplete traumatic memories with positive clinical effect [27,28]. Subsequent studies of Peniston’s Protocol in adult alcoholics showed similar positive changes in personality testing and long-term abstinence and remission of comorbid

depression [29] and long-term abstinence and decreased re-arrest rates in probationers [7]. A critical analysis of the Peniston Protocol is discussed at length in a previous review [1].

In a large randomized study of alpha-theta training for addiction in the Kansas Prison System using group training equipment, little difference was shown between two groups (alpha-theta training plus standard rehabilitation treatment versus standard rehabilitation treatment alone) at 2-year outcome [6]. When results were analyzed for age, race, and drug of choice, however, neurofeedback emerged as a more efficacious treatment for younger and non-white and non–stimulant-abusing participants. The alpha-theta protocol was not effective for cocaine abusers, whereas modifications that incorporate beta training before alpha-theta have been effective with cocaine abusers.

Scott and Kaiser [3,30] described combining a protocol for attentional training (beta or sensorimotor rhythm augmentation with theta suppression) with the Peniston Protocol (alpha-theta training) in a population of subjects with mixed substance abuse rich in stimulant abusers. The beta protocol is similar to that used in ADHD [31] and was used until measures of attention normalized, and then the standard Peniston Protocol without temperature training was applied. Their study group was substantially different than that reported in either the Peniston or replication studies, in that 97% of the subjects were mixed substance abusers with only 6% having alcohol as a drug of choice. One hundred twenty-seven inpatient drug program subjects were randomized to condition, and follow-up was conducted at 1 year. The experimental group received a 40-session biofeedback protocol in addition to the standard residential treatment, the control group received standard treatment alone. Subjects were tested and controlled for the presence of attentional and cognitive deficits, personality states, and traits. The experimental group showed normalization of attentional variables after the sensorimotor rhythm–beta portion of the neurofeedback, whereas the control group showed no improvement. Experimental subjects demonstrated $P < 0.005$ level significant changes beyond the control subjects in five of the ten scales of the Minnesota Multiphasic Personality Inventory (MMPI)-2. Subjects in the experimental group also were more likely to stay in treatment longer and were more likely to complete treatment compared with the control group. Finally, the 1-year sustained abstinence levels were significantly higher for the experimental group compared with the control group.

The approach of beta training before alpha-theta training has been applied successfully in a treatment program aimed at homeless crack cocaine abusers, with impressive results [5]. In a noncontrolled open trial, 270 male addicts received 30 sessions of a modified protocol of beta training before alpha-theta training. One-year follow-up of 94 treatment completers indicated that 95.7% of subjects are maintaining a regular residence, 93.6% are employed or in school or training, and 88.3% have had no subsequent arrests. Self-report depression scores dropped by 50% and self-report anxiety scores dropped by 66%. Of the 270 subjects, 53.2% reported no alcohol or drug use 12 months after biofeedback, and 23.4% used drugs or alcohol one to three times after

their stay. The remaining 23.4% reported using drugs or alcohol more than 20 times over the year. Urinalysis results corroborated self-reports of drug use. This was a substantial improvement from the expected 30% or less expected recovery in this group, typical of the outcome before the introduction of brain wave training at the study facility. Comparable numbers are not available for the program before the introduction of the brain wave training protocol because of the small numbers of program completers. After the introduction of neurofeedback to the mission regimen, length of stay tripled, beginning at 30 days on average and culminating at 100 days after the addition of neurotherapy. Similarly, before neurotherapy, the mission was "graduating" 12 men per year from their drug treatment program, which has increased to an average of 12 graduates per month.

Quantitative electroencephalographic implications for brain wave biofeedback in addictions

Quantitative EEG (qEEG) refers to the mathematical processing of digitally recorded EEG. It may be done to analyze frequency components and amplitude at 1 to 19 or more channels of digitally recorded EEG that are transformed into numerical measures, such as wave amplitude, absolute power, relative power, power ratios, coherence, phase lag, power asymmetry, and comodulation. Such measures provide precise, quantitative descriptions of many different indices of brain function in comparison with a normative database. The qEEG is commonly used by neurotherapists in guiding and evaluating brain wave biofeedback protocols [32,33]. A recent monograph is devoted to the special topic of the validation and clinical use of qEEG databases in neurotherapy [34].

qEEG studies of ADHD and drug abuse suggest that there may be several reasons why alpha-theta training alone may not be successful in populations of mixed substance abusers, especially for persons whose drug of choice is stimulants. Reports of substantial alteration of qEEG seen in stimulant abusers associated with early treatment failure [35] may be associated with marked frontal neurotoxicity and alterations in dopamine receptor mechanisms [36]. The primary abnormality most commonly seen in cocaine abuse is alpha amplitude excess, although there are several subtypes of qEEG abnormality [37]. Cannabis abusers have marked chronic qEEG changes that consist mainly of alpha excess amplitude [38] and dominant frequency slowing [38]. Initial alpha reward training with this group seems to accentuate the most common electrophysiologic abnormalities that are a consequence of drug use. Although it remains to be methodically demonstrated, our data in individual cases suggested that qEEG abnormalities of excess alpha amplitude associated with cannabis and cocaine abuse improved with beta training. Although stimulant preference is associated with pre-existing ADHD in adult and adolescent substance abusers and pre-existing ADHD status is independent of stimulant or cannabis associated qEEG

changes [13], ADHD itself is associated with independent qEEG subtypes in children [39].

The most common qEEG change associated with ADHD in adults, adolescents, and children is theta amplitude excess [40]. It seems that alpha-theta feedback would accentuate abnormal brain electrophysiology in many subjects with ADHD and that theta feedback in subjects with ADHD and theta amplitude excess would accentuate ADHD symptoms. The chronic electrophysiologic abnormality associated with stimulant and cannabis abuse and the high incidence of pre-existing ADHD in stimulant abusers are two potential factors that may impair ability to focus and concentrate sufficiently to engage in the hypnagogic and autosuggestive Peniston Protocol. Remediation by an attention-enhancing protocol may improve ability to attend to the classic alpha-theta approach [13].

Because of the heterogeneity of qEEG subtypes in stimulant dependence [35], cannabis dependence [38], and ADHD [39], qEEG-guided therapy has been suggested as an alternative approach to the protocol-based therapies discussed thus far. In qEEG-guided therapy, specific abnormalities of EEG, defined as deviations from normative values, are trained toward normal, depending on clinical response [33].

A randomized controlled study of qEEG-guided neurotherapy for PSUD is in progress [41]. This study examines the difference between qEEG-guided neurotherapy, research-based treatment (beta training followed by alpha-theta), and wait-list control for chemically dependent outpatients. Preliminary results with 2-year follow-up show no difference between qEEG-guided therapy and alpha-theta after beta pretraining (Roger deBeus, PhD, personal communication, 2004). Because of the small numbers of subjects involved who have completed the study, it is not possible to draw conclusions regarding any advantage regarding qEEG specific training.

Gurnee [42] presented data on a series of 100 sequential participants with PSUD who were treated by qEEG-guided neurotherapy. In this series a marked heterogeneity of qEEG subtypes and corresponding symptom complexes were noted. In this clinically derived scheme, qEEGs that deviated from normative databases in specific ways were associated with symptom complexes. The therapeutic approach is to base neurotherapy on correcting qEEG abnormalities (ie, train beta excess amplitude down when present) while monitoring symptoms. Because this work is presented in the format of an open case series, it is not possible to draw conclusions regarding efficacy of qEEG-guided therapy versus standard protocol therapy. These studies provide possible research models for continued systematic study of the efficacy of qEEG-guided neurotherapy compared with fixed protocol (‘‘one size fits all’’) neurotherapy. A more complete discussion of qEEG subtypes associated with commonly occurring comorbid conditions in PSUD has been presented elsewhere [2,43], with the argument that in devising individual treatment plans it may make good clinical sense to consider comorbidities that are known to influence EEG and have been described as responding to EEG feedback techniques.

Applicability of neurotherapy for psychoactive substance use disorder to adolescents

All of the work presented thus far has been concerned with adults. The focus of child and adolescent work in neurotherapy has been with ADHD and autistic spectrum disorders, which are covered elsewhere in this issue of *Child and Adolescent Psychiatric Clinics of North America*. Although little work is available on the prevention and treatment of PSUD in adolescents and children using neurotherapy, there is no reason to suspect that the applicability of the approaches used in adults would not be applicable in adolescents with PSUD.

There have been several reports of brain wave biofeedback used to treat co-occurring ADHD and conduct problems in adolescents with PSUD. Martin [44] reported on a case series of 20 incarcerated adolescent felons with ADHD and features of conduct disorder and substance abuse using beta reward and theta inhibit. A subset of this group was analyzed further (Cindy Johnson, PsyD, unpublished data). Using neurofeedback alone, improvements in usual parameters of ADHD were noted in this group. Another unpublished report (Alfonso Bermea, Jr, MEd, unpublished data) of use of neurofeedback in adolescent offender populations with mixed features of conduct disorder, substance abuse, and ADHD indicated the use of this nonmedicinal approach in behavioral control and ADHD remediation. None of these studies addressed the issue of PSUD per se, and outcome data regarding long-term follow-up of substance use status are not available. One study of behavioral control in adult offenders using brain wave biofeedback techniques has been published [45], and it suggests the use of the approach of neurotherapy in settings in which conduct and behavior problems are of concern, considering the associations of conduct, substance, and hyperactive attentional problems in adolescents.

Adolescent alcoholics who do not have features of ADHD or nonalcohol drug abuse may be as responsive to alpha-theta protocols as adult alcoholics. Although there are no published studies for adolescent alcoholics with alpha-theta training, finger temperature training is believed to contribute to the overall efficacy of the Peniston Protocol for adult alcoholics [46], and it has been used in alcoholics aged 18 to 21 years [47]. The training was effective in teaching autogenic relaxation, as demonstrated by increased fingertip temperature for the treatment group after training, although no differences were observed for the control group. Most importantly, the treatment group was not only significantly more internal in their locus of control after training but also was significantly more internal than the control group after training. According to the authors of this study, because alcoholics are significantly more external in their locus of control than nonalcoholics and because an internal locus of control implies an individual's belief that he or she has control and is responsible for his or her behavior, autogenic relaxation facilitated through biofeedback may be an important component in therapeutic intervention for adolescent alcoholics. Although it does not use brain wave biofeedback, this study uses one element of the alpha-theta protocol of Peniston [26–29] to an adolescent alcoholic treatment setting

and suggests that relaxation procedures, such as alpha-theta brain wave feedback accompanied by suggestion, may be efficacious in facilitating abstinence in adolescent alcoholics.

Untreated ADHD, especially with hyperactivity and conduct disorder in boys, is a risk factor for PSUD [10–12]. Brain wave biofeedback treatment of ADHD may be important in prevention for children and adolescents at risk for developing PSUD. Stimulant medication treatment of ADHD in children has been shown to not increase subsequent PSUD [48]. Stimulant therapy protected patients who are medicated for ADHD against substance use disorder, which occurred at rates that were three to four times greater among people with untreated ADHD [49]. It may be possible that brain wave biofeedback therapy of childhood ADHD also is associated with a decrease in later life PSUD. Brain wave biofeedback of ADHD in children and adolescents recently was reviewed extensively [50,51]. To date, four controlled group studies [52–55] have been reported in peer-reviewed journals. Each of these studies sought to examine the effects of EEG biofeedback in the treatment of patients diagnosed with ADHD while attempting to control for certain factors (eg, age, intelligence, severity of symptoms before initiating treatment). Maturation effects also were controlled in each of these studies, and comparisons with stimulant medication were included in three of the four studies to control for placebo and trend effects. To date there have been no reported studies of the effect of neurofeedback treatment on prevention of PSUD.

EEG biofeedback of ADHD may be medication free or combined with medication adjunctively. EEG biofeedback may be a preferred approach for child and adolescent ADHD if medication abuse is suspected, if side effects of medication are not tolerated, or if medication is not fully effective. It also may be the choice of patients and therapists who prefer nonmedication treatments. Side effects commonly associated with medication (eg, growth retardation) have not been reported with brain wave biofeedback.

Recommendations for future research

This article suggests several hypotheses to be tested and may raise more questions than answers regarding adolescent substance abuse treatment by neurofeedback. To begin with, case series and case study reports are needed to illustrate the use and feasibility of neurofeedback in adolescent substance abusers. Controlled studies that compare neurofeedback in adolescents as an add-on therapy to conventional therapies should be considered. Of particular interest is the use of neurotherapy in adolescents who are already abusing stimulants and who have comorbid ADHD, in which stimulant use might be contraindicated. The study of neurotherapy in juvenile justice settings, in which PSUD, conduct disorder, and ADHD co-occur, should be continued to assess the clinical effectiveness of this promising technique.

Summary

Neurotherapy treatment for addictions in adults is probably efficacious. It holds promise as a treatment modality for adolescents and is attractive as a medication-free, neurophysiologic, and self-actualizing treatment for a substance-based, brain-impaired, and self-defeating disorder. It may have special applicability to treatment-resistant adolescent substance abusers who have attention and conduct problems and to adolescents who abuse stimulants. More research, beginning with case reporting and open case series and followed by controlled clinical trial, is needed to assess the use and efficacy of neurofeedback techniques for addictions in adolescents.

References

[1] Trudeau DL. A review of the treatment of addictive disorders by EEG biofeedback. Clin Electroencephalogr 2000;31:13–26.
[2] Trudeau DL. EEG biofeedback for addictive disorders: the state of the art in 2004. J Adult Dev 2004, in press.
[3] Scott WC, Brod TM, Sideroff S, Kaiser D, Saga M. Type-specific EEG biofeedback improves residential substance abuse treatment. Presented at the American Psychiatric Association Annual Meeting 2002. Available at: http://eegbiofeedback.com/research.html. Accessed August 12, 2004.
[4] Scott W, Kaiser D. Augmenting chemical dependency treatment with neurofeedback training. Journal of Neurotherapy 1998;3(1):66.
[5] Burkett VS, Cummins JM, Dickson RM, Skolnick MH. Treatment effects related to EEG-biofeedback for crack cocaine dependency in a faith-based homeless mission. Journal of Neurotherapy 2004;8(2):138–40.
[6] Fahrion SL. Group biobehavioral treatment of addiction. Presented at the 4th Meeting on the Neurobiology of Criminal and Violent Behavior. Research and Clinical Applications of Neurofeedback for Offender Populations with Substance Use Disorders and ADD/ADHD. Scottsdale, AZ, February 26, 2002.
[7] Bodenhamer-Davis E, Callaway T. Extended follow-up of Peniston protocol results with chemical dependency. Journal of Neurotherapy 2004;8(2):135.
[8] Peniston EG, Kulkosky PJ. Alpha-theta brainwave training and beta endorphin levels in alcoholics. Alcohol Clin Exp Res 1989;13:271–9.
[9] Horner BR, Scheibe KE. Prevalence and implications of attention-deficit hyperactivity disorder among adolescents in treatment for substance abuse. J Am Acad Child Adolesc Psychiatry 1997; 36(1):30–6.
[10] Manuzzza JS, Klein RG, Bessler A, Malloy P, LaPadula M. Adult psychiatric status of hyperactive boys grown up. Am J Psychiatry 1998;155(4):493–8.
[11] Gittleman R, Mannuzza S, Shenker R, Bonagura N. Hyperactive boys almost grown up. Arch Gen Psychiatry 1985;42:937–47.
[12] Mannuzza S, Klein RG, Bonagura N, Malloy P, Giampino TL, Addalli KA. Hyperactive boys almost grown up. V. Replication of psychiatric status. Arch Gen Psychiatry 1991;48:77–83.
[13] Trudeau DL, Thuras P, Stockley H. Quantitative EEG findings associated with chronic stimulant and cannabis abuse and ADHD in an adult male substance use disorder population. Clin Electroencephalogr 1999;30:165–74.
[14] Biederman J, Wilens T, Mick E, Milberger S, Spencer TJ, Farone SV. Psychoactive substance use disorders in adults with attention deficit hyperactivity disorder (ADHD): effects of ADHD and psychiatric comorbidity. Am J Psychiatry 1995;152(11):1652–8.

[15] Carroll KM, Rounsaville BJ. History and significance of childhood attention deficit disorder in treatment-seeking cocaine abusers. Compr Psychiatry 1993;34:75–82.
[16] Barkley RA, Fischer M, Edelbrock CS, Smallish L. The adolescent outcome of hyperactive children diagnosed by research criteria: I. An 8-year prospective follow-up study. J Am Acad Child Adolesc Psychiatry 1990;29(4):546–57.
[17] Green EE, Green AM, Walters ED. Alpha-theta biofeedback training. J Biofeedback 1974;2: 7–13.
[18] Niedermeyer E. Sleep and the EEG. In: Niedermeyer E, Lopes Da Silva F, editors. Electroencephalography: basic principles, clinical applications, and related fields. 4th edition. Baltimore: Williams and Wilkins; 1999. p. 174–89.
[19] Moore JP, Trudeau DL. Comparison of alpha-theta, alpha and EMG neurofeedback in the production of alpha-theta crossover and the occurrence of visualizations. Journal of Neurotherapy 2000;4(1):29–42.
[20] Taub E, Steiner SS, Smith RB, Weingarten EI, Walton KG. Effectiveness of broad spectrum approaches to relapse prevention in severe alcoholism: a long term randomized controlled trial of transcendental meditation, EMG biofeedback, and electronic neurotherapy. Alcoholism Treatment Quarterly 1994;11:187–220.
[21] Lowe F. How essential is the EEG component of the Peniston and Kulkosky protocol? Appl Psychophysiol Biofeedback 1999;24(2):117–8.
[22] Goslinga JJ. Biofeedback for chemical problem patients: a developmental process. J Biofeedback 1975;2:17–27.
[23] Twemlow SW, Bowen WT. EEG biofeedback induced self actualization in alcoholics. J Biofeedback 1976;3:20–5.
[24] Twemlow SW, Bowen WT. Sociocultural predictors of self actualization in EEG biofeedback treated alcoholics. Psychol Rep 1977;40:591–8.
[25] Twemlow SW, Sizemore DG, Bowen WT. Biofeedback induced energy redistribution in the alcoholic EEG. J Biofeedback 1977;3:14–9.
[26] Peniston EG, Kulkosky PJ. Alcoholic personality and alpha-theta brainwave training. Medical Psychotherapy 1990;2:37–55.
[27] Peniston EG, Kulkosky PG. Alpha-theta brain wave neurofeedback for Vietnam veterans with combat related post traumatic stress disorder. Medical Psychotherapy 1991;4:1–14.
[28] Peniston EG, Marriman DA, Deming WA, Kulkosky PG. EEG alpha-theta brain wave synchronization in Vietnam theater veterans with combat related post traumatic stress disorder and alcohol abuse. Medical Advances in Medical Psychotherapy 1993;6:37–50.
[29] Saxby E, Peniston EG. Alpha-theta brainwave neurofeedback training: an effective treatment for male and female alcoholics with depressive symptoms. J Clin Psychol 1995;51(5):685–93.
[30] Scott W, Kaiser D. Augmenting chemical dependency treatment with neurofeedback training. Journal of Neurotherapy 1998;3(1):66.
[31] Kaiser DA, Othmer S. Effect of neurofeedback on variables of attention in a large multi-center trial. Journal of Neurotherapy 2000;4(1):5–15.
[32] Hoffman DA, Lubar JF, Thatcher RW, Sterman WB, Rosenfeld PJ, Streifel S, et al. Limitations of the American Academy of Neurology and American Clinical Neurophysiology Society paper on QEEG. J Neuropsychiatry Clin Neurosci 1999;11:401–7.
[33] Hammond DC, Walker J, Hoffman D, Lubar JF, Trudeau DL, Gurnee R, et al. Standards for the Use of QEEG in Neurofeedback: A Position Paper of the International Society for Neuronal Regulation. Journal of Neurotherapy 2004;8(1):5–27.
[34] Lubar JF, editor. Quantitative electroencephalographic analysis (QEEG) databases for neurotherapy: description, validation, and application. Haworth Press, Inc.; 2004.
[35] Prichep LS, Alper KA, Sverdlov L, Kowalik SC, John ER, Merkin H, et al. Outcome related electrophysiological subtypes of cocaine dependence. Clin Electroencephalogr 2002;33(1):8–20.
[36] Alper KR. The EEG and cocaine sensitization. J Neuropsychiatry Clin Neurosci 1999;11: 209–21.
[37] Prichep LS, Alper KA, Kowalik SC, Rosenthal M. Neurometric QEEG studies of crack cocaine dependence and treatment outcome. J Addict Dis 1996;15(4):39–53.

[38] Struve FA, Patrick G, Straumanis JJ, Fitz-Gerald MJ, Manno J. Possible EEG sequelae of very long duration marijuana use: pilot findings from topographic quantitative EEG analyses of subjects with 15 to 24 years of cumulative daily exposure to THC. Clin Electroencephalogr 1998;29(1):31–6.
[39] Chabot RJ, Serfontein G. Quantitative EEG profiles of children with attention deficit disorder. Biol Psychiatry 1996;40:951–63.
[40] Monastra V, Lubar JF, Linden M. The development of a quantitative electroencephalographic scanning process for attention deficit-hyperactivity disorder: reliability and validity studies. Neuropsychology 2001;15(1):136–44.
[41] DeBeus R, Prinzel H, Ryder-Cook A, Allen L. QEEG-based versus research-based EEG biofeedback treatment with chemically dependent outpatients: preliminary results. Journal of Neurotherapy 2002;6(1):64–6.
[42] Gurnee R. Subtypes of alcoholism and CNS depressant abuse. In: Abstracts of the Winter Brain, Optimal Functioning, and Positive Psychology Meeting. Palm Springs, 2004. Available at: http://www.brainmeeting.com/2004_abstracts.htm. Accessed August 12, 2004.
[43] Trudeau DL. Individualizing EEG: biofeedback in addictive disorders. Biofeedback 2000;28(3):22–6.
[44] Martin G. EEG biofeedback with incarcerated adolescent felons. Journal of Neurotherapy 2003;7(1):66–7.
[45] Quirk DA. Composite biofeedback conditioning and dangerous offenders. Journal of Neurotherapy 1995;1(2):44–54.
[46] Peniston EG. Comments by Peniston. Appl Psychophysiol Biofeedback 1998;23:273–5.
[47] Sharp C, Hurford DP, Allison J, Sparks R, Cameron BP. Facilitation of internal locus of control in adolescent alcoholics through a brief biofeedback-assisted autogenic relaxation training procedure. J Subst Abuse Treat 1997;14(1):55–60.
[48] Mannuzza S, Klein RG, Moulton III JL. Does stimulant treatment place children at risk for adult substance abuse? A controlled, prospective follow-up study. J Child Adolesc Psychopharmacol 2003;13(3):273–82.
[49] Biederman J. Pharmacotherapy for attention-deficit/hyperactivity disorder (ADHD) decreases the risk for substance abuse: findings from a longitudinal follow-up of youths with and without ADHD. J Clin Psychiatry 2003;64(Suppl 11):3–8.
[50] Lubar JF. Neurofeedback for the management of attention deficit disorders. In: Schwartz MS, Andrasik F, editors. Biofeedback: a practitioner's guide. 3rd edition. New York: Guilford Press; 2003. p. 409–37.
[51] Monastra VJ. Clinical applications of electroencephalographic biofeedback. In: Schwartz MS, Andrasik F, editors. Biofeedback: a practitioner's guide. 3rd edition. New York: Guilford Press; 2003. p. 438–63.
[52] Rossiter TR, LaVaque TJ. A comparison of EEG biofeedback and psychostimulants in treating attention deficit/hyperactivity disorders. Journal of Neurotherapy 1995;1:48–59.
[53] Linden M, Habib T, Radojevic V. A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. Biofeedback Self Regul 1996;21(1):35–49.
[54] Monastra VJ, Monastra DM, George S. The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of attention-deficit/hyperactivity disorder. Appl Psychophysiol Biofeedback 2002;27(4):231–49.
[55] Fuchs T, Birbaumer N, Lutzenberger W, Gruzelier JH, Kaiser J. Neurofeedback treatment for attention-deficit/hyperactivity disorder in children: a comparison with methylphenidate. Appl Psychophysiol Biofeedback 2003;28(1):1–12.