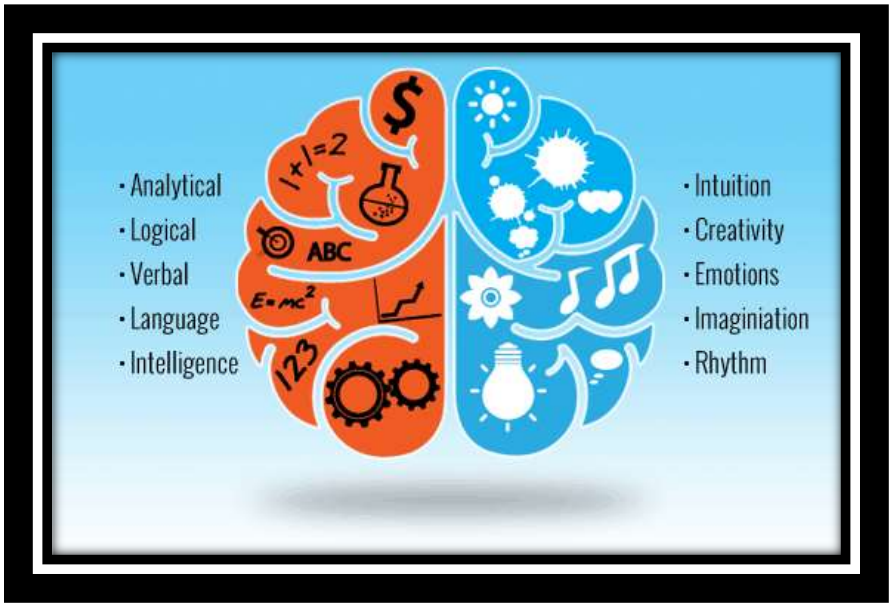
The Efficacy of Neurofeedback

A Bibliography of Verified &Validated EEG Neurofeedback Research Published In Professional Journals

Edited by Brain-Trainer International



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Brain-Trainer International
+1 (833) 224-5895
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ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD) AND RELATED LEARNING DISABILITIES

Arns, M., de Ridder, S., Strehl, U., Breteler, M., Coenen, A. (2009). Efficacy of neurofeedback treatment in ADHD: The effects on attention, impulsivity and hyperactivity: A meta-analysis. ***Clinical EEG and Neuroscience*****; 40(3). 180-189.** In order to study the treatment of the children with attention deficit hyperactivity disorder (ADHD), the integrated visual and auditory continuous performance test (IVA-CPT) was clinically applied to evaluate the effectiveness of electroencephalogram (EEG) biofeedback training. Of all the 60 children with ADHD aged more than 6 years, the effective rate of EEG biofeedback training was 91.6% after 40 sessions of EEG biofeedback training. Before and after treatment by EEG biofeedback training, the overall indexes of IVA were significantly improved among predominately inattentive, hyperactive, and combined subtype of children with ADHD ($P<0.001$). It was suggested that EEG biofeedback training was an effective and vital treatment on children with ADHD.

Beauregard, M., & Levesque, J. (2006). Functional magnetic resonance imaging investigation of the effects of neurofeedback training on the neural bases of selective attention and response inhibition in children with attention-deficit/hyperactivity disorder. ***Applied Psychophysiology & Biofeedback*****, 31(1), 3-20**. Two functional magnetic resonance imaging (fMRI) experiments were undertaken to measure the effect of neurofeedback training (NFT), in AD/HD children, on the neural substrates of selective attention and response inhibition. Twenty unmedicated AD/HD children participated to these experiments. Fifteen children were randomly assigned to the Experimental (EXP) group whereas the other five children were randomly assigned to the Control (CON) group. Only subjects in the EXP group underwent NFT. EXP subjects were trained to enhance the amplitude of the SMR (12-15 Hz) and beta 1 activity (15-18 Hz), and decrease the amplitude of theta activity (4-7 Hz). Subjects from both groups were scanned one week before the beginning of NFT (Time 1) and 1 week after the end of NFT (Time 2), while they performed a "Counting Stroop" task (Experiment 1) and a Go/No-Go task (Experiment 2). At Time 1, in both groups, the Counting Stroop task was associated with significant activation in the left superior parietal lobule. For the Go/No-Go task, no significant activity was detected in the EXP and CON groups. At Time 2, in both groups, the Counting Stroop task was associated with significant activation of the left superior parietal lobule. This time, however, there were significant loci of activation, in the EXP group, in the right ACC, left caudate nucleus, and left substantia nigra. No such activation loci were seen in CON subjects. For the Go/No-Go task, significant loci of activation were noted, in the EXP group, in the right ventrolateral prefrontal cortex, right ACcd, left thalamus, left caudate nucleus, and left substantia nigra. No significant activation of these brain regions was measured in CON subjects. These results suggest that NFT has the capacity to functionally normalize the brain systems mediating selective attention and response inhibition in AD/HD children.

Becerra J, Fernndez T, Harmony T, Caballero MI, Garcia F, Fernandez-Bouzas A, Santiago-Rodriguez E, Prado-Alcalá RA. (2006) "Follow-up study of learning disabled children treated with neurofeedback or placebo." ***Clinical EEG & Neuroscience*****, 37 (3), 98-203.** This report is a 2-year follow-up to a previous study describing positive behavioral changes and a spurt of EEG maturation with theta/alpha neurofeedback (NFB) training in a group of Learning Disabled (LD) children. In a control paired group, treated with placebo, behavioral changes were not observed and the smaller maturational EEG changes observed were easily explained by increased age. Two years later, the EEG maturational lag in Control Group children increased, reaching abnormally high theta Relative Power values; the absence of positive behavioral changes continued and the neurological diagnosis remained LD. In contrast, after 2 years EEG maturation did continue in children who belonged to the Experimental Group with previous neurofeedback training; this was accompanied by positive behavioral changes, which were reflected in remission of LD symptoms.

Breteler, M. H. M., Arns, M., Peters, S., Giepmans, I., & Verhoeven, L. (2010). Improvements in spelling after QEEG-based neurofeedback in dyslexia: A randomized controlled treatment study. ***Applied Psychophysiology & Biofeedback*****, 35(1), 5-11.** Phonological theories of dyslexia assume a specific deficit in representation, storage and recall of phonemes. Various brain imaging techniques, including qEEG, point to the importance of a range of areas, predominantly the left hemispheric temporal

areas. This study attempted to reduce reading and spelling deficits in children who are dyslexic by means of neurofeedback training based on neurophysiological differences between the participants and gender and age matched controls. Nineteen children were randomized into an experimental group receiving qEEG based neurofeedback (n = 10) and a control group (n = 9). Both groups also received remedial teaching. The experimental group improved considerably in spelling (Cohen's d = 3). No improvement was found in reading. An in-depth study of the changes in the qEEG power and coherence protocols evidenced no frontal- central changes, which is in line with the absence of reading improvements. A significant increase of alpha coherence was found, which may be an indication that attentional processes account for the improvement in spelling. Consideration of subtypes of dyslexia may refine the results of future studies.

Egner, T., & Gruzelier, J. H. (2004). EEG biofeedback of low beta band components: Frequency-specific effects on variables of attention and event-related brain potentials. ***Clinical Neurophysiology*****, 115(1), 131-139.** Objective: To test a common assumption underlying the clinical use of electroencephalographic (EEG) biofeedback training (neurofeedback), that the modulation of discreet frequency bands is associated with frequency-specific effects. Specifically, the proposal was assessed that enhancement of the low beta components sensorimotor rhythm (SMR: 12 – 15 Hz) and beta1 (15 – 18 Hz) affect different aspects of attentional processing. Methods: Subjects (n ¼ 25) were randomly allocated to training with either an SMR or beta1 protocol, or to a non-neurofeedback control group. Subjects were assessed prior and subsequent to the training process on two tests of sustained attention. The neurofeedback participants were also assessed on target P300 event-related potential (ERP) amplitudes in a traditional auditory oddball paradigm. Results: Protocol-specific effects were obtained in that SMR training was associated with increased perceptual sensitivity prime' (d0), and reduced omission errors and reaction time variability. Beta1 training was associated with faster reaction times and increased target P300 amplitude whereas no changes were evident in the control group. Conclusions: Neurofeedback training of SMR and beta1 band components led to significant and protocol-specific effects in healthy subjects. The data can be interpreted as indicating a general attention-enhancing effect of SMR training, and an arousal-enhancing effect of beta1 training.

Escolano, C., Navarro-Gil, M., Garcia-Campayo, J., Congedo, M. & Minqueez, j. (2014). The effects of individual upper alpha neurofeedback in ADHD: An open-label pilot study. Applied Psychophysiology and Biofeedback: early E-Pub Sept 9 Standardized neurofeedback (NF) protocols have been extensively evaluated in attention-deficit/hyperactivity disorder (ADHD). However, such protocols do not account for the large EEG heterogeneity in ADHD. Thus, individualized approaches have been suggested to improve the clinical outcome. In this direction, an open-label pilot study was designed to evaluate a NF protocol of relative upper alpha power enhancement in fronto-central sites. Upper alpha band was individually determined using the alpha peak frequency as an anchor point. 20 ADHD children underwent 18 training sessions. Clinical and neurophysiological variables were measured pre- and post-training. EEG was recorded pre- and post-training, and pre- and post-training trials within each session, in both eyes closed resting state and eyes open task-related activity. A power EEG analysis assessed long-term and within- session effects, in the trained parameter and in all the sensors in the (1-30) Hz spectral range. Learning curves over sessions were assessed as well. Parents rated a clinical improvement in children regarding inattention and hyperactivity/impulsivity. Neurophysiological tests showed an improvement in working memory, concentration and impulsivity (decreased number of commission errors in a continuous performance test). Relative and absolute upper alpha power showed long-term enhancement in task-related activity, and a positive learning curve over sessions. The analysis of within-session effects showed a power decrease ("rebound" effect) in task-related activity, with no significant effects during training trials. We conclude that the enhancement of the individual upper alpha power is effective in improving several measures of clinical outcome and cognitive performance in ADHD. This is the first NF study evaluating such a protocol in ADHD. A controlled evaluation seems warranted due to the positive results obtained in the current study.

Fleischman, M. J., & Othmer, S. (2005). Case study: Improvements in IQ score and maintenance of gains following EEG biofeedback with mildly developmentally delayed twins. ***Journal of Neurotherapy*****, 9(4), 35-46.** This study reports on the improvements in IQ scores and maintenance of the gains following EEG biofeedback with identical twin girls with mild developmental delay and symptoms suggestive of Attention Deficit Hyperactivity Disorder (ADHD). Full Scale IQ scores increased 22 and 23 points after treatment and were maintained at three follow-up retests over a 52-month period. ADHD symptom checklists completed by their mother showed a similar pattern of improvement and maintenance of gains. The extent of improvement is

supported by anecdotal reports of behavioral changes. The results are discussed in the context of other studies of EEG biofeedback also showing improved intelligence following EEG biofeedback.

Foks, M. (2005). Neurofeedback training as an educational intervention in a school setting: How the regulation of arousal states can lead to improved attention and behavior in children with special needs. *Educational & Child Psychology*, 22(3), 67-77. The current choice of treatment for the remediation of attentional and behavioral difficulties among primary school children with special educational needs (SEN) is, increasingly, pharmacological. If-neurofeedback can regulate brain arousal states and thereby improve attention, behavior and readiness to learn, there may be a case for incorporating it into the special needs provision of mainstream primary schools, thus avoiding the use of potentially damaging stimulant medication as a means of controlling behavior and promoting inclusion. An experimental design was used, employing the TOVA test as a pre-/post-test measure of attention and the TOVA rating scale as parental pre/post measure of behavior, plus qualitative feedback as a post-treatment measure of attention/behavior. Results indicate that neurofeedback may make an important impact on emotions and affect of the SEN individual, leading to improved behavior and improved attentional capability; quality time spent on a no-failure task of any kind on a one-to-one basis may be beneficial to children with SEN, affecting their personal belief system and behavior; incorporating neurofeedback as part of the school-based special needs provision is feasible and practicable

Fuchs, T., Birbaumer, N., Lutzenberger, W., Gruzelier, J. H., & Kaiser, J. (2003). Neurofeedback treatment for attention deficit/hyperactivity disorder in children: A comparison with methylphenidate. *Applied Psychophysiology and Biofeedback*, 28, 1-12. Clinical trials have suggested that neurofeedback may be efficient in treating attention-deficit/hyperactivity disorder (ADHD). We compared the effects of a 3-month electroencephalographic feedback program providing reinforcement contingent on the production of cortical sensorimotor rhythm (12–15 Hz) and beta1 activity (15–18 Hz) with stimulant medication. Participants were N = 34 children aged 8–12 years, 22 of which were assigned to the neurofeedback group and 12 to the methylphenidate group according to their parents' preference. Both neurofeedback and methylphenidate were associated with improvements on all subscales of the Test of Variables of Attention, and on the speed and accuracy measures of the d2 Attention Endurance Test. Furthermore, behaviors related to the disorder were rated as significantly reduced in both groups by both teachers and parents on the IOWA-Conners Behavior Rating Scale. These findings suggest that neurofeedback was efficient in improving some of the behavioral concomitants of ADHD in children whose parents favored a non-pharmacological treatment.

Gani C, Birbaumer N & Strehl U. (2008). Long term effects after feedback of slow cortical potentials and of theta-beta amplitudes in children with attention-deficit/hyperactivity disorder (ADHD). *International Journal of Bioelectromagnetism*, 10(4), 209-232. Though it had already been shown in the 1970s that neurofeedback improves attention, academic performance and social behavior in children with ADHD, it has not been considered as a standard therapy so far. This is mainly due to the small number of controlled studies fulfilling methodological standards - especially long-term data was not available so far. We are the first to present long term data of children undergoing neurofeedback training. 47 patients in the age of 8 – 12 years were randomly assigned to two different training groups. One group was trained to self-regulate slow cortical potentials (SCP), the other group tried to influence Theta- and Beta-amplitudes. Follow-up evaluation was carried out 6 months and more than 2 years after the last training session. Eleven children of the SCP group and 12 CHildren of the Theta/Beta group took part in three booster sessions. Parents rated behavioral symptoms as well as frequency and impact of problems. Attention was measured with the Testbatterie zur Aufmerksamkeitsprüfung (TAP). All improvements in behavior and attention that had been observed at previous assessments turned out to be stable. Yet another significant reduction of number of problems and significant improvement in attention was observed. EEG-self regulation skills were preserved. In each group, half of the children no longer met ADHD criteria. Neurofeedback appears to be an alternative or complement to traditional treatments. The stability of changes might be explained by normalizing of brain functions that are responsible for inhibitory control, impulsivity and hyperactivity.

Gevensleben H, Moll GH, Rothenberger A, Heinrich H. (2011). The usage of neurofeedback with children with ADHD: The method and its evaluation. *Prax Kinderpsychol Kinderpsychiatr*. 2011;60(8):666-76. Neurofeedback is a computer-based behavior training, which is gaining increasing interest in the treatment of children with attention-deficit/hyperactivity disorder (ADHD). This article gives an introduction to neurofeedback and summarizes the state of research, discussing inter alia methodical aspects (e. g., requirements to a control training). Evaluation studies conducted so far indicate clinical efficacy. For example, neurofeedback training was superior to a computerized attention training in a randomized controlled trial (medium

effect size). Follow-up investigations suggest that treatment effects remain stable (at least six months). At the clinical level, comparable improvements could be obtained for the neurofeedback protocols theta/beta training and training of slow cortical potentials. Neurophysiological findings document different mechanisms of theta/beta training and slow cortical potential training Future studies should further elucidate the specificity of training effects related to the kind of training and certain disorders and address how to optimize and individualize neurofeedback training.

Gevensleben, H., Holl, B., Albrecht,B., Vogel, C., Schlamp, D., Kratz, O., Studer,P., Rothenberger, A., Moll,G. H. & Heinrich, H. (2009). Is neurofeedback an efficacious treatment for ADHD? A randomized controlled clinical trial. ***The Journal of Child Psychology and Psychiatry*****; 74(2). 149-157.** In a randomized controlled trial, neurofeedback (NF) training was found to be superior to a computerized attention skills training concerning the reduction of ADHD symptomatology (Gevensleben et al., 2009). The aims of this investigation were to assess the impact of different NF protocols (theta/beta training and training of slow cortical potentials, SCPs) on the resting EEG and the association between distinct EEG measures and behavioral improvements. In 72 (of initially 102) children with ADHD, aged 8-12, EEG changes after either a NF training (n=46) or the control training (n=26) could be studied. The combined NF training consisted of one block of theta/beta training and one block of SCP training, each block comprising 18 units of 50 minutes (balanced order). Spontaneous EEG was recorded in a two-minute resting condition before the start of the training, between the two training blocks and after the end of the training. Activity in the different EEG frequency bands was analyzed. In contrast to the control condition, the combined NF training was accompanied by a reduction of theta activity. Protocol-specific EEG changes (theta/beta training: decrease of posterior-midline theta activity; SCP training: increase of central-midline alpha activity) were associated with improvements in the German ADHD rating scale. Related EEG-based predictors were obtained. Thus, differential EEG patterns for theta/beta and SCP training provide further evidence that distinct neuronal mechanisms may contribute to similar behavioral improvements in children with ADHD.

Ghaziri J, Tucholka A, Larue V, Blanchette-Sylvestre M, Reyburn G, Gilbert G, Lévesque J, Beauregard M. Neurofeedback Training Induces Changes in White and Gray Matter. Clin EEG Neurosci. 2013 Mar 26. The main objective of this structural magnetic resonance imaging (MRI) study was to investigate, using diffusion tensor imaging, whether a neurofeedback training (NFT) protocol designed to improve sustained attention might induce structural changes in white matter (WM) pathways, purportedly implicated in this cognitive ability. Another goal was to examine whether gray matter (GM) volume (GMV) might be altered following NFT in frontal and parietal cortical areas connected by these WM fiber pathways. Healthy university students were randomly assigned to an experimental group (EXP), a sham group, or a control group. Participants in the EXP group were trained to enhance the amplitude of their β1 waves at F4 and P4. Measures of attentional performance and MRI data were acquired one week before (Time 1) and one week after (Time 2) NFT. Higher scores on visual and auditory sustained attention were noted in the EXP group at Time 2 (relative to Time 1). As for structural MRI data, increased fractional anisotropy was measured in WM pathways implicated in sustained attention, and GMV increases were detected in cerebral structures involved in this type of attention. After 50 years of research in the field of neurofeedback, our study constitutes the first empirical demonstration that NFT can lead to microstructural changes in white and gray matter.

Hammond, D. C. (2006). What is neurofeedback? ***Journal of Neurotherapy*****; 10(4). 25-36.** EEG biofeedback (neurofeedback) originated in the late 1960s as a method for retraining brainwave patterns through operant conditioning. Since that time a sizable body of research has accumulated on the effectiveness of neurofeedback in the treatment of uncontrolled epilepsy, ADD/ADHD, anxiety, alcoholism, posttraumatic stress disorder, and mild head injuries. Studies also provide encouraging indications that neurofeedback offers a treatment alternative for use with learning disabilities, stroke, depression, fibromyalgia, autism, insomnia, tinnitus, headaches, problems with physical balance, and for the enhancement of peak performance. At a time when an increasing number of people are concerned with negative effects from relying solely on medication treatments, neurofeedback may offer an additional treatment alternative for many conditions. This article assists the reader to understand how neurofeedback works, how assessment allows neurofeedback to be individualized, and briefly reviews evidence for the neurofeedback treatment of many conditions. The public is cautioned that in selecting a practitioner for the treatment of the kinds of medical, psychiatric and psychological conditions cited above, a practitioner should be licensed for independent practice in their state or province and should ideally also be certified by a legitimately recognized body

Hansen, L. M., Trudeau, D., & Grace, L. (1996). Neurotherapy and drug therapy in combination for adult ADHD, personality disorder, and seizure. *Journal of Neurotherapy*, 2(1), 6-14. This is a case report of an adult female patient with ADHD, temporal seizure disorder, and Borderline Personality Disorder treated with 30 weekly sessions of SMR neurofeedback and carbamazepine. Posttreatment measures showed improvements in T.O.V.A., self-report, and QEEG. Both neurofeedback and carbamazepine showed the most effect in early treatment. Progress continued after discontinuance of the drug.

Kaiser, D. A., & Othmer, S. (2000). Effect of Neurofeedback on variables of attention in a large multi-center trial. *Journal of Neurotherapy*, 4(1), 5-15. Since the first reports of Neurofeedback treatment in ADHD in 1976 many studies have been carried out investigating the effects of Neurofeedback on different symptoms of ADHD such as inattention, impulsivity and hyperactivity. This technique is also used by many practitioners, but the question as to the evidence-based level of this treatment is still unclear. In this study selected research on Neurofeedback treatment for ADHD was collected and a meta-analysis was performed. Both prospective controlled studies and studies employing a pre- and post-design found large effect sizes (ES) for Neurofeedback on impulsivity and inattention and a medium ES for hyperactivity. Randomized studies demonstrated a lower ES for hyperactivity suggesting that hyperactivity is probably most sensitive to non-specific treatment factors. Due to the inclusion of some very recent and sound methodological studies in this meta-analysis potential confounding factors such as small studies, lack of randomization in previous studies and a lack of adequate control groups have been addressed and the clinical effects of Neurofeedback in the treatment of ADHD can be regarded as clinically meaningful. Four randomized controlled trials have shown Neurofeedback to be superior to a (semi- active) control group, whereby the requirements for Level 4: Efficacious are fulfilled (Criteria for evaluating the level of evidence for efficacy established by the AAPB and ISNR). Three studies have employed a semi-active control group, which can be regarded as a credible sham control providing an equal level of cognitive training and client-therapist interaction. Therefore, in line with the AAPB and ISNR guidelines for rating clinical efficacy, we conclude that Neurofeedback treatment for ADHD can be considered 'Efficacious and Specific' (Level 5) with a large ES for inattention and impulsivity and a medium ES for hyperactivity.

Leins, U., Goth, G., Hinterberger, T., Klinger, C., Rumpf, M., & Strehl, U. (2007). Neurofeedback for children with ADHD: A comparison of SCP and theta/beta protocols. *Applied Psychophysiology & Biofeedback*, 32. Behavioral and cognitive improvements in children with ADHD have been consistently reported after neurofeedback treatment. However, neurofeedback has not been commonly accepted as a treatment for ADHD. This study addresses previous methodological shortcomings while comparing a neurofeedback training of Theta-Beta frequencies and training of slow cortical potentials (SCPs). The study aimed at answering (a) whether patients were able to demonstrate learning of cortical self- regulation, (b) if treatment leads to an improvement in cognition and behavior and (c) if the two experimental groups differ in cognitive and behavioral outcome variables. SCP participants were trained to produce positive and negative SCP-shifts while the Theta/Beta participants were trained to suppress Theta (4–8 Hz) while increasing Beta (12–20 Hz). Participants were blind to group assignment. Assessment included potentially confounding variables. Each group was comprised of 19 children with ADHD (aged 8–13 years). The treatment procedure consisted of three phases of 10 sessions each. Both groups were able to intentionally regulate cortical activity and improved in attention and IQ. Parents and teachers reported significant behavioral and cognitive improvements. Clinical effects for both groups remained stable six months after treatment. Groups did not differ in behavioral or cognitive outcome.

Lenartowitz, A., Delorme, A., Walshaw, PD., Cho, AL., Bilder, RM., McGough, JJ., McCracken, JT., Makeaig, S & Loo, S. (2014). Electroencephalography Correlates of Spatial Working Memory Deficits in Attention-Deficit/Hyperactivity Disorder: Vigilance, Encoding, and Maintenance. Journal of Neuroscience:34(4). 1171-1182. In the current study we sought to dissociate the component processes of working memory (WM) (vigilance, encoding and maintenance) that may be differentially impaired in attention-deficit/ hyperactivity disorder (ADHD). We collected electroencephalographic (EEG) data from 52 CHildren with ADHD and 47 typically developing (TD) children, ages 7–14 years, while they performed a spatial Sternberg working memory task. We used independent component analysis and time-frequency analysis to identify midoccipital alpha (8 –12 Hz) to evaluate encoding processes and frontal midline theta (4 –7 Hz) to evaluate maintenance processes. We tested for effects of task difficulty and cue processing to evaluate vigilance. Children with ADHD showed attenuated alpha band event-related desynchronization (ERD) during encoding. This effect was more pronounced when task difficulty was low (consistent with impaired vigilance) and was predictive of memory task performance and symptom severity. Correlated with alpha ERD during encoding were alpha power increases during the maintenance period (relative to baseline), suggesting a compensatory effort. Consistent with this interpretation, midfrontal theta power increases during maintenance were stronger in ADH D and in high-load memory

conditions. Furthermore, children with ADHD exhibited a maturational lag in development of posterior alpha power whereas age-related changes in frontal theta power deviated from the TD pattern. Last, subjects with ADHD showed age-independent attenuation of evoked responses to warning cues, suggesting low vigilance. Combined, these three EEG measures predicted diagnosis with 70% accuracy. We conclude that the interplay of impaired vigilance and encoding in ADHD may compromise maintenance and lead to impaired WM performance in this group.

Levesque, J., Beauregard, M., & Mensour, B. (2006). Effect of neurofeedback training on the neural substrates of selective attention in children with attention-deficit/hyperactivity disorder: a functional magnetic resonance imaging study. *Neuroscience Letters*, 394(3), 216-221. Attention De cit Hyperactivity Disorder (AD/HD) is a neurodevelopmental disorder mainly characterized by impairments in cognitive functions. Functional neuroimaging studies carried out in individuals with AD/HD have shown abnormal functioning of the anterior cingulate cortex (ACC) during tasks involving selective attention. In other respects, there is mounting evidence that neurofeedback training (NFT) can significantly improve cognitive functioning in AD/HD children. In this context, the present functional magnetic resonance imaging (fMRI) study was conducted to measure the effect of NFT on the neural substrates of selective attention in children with AD/HD. Twenty AD/HD children— not taking any psychostimulant and without co-morbidity-participated to the study Fifteen children were randomly assigned to the Experimental (EXP) group (NFT), whereas the other children were assigned to the Control (CON) group (no NFT). Subjects from both groups were scanned 1 week before the beginning of the NFT (Time 1) and 1 week after the end of this training (Time 2), while they performed a Counting Stroop task. At Time 1, for both groups, the Counting Stroop task was associated with significant loci of activation in the left superior parietal lobule. No activation was noted in the ACC. At Time 2, for both groups, the counting Stroop task was still associated with significant activation of the left superior parietal lobule. This time, however, for the EXP group only there was a significant activation of the right ACC. These results suggest that in AD/HD children, NFT has the capacity to normalize the functioning of the ACC, the key neural substrate of selective attention.

Linden, M., Habib, T., & Radojevic, V. (1996). A controlled study of the effects of EEG biofeedback on cognition and behavior of children with attention deficit disorder and learning disabilities. *Biofeedback & Self-Regulation*, 21(1), 35-49. Eighteen children with ADD/ADHD, some of whom were also LD, ranging in ages from 5 through 15 were randomly assigned to one of two conditions. The experimental condition consisted of 40 45-minute sessions of training in enhancing beta activity and suppressing theta activity, spaced over 6 months. The control condition, waiting list group, received no EEG biofeedback. No other psychological treatment or medication was administered to any subjects. All subjects were measured at pretreatment and at posttreatment on an IQ test and parent behavior rating scales for inattention, hyperactivity, and aggressive/defiant (oppositional) behaviors. At posttreatment the experimental group demonstrated a significant increase (mean of 9 points) on the K-Bit IQ Composite as compared to the control group ($p < .05$). The experimental group also significantly reduced inattentive behaviors as rated by parents ($p < .05$). The significant improvements in intellectual functioning and attentive behaviors might be explained as a result of the attentional enhancement affected by EEG biofeedback training. Further research utilizing improved data collection and analysis, more stringent control groups, and larger sample sizes are needed to support and replicate these findings.

Lofthouse N, Arnold LE, Hersch S, Hurt E, DeBeus R. (2011). A review of neurofeedback for pediatric ADHD. *Journal of Attention Disorders*; 16(5). 351-372. The aim of this paper was to review all randomized published trials and unpublished conference presentations on the neurofeedback (NF) treatment of pediatric ADHD, and their relevance, strengths, and limitations. METHOD: Via PsychInfo and Medline searches and contacts with NF researchers 14 studies were identified and reviewed. RESULTS: The majority were conducted from 1994 to 2010, with 5- to 15-year-olds, usually male and White with the combined type of ADHD. Most studies used theta/beta NF with a unipolar-electrode placement at Cz and demonstrated, where reported, an overall ADHD mean effect size of $d = 0.69$, a medium effect. Main study strengths, within some studies, include use of randomization, treatment control conditions, Diagnostic and Statistical Manual of Mental Disorders criteria, evidence-based assessment of ADHD, standard treatment outcome measures, multi-domain assessment, and, for some studies, moderate sample size, some type of blind and the identification of medication as a concomitant treatment. Main study limitations (and directions for future research) include the lack of adequate blinding of participants, raters and NF trainers, a sham-NF/blinded control treatment condition, post treatment follow-up, generalizability, specific details about delivery of NF, identification and control of comorbidity, and the identification, measurement, and control of concomitant treatments and potential side effects. CONCLUSION: Based on the results and methodologies of published studies, this review concludes that NF for pediatric ADHD

can be currently considered as "probably efficacious."

Loo, S., & Barkley, R. (2005). Clinical utility of EEG in attention deficit hyperactivity disorder. *Applied Neuropsychology*, 12(2), 64-76. Electrophysiological measures were among the first to be used to study brain processes in children with attention deficit hyperactivity disorder (ADHD; Diagnostic and Statistical Manual of Mental Disorders [4th ed.], American Psychiatric Association, 1994) and have been used as such for over 30 years (see Hastings & Barkley, 1978, for an early review). More recently, electroencephalography (EEG) has been used both in research to describe and quantify the underlying neurophysiology of ADHD, but also clinically in the assessment, diagnosis, and treatment of ADHD. This review will first provide a brief overview of EEG and then present some of the research findings of EEG correlates in ADHD. Then, the utility of EEG in making an ADHD diagnosis and predicting stimulant response will be examined. Finally, and more controversially, we will review the results of the most recent studies on EEG biofeedback (neurofeedback) as a treatment for ADHD and the issues that remain to be addressed in the research examining the efficacy this therapeutic approach.

Lubar, J. O., & Lubar, J. F. (1984). Electroencephalographic biofeedback of SMR and beta for treatment of attention deficit disorders in a clinical setting. *Biofeedback & Self-Regulation*, 9, 1-23. Six children were provided with long-term biofeedback and academic treatment for attention deficit disorders. Their symptoms were primarily learning disabilities, and, in some cases, there were varying degrees of hyperkinesis. The training consisted of two sessions per week for ten to 27 months, with a gradual phase-out. Feedback was provided for either increasing 12- 15 Hz SMR or 16-20 beta activity. Inhibit circuits were employed for SMR or beta when either gross movement excessive EMG, or theta (4-8 HZ) activity was present. Treatment also consisted of combining the biofeedback with academic training, including reading, arithmetic and spatial tasks to improve their attention. All children increased SMR or beta and decreased slow EEG and EMG activity. Changes could be seen in their power spectra after training in terms of increased beta and decreased slow activity. All six children demonstrated considerable improvement in their schoolwork in terms of grades or achievement test scores. None of the children are currently on any medications for hyperkinetic behavior. The results indicate that EEG biofeedback training, if applied comprehensively, can be highly effective in helping to remediate children who are experiencing attention deficit disorders.

Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & O'Donnell, P. H. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in T.O.V.A., scores, behavioral ratings, and WISC-R performance. *Biofeedback & Self- Regulation*, 20(1), 83-99. A study with three component parts was performed to assess the effectiveness of neurofeedback treatment for Attention Deficit/Hyperactivity Disorder (ADHD). The subject pool consisted of 23 children and adolescents ranging in age from 8 to 19 years with a mean of 11.4 years who participated in a 2-to 3-month summer program of intensive neurofeedback training. Feedback was contingent on the production of 16-20 hertz (beta) activity in the absence of 4-8 hertz (theta) activity. Post training changes in EEG activity, T.O.V~I. performance, (ADDES) behavior ratings, and WISC-R performance were assessed. Part I indicated that subjects who successfully decreased theta activity showed significant improvement in T.O. VM. performance; Part II revealed significant improvement in parent ratings following neurofeedback training; and Part III indicated significant increases in WISC-R scores following neurofeedback training. This study is significant in that it examines the effects of neurofeedback training on both objective and subjective measures under relatively controlled conditions. Out findings corroborate and extend previous research, indicating that neurofeedback training can be an appropriate and efficacious treatment for children with ADHD.

Monastra, V. J., Monastra, D. M., & George, S. (2002). The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of attention-deficit/hyperactivity disorder. *Applied Psychophysiology & Biofeedback*, 27(4), 231-249.One hundred children, ages 6– 19, who were diagnosed with attention-deficit/hyperactivity disorder (ADHD), either inattentive or combined types, participated in a study examining the effects of Ritalin, EEG biofeedback, and parenting style on the primary symptoms of ADHD. All of the patients participated in a 1- year, multimodal, outpatient program that included Ritalin, parent counseling, and academic support at school (either a 504 Plan or an IEP). Fifty-one of the participants also received EEG biofeedback therapy. Post treatment assessments were conducted both with and without stimulant therapy. Significant improvement was noted on the Test of Variables of Attention (TOVA; L. M. Greenberg, 1996) and the Attention Deficit Disorders

Evaluation Scale (ADDES; S. B. McCarney, 1995) when participants were tested while using Ritalin. However, only those who had received EEG biofeedback sustained these gains when tested without Ritalin. The results of a Quantitative Electroencephalographic Scanning Process (QEEG-Scan; V. J. Monastra et al., 1999) revealed significant reduction in cortical slowing only in patients who had received EEG biofeedback. Behavioral measures indicated that parenting style exerted a significant moderating effect on the expression of behavioral symptoms at home but not at school.

Rasey, H. W., Lubar, J. E., McIntyre, A., Zoffuto, A. C., & Abbott, P. L. (1996). EEG biofeedback for the enhancement of attentional processing in normal college students. *Journal of Neurotherapy*, 1(3), 15-21. College students diagnosed as free of any neurological or attention deficit disorder received EEG biofeedback to enhance beta (16-22 HZ) activity while simultaneously inhibiting high theta and low alpha (6-10 Hz) activity in order to evaluate improvements in attentional measurers. Following short-term treatment (mean number of sessions = 20), subjects were evaluated as either learners or non-learners based upon standard pre- and post-treatment neurofeedback measurers. Attention quotients taken from pre- and post-treatment measurements using the Integrated Visual and Auditory Continuous Performance Test (IVA) identified significant improvements in attentional measures in learners, while non-learners showed no significant improvements. Results suggest that some "normal" young adults can learn to increase EEG activity associated with improved attention. Twenty sessions, however, even for this population may represent the lower limit for achieving significant improvement.

Shin, D. I., Lee, J. H., Lee, S. M., Kim, I. Y., & Kim, S. I. (2004). Neurofeedback training with virtual reality for inattention and impulsiveness. *Cyberpsychology & Behavior*, 7(5), 519-526. In this research, the effectiveness of neurofeedback, along with virtual reality (VR), in reducing the level of inattention and impulsiveness was investigated. Twenty-eight male participants, aged 14-18, with social problems, took part in this study. They were separated into three groups: a control group, a VR group, and a non-VR group. The VR and non-VR groups underwent eight sessions of neurofeedback training over 2 weeks, while the control group just waited during the same period. The VR group used a head-mounted display (HMD) and a head tracker, which let them look around the virtual world. Conversely, the non-VR group used only a computer monitor with a fixed viewpoint. All participants performed a continuous performance task (CPT) before and after the complete training session. The results showed that both the VR and non-VR groups achieved better scores in the CPT after the training session, while the control group showed no significant difference. Compared with the other groups, the VR group presented a tendency to get better results, suggesting that immersive VR is applicable to neurofeedback for the rehabilitation of inattention and impulsiveness.

Steiner, NJ., Frenette, EC., Rene, KM., Brennan, RT & Perrin, EC. (2014). In-school neurofeedback training for ADHD: Sustained improvements from a randomized control trial. Pediatrics:133. 483. OBJECTIVE: To evaluate sustained improvements 6 months after a 40- session, in-school computer attention training intervention using neurofeedback or cognitive training (CT) administered to 7- to 11-year-olds with attention-deficit/hyperactivity disorder (ADHD). METHODS: One hundred four children were randomly assigned to receive neurofeedback, CT, or a control condition and were evaluated 6 months post intervention. A 3-point growth model assessed change over time across the conditions on the Conners 3–Parent Assessment Report (Conners 3-P), the Behavior Rating Inventory of Executive Function Parent Form (BRIEF), and a systematic double-blinded classroom observation (Behavioral Observation of Students in Schools). Analysis of variance assessed community-initiated changes in stimulant medication. RESULTS: Parent response rates were 90% at the 6-month follow-up. Six months post intervention, neurofeedback participants maintained significant gains on Conners 3-P (Inattention effect size [ES] = 0.34, Executive Functioning ES = 0.25, Hyperactivity/Impulsivity ES = 0.23) and BRIEF subscales including the Global Executive Composite (ES = 0.31), which remained significantly greater than gains found among children in CT and control conditions. Children in the CT condition showed delayed improvement over immediate post intervention ratings only on Conners 3- P Executive Functioning (ES = 0.18) and 2 BRIEF subscales. At the 6- month follow-up, neurofeedback participants maintained the same stimulant medication dosage, whereas participants in both CT and control conditions showed statistically and clinically significant increases (9 mg [P = .002] and 13 mg [P , .001], respectively). CONCLUSIONS: Neurofeedback participants made more prompt and greater improvements in ADHD symptoms, which were sustained at the 6-month follow- up, than did CT participants or those in the control group. This finding suggests that neurofeedback is a promising attention training treatment for children with ADHD. Pediatrics 2014;133:483– 492

Steiner, NJ., Frenette, EC., Rene, KM., Brennan, RT & Perrin, EC. (2014). Neurofeedback and cognitive attention training for children with attention-deficit hyperactivity disorder in schools. J Dev Bahav Peadiatr:35(1). 18-27. OBJECTIVE: To evaluate the efficacy of 2 computer attention training systems administered in school for children with attention-deficit hyperactivity disorder (ADHD). METHOD: Children in second and fourth grade with a diagnosis of ADHD (n = 104) were randomly assigned to neurofeedback (NF) (n = 34), cognitive training (CT) (n = 34), or control (n = 36) conditions. A 2-point growth model assessed change from pre-post intervention on parent reports (Conners 3- Parent [Conners 3-P]; Behavior Rating Inventory of Executive Function [BRIEF] rating scale), teacher reports (Swanson, Kotkin, Agler, M-Flynn and Pelham scale [SKAMP]; Conners 3-Teacher [Conners 3-T]), and systematic classroom observations (Behavioral Observation of Students in Schools [BOSS]). Paired t tests and an analysis of covariance assessed change in medication. RESULTS: Children who received NF showed significant improvement compared with those in the control condition on the Conners 3-P Attention, Executive Functioning and Global Index, on all BRIEF summary indices, and on BOSS motor/verbal off-task behavior. Children who received CT showed no improvement compared to the control condition. Children in the NF condition showed significant improvements compared to those in the CT condition on Conners 3-P Executive Functioning, all BRIEF summary indices, SKAMP Attention, and Conners 3-T Inattention subscales. Stimulant medication dosage in methylphenidate equivalencies significantly increased for children in the CT (8.54 mg) and control (7.05 mg) conditions but not for those in the NF condition (0.29 mg). CONCLUSION: Neurofeedback made greater improvements in ADHD symptoms compared to both the control and CT conditions. Thus, NF is a promising attention training treatment intervention for children with ADHD.

Strehl, U., Leins, U., Goth, G., Klinger, C., Hinterberger, T., and Birbaumer, N. (2006). Self-regulation of slow cortical potentials: A new treatment for children with attention deficit/hyperactivity disorder. *Pediatrics*, 118, 1530-1540. We investigated the effects of self-regulation of slow cortical potentials for children with attention-deficit/hyperactivity disorder. Slow cortical potentials are slow event-related direct-current shifts of the electroencephalogram. Slow cortical potential shifts in the electrical negative direction reflect the depolarization of large cortical cell assemblies, reducing their excitation threshold. This training aims at regulation of cortical excitation thresholds considered to be impaired in children with attention-deficit/hyperactivity disorder. Electroencephalographic data from the training and the 6-month follow-up are reported, as are changes in behavior and cognition. Twenty-three children with attention-deficit/hyperactivity disorder aged between 8 and 13 years received 30 sessions of self-regulation training of slow cortical potentials in 3 phases of 10 sessions each. Increasing and decreasing slow cortical potentials at central brain regions was fed back visually and auditorily. Transfer trials without feedback were intermixed with feedback trials to allow generalization to everyday-life situations. In addition to the neurofeedback sessions, children exercised during the third training phase to apply the self-regulation strategy while doing their homework. For the first time, electroencephalographic data during the course of slow cortical potential neurofeedback are reported. Measurement before and after the trials showed that children with attention-deficit/hyperactivity disorder learn to regulate negative slow cortical potentials. After training, significant improvement in behavior, attention, and IQ score was observed. The behavior ratings included Diagnostic and Statistical Manual of Mental Disorders criteria, number of problems, and social behavior at school and were conducted by parents and teachers. The cognitive variables were assessed with the Wechsler Intelligence Scale for Children and with a computerized test battery that measures several components of attention. All changes proved to be stable at 6 months' follow-up after the end of training. Clinical outcome was predicted by the ability to produce negative potential shifts in transfer sessions without feedback.

Studer, P., Kratz, O., Gevensleben, H., Rothenberger, A., Moll, GH., Hautzinger, M & Heinrich, H. (2014). Frontiers in Human Neuroscience:24(8) 555. Neurofeedback (NF) is being successfully applied, among others, in children with attention deficit/hyperactivity disorder (ADHD) and as a peak performance training in healthy subjects. However, the neuronal mechanisms mediating a successful NF training have not yet been sufficiently uncovered for both theta/beta (T/B), and slow cortical potential (SCP) training, two protocols established in NF in ADHD. In the present, randomized, controlled investigation in adults without a clinical diagnosis (n = 59), the specificity of the effects of these two NF protocols on attentional processes and motor system excitability were to be examined, focusing on the underlying neuronal mechanisms. Neurofeedback training consisted of 10 double sessions, and self-regulation skills were analyzed. Pre- and post-training assessments encompassed performance and event-related potential measures during an attention task, and motor system excitability assessed by transcranial magnetic stimulation. Some NF protocol-specific effects have been obtained. However, due to the limited sample size medium effects did not reach the level of significance. Self-regulation abilities during negativity trials of the SCP training were associated with increased contingent negative variation amplitudes, indicating improved resource allocation during cognitive preparation.

Theta/beta training was associated with increased response speed and decreased target-P3 amplitudes after successful theta/beta regulation suggested reduced attentional resources necessary for stimulus evaluation. Motor system excitability effects after theta/beta training paralleled the effects of methylphenidate. Overall, our results are limited by the non-sufficiently acquired self-regulation skills, but some specific effects between good and poor learners could be described. Future studies with larger sample sizes and sufficient acquisition of self-regulation skills are needed to further evaluate the protocol-specific effects on attention and motor system excitability reported.

Tansey, M. A. (1985). Brainwave signatures--An index reflective of the brain=s functional neuroanatomy: Further findings on the effect of EEG sensorimotor rhythm biofeedback training on the neurologic precursors of learning disabilities. *International Journal of Psychophysiology*, 3, 85-89. Eight boys, ages 7 years 11 months to 15 years 3 months, were provided with long-term--symptom duration-- sensorimotor rhythm biofeedback training for the remediation of their learning disabilities. Concurrently, the simultaneous recording of five frequency bands of brainwave activity (5 Hz, 7 Hz, 10 Hz, 12 Hz and 14 Hz), from one active electrode equidistant from reference and ground, was intended to provide a glimpse of the 'brainwave signature' reflective of the dynamic and synergistic processes involved in such cerebro-neural activation and the brain's global response to such an alteration in the sensorimotor subnetwork. Overall, the main effect of this procedure, for the biofeedback and subsequent conditioning of increased 14 Hz neural discharge patterns over the central Rolandic cortex in a clinical office setting, seems to be to increase bilateral sensorimotor transactions resulting in substantive remediation of the learning disabilities of the recipients of such training--by way of internally exercising of, and/or recruitment of additional neural activation within, the sensorimotor subnetwork/matrix. Observation of the changing brainwave signatures showed a tendency for decreased slow wave activity concomitant with increases in fast wave activity, for cases with a Full Scale I.Q. within the range of 76 and 85; with those cases with a Full Scale I.Q. within the range of 102 and 116 exhibiting increased amplitudes over most of the monitored bands, but with the increases being much less at the slower frequencies. It is noteworthy that those four subjects with either a significant Verbal greater than Performance, or Performance greater than Verbal, I.Q. Score discrepancy exhibited no less than a 40% greater increase in the lower of the two I.Q. scores; indicating that this SMR training procedure also resulted in an increased symmetry in the interhemispheric interactions reflective of the higher cortical functions for these no longer learning disabled boys.

Tansey, M. A. (1993). Ten-year stability of EEG biofeedback results for a hyperactive boy who failed fourth grade perceptually impaired class. *Biofeedback & Self-Regulation*, 18, 33-44. Ten years ago, the first successful application of a clinical, private-practice based, EEG 14-Hz biofeedback training regimen for the treatment of learning disorders was performed by the author. After the 10-year-old boy, with presenting symptomatology including a developmental reading disorder, hyperactivity, and an educational classification of perceptually impaired, continued symptom free for a period of two years, his case was submitted for publication. Ten years after his termination from successful treatment, his ongoing normal social and academic functioning is noted and his EEG brainwave signature examined and compared with a population of 24 "used-to-be" learning disabled, one-half of which had a pretreatment state including the educational classification of perceptually impaired. This 10-year follow-up confirms the long-term stability of the results of this EEG 14-Hz biofeedback regimen. Current findings on recent medical research identifying a major cerebral locus of dysfunction for hyperkinesis and how it supports the electrode placements of this clinical office setting regimen is also discussed.

Tansey, M. A., & Bruner, R. L. (1983). EMG and EEG biofeedback training in the treatment of 10-year old hyperactive boy with a developmental reading disorder. *Biofeedback & Self-Regulation*, 8(1), 25-37. The serial application of electromyographic (EMG) and sensorimotor (SMR) biofeedback training was attempted with a 10-year-old boy presenting a triad of symptoms: an attention deficit disorder with hyperactivity, developmental reading disorder, and ocular instability. Symptom elimination was achieved, for all three aspects of the triad, following the procedure of first conditioning a decrease in EMG-monitored muscle tension and then conditioning increases in the amplitude of sensorimotor rhythm over the Rolandic cortex. The learned reduction of monitored EMG levels was accompanied by a reduction in the child's motoric activity level to below that which had been achieved by past administration of Ritalin. In addition, the attention deficit disorder with hyperactivity was no longer diagnosable following the EMG biofeedback training. The learned increase in the amplitude of monitored SMR was accompanied by remediation of the developmental reading disorder and the ocular instability. These results remained unchanged, as ascertained by follow-ups conducted over a 24-month period subsequent to the termination of biofeedback training.

Thompson, L., & Thompson, M. (1998). Neurofeedback combined with training in metacognitive strategies: Effectiveness in students with ADD. *Applied Psychophysiology & Biofeedback*, 23(4), 243-263. Seven autistic children diagnosed with autism spectrum disorders (ASD) received a neurofeedback treatment that aimed to improve their level of executive control. Neurofeedback successfully reduced children's heightened theta/beta ration by inhibiting theta activation and enhancing beta activation over sessions. Following treatment children's executive capacities were found to have improved greatly relative to pre-treatment assessment on a range of executive function tasks. Additional improvements were found in children's social, communicative and typical behavior, relative to a waiting list control group. These findings suggest a basic executive function impairment in ASD that can be alleviated through specific neurofeedback treatment. Possible neural mechanisms that may underlie neurofeedback mediated improvement in executive functioning in autistic children are discussed.

Williams, J. (2010). Does neurofeedback help reduce attention-deficit hyperactivity disorder? *Journal of Neurotherapy*; 14(4), 261-279. Introduction: Neurofeedback is an alternative treatment for Attention Deficit Hyperactivity Disorder (ADHD), but its efficacy is unknown. This narrative review examines rigorous studies conducted utilizing neurofeedback as a treatment for ADHD. Methods: Studies were located by searching the Web of Science and PsycINFO databases with the keywords ADHD or attention deficit hyperactivity disorder AND neurofeedback or EEG biofeedback or electroencephalogram biofeedback. Located studies were chosen for initial review if they met the following criteria: (a) randomized controlled trial or quasi-experiment, (b) ADHD diagnosis based on DSM criteria, (c) published at any time prior to March 2010, (d) English language, and (e) published in a peer-reviewed journal. Participants included children, adolescents, and adults diagnosed with ADHD. Results: Twelve articles reporting 9 different studies met the eligibility criteria and were included in the review. All 9 studies produced results that indicated significant improvements on either tests scores or behavioral conduct for individuals who were treated with neurofeedback for ADHD. Alternative treatments also demonstrated effectiveness. Conclusion: Neurofeedback may be an effective treatment for ADHD. Future research is needed with larger sample sizes, comparing the efficacy of neurofeedback with the efficacy of other ADHD treatments and comparing different neurofeedback protocols.

Vernon, D., Egner, T., Cooper, N., Compton, T., Neilands, C., Sheri, A., & Gruzelier, J. (2003). The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *International Journal of Psychophysiology*, 47, 75-85. The use of neurofeedback as an operant conditioning paradigm has disclosed that participants are able to gain some control over particular aspects of their electroencephalogram (EEG). Based on the association between theta activity (4-7 Hz) and working memory performance, and sensorimotor rhythm (SMR) activity (12-15 Hz) and attentional processing, we investigated the possibility that training healthy individuals to enhance either of these frequencies would specifically influence a particular aspect of cognitive performance, relative to a non-neurofeedback control-group. The results revealed that after eight sessions of neurofeedback the SMR-group were able to selectively enhance their SMR activity, as indexed by increased SMR/theta and SMR/beta ratios. In contrast, those trained to selectively enhance theta activity failed to exhibit any changes in their EEG. Furthermore, the SMR- group exhibited a significant and clear improvement in cued recall performance, using a semantic working memory task, and to a lesser extent showed improved accuracy of focused attentional processing using a 2-sequence continuous performance task. This suggests that normal healthy individuals can learn to increase a specific component of their EEG activity, and that such enhanced activity may facilitate semantic processing in a working memory task and to a lesser extent focused attention. We discuss possible mechanisms that could mediate such effects and indicate a number of directions for future research.

Walker, J. E., & Norman, C. A. (2006). The neurophysiology of dyslexia: A selective review with implications for neurofeedback remediation and results of treatment in twelve consecutive patients. *Journal of Neurotherapy*, 10(1), 45-55. Dyslexia is a common and important problem in all industrial societies, with a prevalence rate of five to ten percent, for which no consistently effective treatment is available. Recent advances in imaging (morphometric MRI, functional MRI, PET, regional cerebral blood flow), as well as in neurophysiology (evoked potentials, QEEG, event-related desynchronization, coherence studies, magnetic source imaging, reading difference topography) have clarified our understanding of the normal circuitry involved in reading and differences seen in individuals who have trouble learning to read. These studies have important implications for the use of

neurofeedback to help dyslexic individuals learn to read more easily. First, we obtained a QEEG and a reading difference topography. We then train down any abnormalities that are significantly increased and train up any abnormalities that are significantly decreased. Increasing 16–18 Hz activity at T3 (left mid-temporal area) has also proved quite helpful in improving reading speed and comprehension. These combined approaches have been helpful in all cases of dyslexia we have treated, dramatically so in some cases. Each of the 12 individuals treated improved by at least two grade levels after 30 to 35 sessions.

Xiong, Z., Shi, S., & Xu, H. (2005). A controlled study of the effectiveness of EEG biofeedback training on children with attention deficit hyperactivity disorder. ***Journal of Huazhong University of Science & Technology*****, 25(3), 368-370.** In order to study the treatment of the children with attention deficit hyperactivity disorder (ADHD), the integrated visual and auditory continuous performance test (IVA-CPT) was clinically applied to evaluate the effectiveness of electroencephalogram (EEG) biofeedback training. Of all the 60 children with ADHD aged more than 6 years, the effective rate of EEG biofeedback training was 91.6% after 40 sessions of EEG biofeedback training. Before and after treatment by EEG biofeedback training, the overall indexes of IVA were significantly improved among predominately inattentive, hyperactive, and combined subtype of children with ADHD ($P<0.001$). It was suggested that EEG biofeedback training was an effective and vital treatment on children with ADHD.

ANXIETY, PTSD, OCD AND PANIC DISORDERS

Hammond, D. C. (2003). QEEG-guided neurofeedback in the treatment of obsessive compulsive disorder. *Journal of Neurotherapy*, 7(2), 25-52. Introduction. Blinded, placebo-controlled research (e.g., Sterman, 2000) has documented the ability of brainwave biofeedback to recondition brain wave patterns. Neurofeedback has been used successfully with uncontrolled epilepsy, ADD/ADHD, learning disabilities, anxiety, and head injuries. However, nothing has been published on the treatment of obsessive-compulsive disorder (OCD) with neurofeedback. Method. Quantitative EEGs were gathered on two consecutive OCD patients who sought treatment. This assessment guided protocol selection for subsequent neurofeedback training. Results. Scores on the Yale-Brown Obsessive-Compulsive Scale and the Padua Inventory normalized following treatment. An MMPI was administered pre-post to one patient, and she showed dramatic improvements not only in OCD symptoms, but also in depression, anxiety, somatic symptoms, and in becoming extroverted rather than introverted and withdrawn. Discussion. In follow-ups of the two cases at 15 and 13 months after completion of treatment, both patients were maintaining improvements in OCD symptoms as measured by the Padua Inventory and as externally validated through contacts with family members. Since research has found that pharmacologic treatment of OCD produces only very modest improvements and behavior therapy utilizing exposure with response prevention is experienced as quite unpleasant and results in treatment dropouts, neurofeedback appears to have potential as a new treatment modality.

Hardt, J. V., & Kamiya, J. (1978). Anxiety change through electroencephalographic alpha feedback seen only in high anxiety subjects. *Science*, 201, 79-81. Subjects who were either high or low in trait anxiety used alpha feedback to increase and to decrease their electroencephalographic alpha activity. The alpha changes were tightly linked to anxiety changes, but only in high anxiety subjects (for whom anxiety was reduced in proportion to alpha increases, and was increased in proportion to alpha suppression). Low trait-anxiety subjects were superior at both enhancement and suppression training, but their alpha changes were not related to anxiety changes. In both groups, anxiety changes were generally unrelated to either resting levels or changes in frontalis electromyograms and respiration rate. These results suggest that long-term alpha feedback training (at least 5 hours) may be useful in anxiety therapy.

Huang,-Storms, L., Bodenhamer-Davis, E., Davis, R., & Dunn, J. (2006). QEEG-guided neurofeedback for children with histories of abuse and neglect: Neurodevelopmental rationale and pilot study. *Journal of Neurotherapy*, 10(4), 3-16. Background. Poor self-regulation of arousal is central to the behavioral difficulties experienced by children with traumatic caretaker attachment histories. EEG biofeedback teaches children to self- regulate brain rhythmicity, which may in turn affect global improvements in the areas of attention, aggression, impulse control, and trust formation. Research literature reports successful use of neurofeedback for children with ADHD, autism, asthma, stroke, and migraine. This study extends current research by investigating the effectiveness of neurofeedback in reducing behavioral problems commonly observed in abused/neglected children. Methods. Treatment records of twenty adopted children with histories of removal from their biological home by Child Protective Services were obtained from a private neurofeedback practice. All of the children were assessed prior to treatment using the Child Behavior Checklist (CBCL) and the Test of Variables of Attention (TOVA) and again after 30 sessions of individualized, qEEG-guided neurofeedback. Results. T-test analysis of pre- and post-scores on the CBCL showed significant changes in the areas of externalizing problems, internalizing problems, social problems, aggressive behavior, thought problems, delinquent behavior, anxiety/depression, and attention problems ($p < .05$). TOVA omission error, commission error, and variability scores also improved significantly following neurofeedback training ($p < .05$). Some pre-treatment qEEG patterns common to this group of children were identified. Conclusions. The CBCL and TOVA score improvements observed in this study indicate that neurofeedback is effective in reducing behavioral, emotional, social, and cognitive problems in children with histories of neglect and/or abuse.

Kerson, C., Sherman, R.A., Kozlowski, G.P. (2009). Alpha suppression and symmetry training for generalized anxiety disorders. Journal of Neurotherapy,13(3) 146-158. Alpha suppression and symmetry training for generalized anxiety symptoms. Journal of Neurotherapy 13(3), 146 – 155. Introduction. Twenty-eight anxious adults were assessed for frontal lobe alpha asymmetry, a brain state associated with depression and anxiety. Fifteen of the 28 exhibited significant asymmetry and 12 agreed to participate in a biofeedback program addressed at reducing frontal alpha asymmetry. Method. The program consisted of earlobe temperature biofeedback (ETB) and two forms of neurofeedback, alpha suppression and alpha symmetry training. Individuals were instructed to warm their right earlobe for six sessions, and half succeeded, though success was not required to advance to the next stage of training. For subsequent EEG training, two anterior sites were selected on the basis of poor alpha coherence. Individuals were trained to reduce alpha magnitude at these sites by 10% for 30 min or more, which took from 6 to 16 sessions to achieve. Once successful with alpha suppression, individuals were trained to improve alpha symmetry between the sites by 15% for 30 min or more. Results. This feat took 8 to 32 sessions to achieve, and eventually all eight individuals were able to reduce alpha asymmetry. The State–Trait Anxiety Inventory (STAI) was used to measured anxiety levels after each training type and both state and trait scores significantly improved by a 6-month follow-up. Conclusion. Participants also completed a daily shortened version of the STAI, which indicated that anxiety improved after neurofeedback but not after ETB.

Kleutsch, RC., Ros, T., Theberge, J., Frewen, PA., Calhoun, VD., Schmal, C., Jetly, R. & Lanius, RA. (2014). Plastic modulation of PTSD resting state networks and subjective wellbeing by EEG neurofeedback. Acta Psychiatry Scand Aug:130(2). 123-36. OBJECTIVE: Electroencephalographic (EEG) neurofeedback training has been shown to produce plastic modulations in salience network and default mode network functional connectivity in healthy individuals. In this study, we investigated whether a single session of neurofeedback training aimed at the voluntary reduction of alpha rhythm (8-12 Hz) amplitude would be related to differences in EEG network oscillations, functional MRI (fMRI) connectivity, and subjective measures of state anxiety and arousal in a group of individuals with post-traumatic stress disorder (PTSD). METHOD: Twenty-one individuals with PTSD related to childhood abuse underwent 30 min of EEG neurofeedback training preceded and followed by a resting-state fMRI scan. RESULTS: Alpha desynchronizing neurofeedback was associated with decreased alpha amplitude during training, followed by a significant increase ('rebound') in resting-state alpha synchronization. This rebound was linked to increased calmness, greater salience network connectivity with the right insula, and enhanced default mode network connectivity with bilateral posterior cingulate, right middle frontal gyrus, and left medial prefrontal cortex. CONCLUSION: Our study represents a first step in elucidating the potential neurobehavioral mechanisms mediating the effects of neurofeedback treatment on regulatory systems in PTSD. Moreover, it documents for the first time a spontaneous EEG 'rebound' after neurofeedback, pointing to homeostatic/compensatory mechanisms operating in the brain.

Kopřivová J, Congedo M, Raszka M, Praško J, Brunovský M, Horáček J. (2013). Prediction of treatment response and the effect of independent component neurofeedback in obsessive-compulsive disorder: a randomized, sham- controlled, double-blind study. Neuropsychobiology. 2013;67(4):210-23. doi: 10.1159/000347087. Epub 2013 Apr 27. Aims: The goal of this study was to assess the effect of independent component neurofeedback (NFB) on EEG and clinical symptoms in patients with obsessive-compulsive disorder (OCD). Subsequently, we explored predictors of treatment response and EEG correlates of clinical symptoms. Methods: In a randomized, double-blind, parallel design, 20 inpatients with OCD underwent 25 sessions of NFB or sham feedback (SFB). NFB aimed at reducing EEG activity in an independent component previously reported abnormal in this diagnosis. Resting-state EEG recorded before and after the treatment was analyzed to assess its posttreatment changes, relationships with clinical symptoms and treatment response. Results: Overall, clinical improvement in OCD patients was not accompanied by EEG change as assessed by standardized low-resolution electromagnetic tomography and normative independent component analysis. Pre- to posttreatment comparison of the trained component and frequency did not yield significant results; however, in the NFB group, the nominal values at the down trained frequency were lower after treatment. The NFB group showed significantly higher percentage reduction of compulsions compared to the SFB group ($p = 0.015$). Pretreatment higher amount of delta (1-6 Hz) and low alpha oscillations as well as a lower amount of high beta activity predicted a worse treatment outcome. Source localization of these delta and high beta oscillations corresponded with previous EEG resting-state findings in OCD patients compared to healthy controls. Conclusion: Independent component NFB in OCD proved useful in percentage improvement of compulsions. Based on our correlation analyses, we hypothesize that we targeted a network related to treatment resistance.

Mills, G. K., & Solyom, L. (1974). Biofeedback of EEG alpha in the treatment of obsessive ruminations:
An exploration. ***Journal of Behavior Therapy & Experimental Psychiatry*****, 5, 37-41.** The enhancement of EEG alpha through various meditative techniques and biofeedback has been shown to correlate with alterations in mental as well as muscular activity towards a state of relaxation. We thought that such mental relaxation might be reciprocally inhibitory to ruminative activity characteristic of the obsessive neurotic. Five ruminating obsessives were given 7– 20 biofeedback training sessions to learn control of EEG alpha. Results indicate that (1) some obsessives can learn EEG control; (2) special augmented instructions seem no better than standard, minimal instructions in aiding alpha; (3) subjective states during alpha are reported as relaxed, daydreaming and not thinking; and (4) although difficult to generalize beyond the feedback situation, virtually no ruminations occur during alpha regardless of the amount of alpha produced. Further study is indicated before a treatment program can be considered.

Moore, N. C. (2000). A review of EEG biofeedback treatment of anxiety disorders. ***Clinical Electroencephalography*****, 31(1), 1-6.** Alpha, theta and alpha-theta enhancements are effective treatments of the anxiety disorders (Table 1). Alpha suppression is also effective, but less so (Table 2). Perceived success in carrying out the task plays an important role in clinical improvement. Research is needed to find out how much more effective they are than placebo, and which variables are important for efficacy. Variables needing study are: duration of treatment, type and severity of anxiety, number and type of EEG waveforms used, pretreatment with other kinds of feedback, position and number of electrodes, and presence of concomitant medication.

Peeters, F., Ronner, J., Bodar, L., van Os, J. & Louisberg, R. (2013). Validation of a neurofeedback paradigm: Manipulating frontal EEG alpha-activity and its impact on mood. Int J Psychophysiol. doi: 10.1016/j.ijpsycho.2013.06.010. It is claimed that neurofeedback (NF) is an effective treatment for a variety of psychiatric disorders. NF, within an operant conditioning framework, helps individuals to regulate cortical electroencephalographic (EEG) activity while receiving feedback from a visual or acoustic signal. For example, changing asymmetry between left and right frontal brain alpha activity by NF, is claimed to be an efficacious treatment for major depressive disorder. However, the specificity of this intervention in occasioning electrophysiological changes at target locations and target wave-frequencies, and its relation to changes in mood, has not been established. During a single session of NF, it was tested if the balance between left and right frontal alpha-activity could be changed, regardless of direction, in 40 healthy females. Furthermore, we investigated whether this intervention was electrophysiologically specific and if it was associated with changes in mood. Participants were able to decrease or increase frontal alpha-asymmetry during the intervention. However, no changes in mood were observed. (*Note from bibliographer: one session would rarely provide changes in behavior*). Changes in EEG activity were specific in terms of location and wave-frequency.

Peniston, E. G., & Kulkosky, P. J. (1991). Alpha-theta brainwave neuro-feedback therapy for Vietnam veterans with combat-related post-traumatic stress disorder. ***Medical Psychotherapy*****, 4, 47-60.** The Minnesota Personality Inventory (MMPI) was used to assess personality changes in Vietnam combat veterans with PTSD after either traditional medical treatment (TC) or alpha-theta brainwave neuro-feedback therapy (BWT). Application of brainwave training for thirty 30-minute sessions resulted in decreases in MMPI T-scores on clinical scales labeled hypochondriasis, depression, hysteria, psychopathy, deviate masculinity-femininity, paranoia, psychasthenia, schizophrenia, hypomania and social introversion-extroversion. The traditional medical control group showed decreases in T-scores only on the scale labeled schizophrenia. All 14 BWT patients initially receiving psychotropic medication reduced their dosages after treatment, but only one of thirteen TC patients reduced dosage. A thirty-month follow up study showed that all fourteen TC patients had relapsed, in contract to only three of fifteen BWT patients. These findings indicate that application of alpha-theta brainwave training is a more efficacious treatment modality in the treatment of PTSD and preventative of relapse.

Raymond, J., Varney, C., Parkinson, L. A., & Gruzelier, J.H. (2005). The effects of alpha/theta neurofeedback on personality and mood. ***Brain Research & Cognitive Brain Research*****, 23(2-3), 287-292.** Alpha/theta neurofeedback has been shown to be successful both in treating addictions and in enhancing artistry in music students. How its effects are mediated are not yet clear. The present study aimed to test the hypothesis that alpha/theta neurofeedback works inter alia by normalizing extreme personality and raising feelings of wellbeing. 12 participants with high scores for Withdrawal (as measured by the PSQ) were given either alpha/theta neurofeedback or mock feedback and their personality and mood were assessed. Withdrawal scores on the PSQ-80 were not found to change in either group but significant effects were found for the Profile Of Mood States (POMS), with real feedback producing higher overall scores than mock feedback ($P = 0.056$). Real feedback caused participants to feel significantly more energetic ($P < 0.01$) than did mock feedback. Sessions of real feedback made participants feel more composed ($P < 0.01$), agreeable ($P < 0.01$), elevated ($P < 0.01$) and confident ($P < 0.05$), whilst sessions of mock feedback made participants feel more tired ($P < 0.05$), yet composed ($P < 0.01$). These findings suggest that, whilst 9 sessions of alpha/theta neurofeedback was insufficient to change personality, improvements in mood may provide a partial explanation for the efficacy of alpha/theta neurofeedback.

Rice, K. M., Blanchard, E. B., & Purcell, M. (1993). Biofeedback treatments of generalized anxiety disorder: Preliminary results. ***Biofeedback & Self-Regulation,*** **18, 93-105.** Forty-five individuals with generalized anxiety (38 with GAD as defined by DSM-III) were randomized to 4 treatment conditions or a waiting list control. Patients received 8 sessions of either frontal EMG biofeedback, biofeedback to increase EEG alpha, biofeedback to decrease EEG alpha, or a pseudomeditation control condition. All treated subjects showed significant reductions in STAI- Trait Anxiety and psychophysiologic symptoms on the Psychosomatic Symptom Checklist. Only alpha-increase biofeedback subjects showed significant reductions in heart rate reactivity to stressors at a separate psychophysiological testing session. Decreased self-report of anxiety was maintained at 6 weeks post treatment.

Simkin, DR., Thatcher, RW. & Lubar, J. (2014). Quantitative EEGB and Neurofeedback in Children and adolescents: Anxiety disorders, depressive disorders, comorbid addiction and attention-deficit/hyperactivity disorder and brain injury. ***Child and Adolescent Psychiatric Clinics of North America*****:23(3). 427-464.** This article explores the science surrounding neurofeedback. Both surface neurofeedback (using 2-4 electrodes) and newer interventions, such as real-time z-score neurofeedback (electroencephalogram [EEG] biofeedback) and low- resolution electromagnetic tomography neurofeedback, are reviewed. The limited literature on neurofeedback research in children and adolescents is discussed regarding treatment of anxiety, mood, addiction (with comorbid attention-deficit/hyperactivity disorder), and traumatic brain injury. Future potential applications, the use of quantitative EEG for determining which patients will be responsive to medications, the role of randomized controlled studies in neurofeedback research, and sensible clinical guidelines are considered.

Thomas, J. E., & Sattlberger, B. A. (1997). Treatment of chronic anxiety disorder with neurotherapy: A case study. ***Journal of Neurotherapy,*** **2(2), 14-19.** The objective of the present case study is to report the effects of alpha- decrease biofeedback training on a patient diagnosed with Anxiety Disorder. Three Minnesota Multiphasic Personality Inventories (MMPI and MMPI-2) were used as objective measures of treatment efficacy. Following 15 sessions of slow wave inhibit/fast wave increase EEG feedback training, the patient reported a significant reduction in anxiety-related symptoms. At three-year follow-up, results of an MMPI-2 showed all clinical scales within normal range. In addition, self-reports confirmed that the patient was symptom free. After treating the patient with several other clinical modalities, only the alpha-decrease feedback training produced effective, long-term improvement of symptoms.

AUTISM SPECTRUM DISORDERS

Coben, R., & Pudolsky, I. (2007). Assessment-guided neurofeedback for autistic spectrum disorder. *Journal of Neurotherapy*,11(1), 5-23. Background. Research reviewing the epidemiology of Autism (Medical Research Council, 2001) indicated that approximately 60 per 10,000 children (1/166) are diagnosed with Autistic Spectrum Disorder (ASD). Jarusiewicz (2002) published the only controlled study documenting the effectiveness of neurofeedback for Autism based on one outcome measure. The present study extended these findings with a larger sample size, broader range of assessments, and physiological measures of brain functioning. Methods. Assessment- guided neurofeedback was conducted in 20 sessions for 37 patients with ASD. The experimental and control groups were matched for age, gender, race, handedness, other treatments, and severity of ASD. Results. Improved ratings of ASD symptoms reflected an 89% success rate. Statistical analyses revealed significant improvement in Autistics who received Neurofeedback compared to a wait list control group. Other major findings included a 40% reduction in core ASD symptomatology (indicated by ATEC Total Scores), and 76% of the experimental group had decreased hyper-connectivity. Reduced cerebral hyperconnectivity was associated with positive clinical outcomes in this population. In all cases of reported improvement in ASD symptomatology, positive treatment outcomes were confirmed by neuropsychological and neurophysiological assessment. Conclusions. Evidence from multiple measures has demonstrated that neurofeedback can be an effective treatment for ASD. In this population, a crucial factor in explaining improved clinical outcomes in the experimental group may be the use of assessment-guided neurofeedback to reduce cerebral hyperconnectivity. Implications of these findings are discussed.

Jarusiewicz, B. (2002). Efficacy of neurofeedback for children in the autistic spectrum: A pilot study. *Journal of Neurotherapy*, 6(4), 39-49. Background. The efficacy of neurofeedback training was evaluated in 12 children in the autistic spectrum with matched controls, based on established training protocols for other conditions with similar symptoms. Method. Twenty-four autistic children were divided into two groups, matched by sex, age, and disorder severity. One group received neurofeedback training and the second acted as a control group. Responses to the Autism Treatment Evaluation Checklists (ATEC) and parental assessments of problem behaviors were analyzed to evaluate the effectiveness of neurofeedback training for this condition. Results. Neurofeedback training resulted in a 26% average reduction in total ATEC rated autism symptoms, compared to 3% for the control group. Parental assessments reported improvement in all behavioral categories: socialization, vocalization, anxiety, schoolwork, tantrums, and sleep, compared with minimal changes in the control group. Discussion. Autistic spectrum children who underwent neurofeedback training showed significant improvements in autism symptoms and behaviors. The magnitude of improvement was independent of initial severity or age.

Kouijzer, M. E. UJ., de Moor, J. M. H., Gerrits, B. J. L., Buitelaar, J. K., & van Schie, H. T. (2009). Long-term effects of neurofeedback treatment in autism. *Research in Autism Spectrum Disorders*, 3, 496-501. Previously we demonstrated significant improvement of executive functions and social behavior in children with autism spectrum disorders (ASD) treated with 40 sessions of EEG neurofeedback in a nonrandomized waiting list control group design. In this paper we extend these findings by reporting the long-term results of neurofeedback treatment in the same group of children with ASD after 12 months. The present study indicates maintenance of improvement of executive functions and social behavior after 12 months in comparison with the immediate outcomes. Neurofeedback mediated suppression of theta power is supposed to promote more flexible functioning of the brain by enhancing activation in the medial prefrontal cortex and improving flexibility of activation in the default mode network supporting the improvement of executive functions and theory of mind in ASD. high-functioning ASD children, but does not affect imitation behavior *per se*.

Pop-Jordanova, N & Plasevska-Karanfilska, D. (2014). Autism – Genetics, electrophysiology and clinical syndromes. Prilozi;35(1). 133-46. (Full text is available at http://www.manu.edu.mk/prilozi). Autism is a severe and the most heritable developmental disorder, whose pathogenesis is still largely unknown. The rising incidence of autism in the last decade has increased the scientific interest and research. More than a thousand papers concerned with information about the etiology of this "static disorder of the immature brain" can be found on Pub Med. The aim of this paper is to give a review of published genetic chromosomal anomalies associated with autistic spectrum disorders, as well as to discuss common syndromes associated with autistic traits. In addition, some of our own findings in genetics, as well as in quantitative electroencephalography and neurofeedback training in autistic children, will be presented and discussed. Generally, the subsequent analyses indicate that the causes of autism include fewer common single-gene mutations and chromosomal abnormalities, as well as multiple interacting genes of weak effect. Genome-wide linkage analysis has identified several susceptibility loci and positional and functional candidate genes which appear to represent possible risks of the autistic spectrum. Electrophysiological findings showed high delta/theta activity in frontal-central regions, while in 25% high beta activity was detected as a result of anxiety. Neurofeedback is a promising therapy for symptom mitigation.

DEPRESSION AND BIPOLAR DISORDER

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Baehr, E., Rosenfeld, J. P., & Baehr, R. (1997). The clinical use of an alpha asymmetry protocol in the neurofeedback treatment of depression: Two case studies. *Journal of Neurotherapy*, 2(3), 10-23. In this study we are presenting case studies of two depressed women who were trained with more than 34 sessions each of EEG biofeedback (neurofeedback) using an Alpha Asymmetry protocol, the purpose of this training was to determine if depression could be alleviated when the subjects learned to increase the activation of the left hemisphere and/ or decrease the activation of the right hemisphere. The MMPI-2 was administered before and after training to measure changes in personality factors, including depression. The results suggest that Alpha Asymmetry neurofeedback training may be an effective adjunct to psychotherapy in the treatment of certain types of mood disorders.

Baehr, E., Rosenfeld, J. P., & Baehr, R. (2001). Clinical use of an alpha asymmetry neurofeedback protocol in the treatment of mood disorders: Follow-up study one to five years post therapy. *Journal of Neurotherapy*, 4(4), 11-18. *Background:* This study reports on three of six patients who have completed an average of 27 neurofeedback sessions using a patented alpha asymmetry protocol for the treatment of depression. *Method:* The follow-up data, from one to five years post therapy, were derived from a single session re-test using the same alpha asymmetry protocol and the Beck Depression Inventory. *Results:* The three patients originally diagnosed as having unipolar depression reached the training criteria for the non-depressed range by the end of their initial training, and they have maintained their normal scores for right hemisphere alpha asymmetry training over time. The follow-up Beck Depression Inventory scores were also within the normal range. *Discussion:* This finding is contrary to the previously held demonstrations by Davidson and Henriques regarding the stability of decreased left anterior cortical activation in remitted depression. While some patients have reported mood changes with life's vicissitudes, none have experienced clinical depression since they have terminated therapy.

Choi SW, Chi SE, Chung SY, Kim JW, Ahn CY, Kim HT. (2011). Is alpha wave neurofeedback effective with randomized clinical trials in depression? A pilot study. *Neuropsychobiology.* 2011;63(1):43-51. Frontal asymmetric activation has been proposed to be the underlying mechanism for depression. Some case studies have reported that the enhancement of a relative right frontal alpha activity by an asymmetry neurofeedback training leads to improvement in depressive symptoms. In the present study, we examined whether a neurofeedback training designed to increase the relative activity of the right frontal alpha band would have an impact on symptoms of depressive subjects suffering from emotional, behavioral, and cognitive problems. Our results indicated that the asymmetry neurofeedback training increased the relative right frontal alpha power, and it remained effective even after the end of the total training sessions. In contrast to the training group, the placebo control group did not show a difference. The neurofeedback training had profound effects on emotion and cognition. First, we replicated earlier findings that enhancing the left frontal activity led to alleviation of depressive symptoms. Moreover, cognitive tests revealed that the asymmetry training improved performance of executive function tests, whereas the placebo treatment did not show improvement. We preliminarily concluded that the asymmetry training is important for controlling and regulating emotion, and it may facilitate the left frontal lobe function.

Escalano, C., Navarro-Gil, M., Garcia-Campayo, J & Minguez, J. (2013). EEG-based upper-alpha neurofeedback for cognitive enhancement in major depressive disorder: a preliminary, uncontrolled study. Conference Proceedings: IEEE 2103:6293-6. Conditioning of the upper-alpha rhythm to improve cognitive performance in healthy users by means of neurofeedback (NF) has been evaluated by several studies, however its effectiveness in people with severe cognitive deficits, such as depressive subjects, remains underexplored. This paper reports on a preliminary uncontrolled study to assess the effects of an upper-alpha NF intervention on patients with major depressive disorder (MDD). The NF effects on the EEG and cognitive performance were assessed. The EEG results showed that patients were able to modulate the upper-alpha rhythm in task-related EEG and during training, in both cases across the executions of the NF sessions, and pre and post within each session. The behavioral results showed the effectiveness of this intervention in a variety of cognitive functions such as working memory, attention, and executive functions.

Hammond, D. C. (2001). Neurofeedback treatment of depression with the Roshi. *Journal of Neurotherapy*, 4(2), 45-56. *Introduction*. A patient with severe, medication resistant depression was found to have the frontal alpha asymmetry described in Davidson's (1998a) research as demonstrating a predisposition to depression. *Treatment*. Initial sessions of EEG neurofeedback using Rosenfeld's (1997) protocol for correcting the alpha asymmetry were discouraging, actually producing slight negative change. Therefore, treatment shifted to using the Roshi, a two channel unit combining neurofeedback and photic stimulation, doing primarily left hemisphere beta training. *Results*. The very first Roshi session produced positive changes, and within five sessions the patient reported feeling less depressed and more energetic. At the conclusion of thirty training sessions, objective testing documented dramatic reductions in depression, somatic symptoms, over emotionality, anxiety, rumination, and fatigue. *Discussion*. In support of Henriques and Davidson's (1991) belief that hypoactivation of the left hemisphere results in an "approach deficit" and more withdrawal behavior, post-testing and interview data also documented that the patient had become less withdrawn, more active, sociable, and less distrustful. Eight and one-half month follow-up documented maintenance of changes. Continued exploration of left hemisphere beta protocols in treating depression, and of the combined use of neurofeedback with photic stimulation are encouraged.

Peeters, F., Oehlen, M., Ronner, J., van Os, J & Lousberg, R. (2014). Neurofeedback as a treatment for major depressive disorder – A pilot study. PLoS One Mar 18;9(3). Biofeedback potentially provides non-invasive, effective psychophysiological interventions for psychiatric disorders. The encompassing purpose of this review was to establish how biofeedback interventions have been used to treat select psychiatric disorders [anxiety, autistic spectrum disorders, depression, dissociation, eating disorders, schizophrenia and psychoses] to date and provide a useful reference for consultation by clinicians and researchers planning to administer a biofeedback treatment. A systematic search of EMBASE, MEDLINE, PsycINFO, and WOK databases and hand searches in Applied Psychophysiology and Biofeedback, and Journal of Neurotherapy, identified 227 articles; 63 of which are included within this review. Electroencephalographic neurofeedback constituted the most investigated modality (31.7%). Anxiety disorders were the most commonly treated (68.3%). Multi-modal biofeedback appeared most effective in significantly ameliorating symptoms, suggesting that targeting more than one physiological modality for bio- regulation increases therapeutic efficacy. Overall, 80.9% of articles reported some level of clinical amelioration related to biofeedback exposure, 65.0% to a statistically significant ($p < .05$) level of symptom reduction based on reported standardized clinical parameters. Although the heterogeneity of the included studies warrants caution before explicit efficacy statements can be made. Further development of standardized controlled methodological protocols tailored for specific disorders and guidelines to generate comprehensive reports may contribute towards establishing the value of biofeedback interventions within mainstream psychiatry.

Putnam, J. A., (2001). EEG biofeedback on a female stroke patient with depression: A case study. *Journal of Neurotherapy*, 5(3), 27-38. *Background*. This single case concerns the treatment of a 71-year-old female stroke patient. The patient's MRI revealed that the location of the stroke was in the right side basal ganglia with damage extending into the anterior limb of the internal capsule. She presented with a virtual paralysis of the left side of her body (hemiplegia with immobilized left arm, contracted fist, minimal motor control over left leg, absence of muscle tonus in left side of face and slurred, monotonic speech). *Method*. The client was provided with EEG biofeedback training on a one to two half-hour sessions per week schedule. Bipolar montages were used along with single site protocols. This was based largely on the idea of reciprocal communication loops between widely separated cortical generators. It was thought that encouraging communication between cortical sites would have a beneficial impact on impairments related to both functional and structural damage. EEG training protocols included SMR (12-15 Hz) enhancement at C4, C4-Pz and T3-T4 with theta suppression; beta (15-18 Hz) enhancement with theta suppression at C3, C3-Fpz and at C3-Fp1. *Results*. Patient showed significant improvement in gross motor control and range of movement of left arm and leg. The most dramatic improvement was observed in speech (articulation, strength and tone). While substantial improvements were observed in motor ability, restoration of mood stability proved somewhat more elusive. Since she was receiving additional treatment (physical therapy and medication management), it is impossible to attribute the improvement in functioning solely to the EEG training. However, the consensus among the attending medical personnel was that the improvements noted above took place with unusual expeditiousness. *Discussion*. When performing EEG biofeedback it may be most practical to adopt an "exercise model" approach in which the regulatory mechanisms in the brain are challenged through the sequential use of

multiple protocol configurations. In this case several different training protocols proved useful in her ongoing recovery. While improvements in functioning were a result of a concerted effort involving multiple therapeutic interventions, it is likely that neurofeedback played a vital synergistic role.

Raymond, J., Varney, C., Parkinson, L. A., & Gruzelier, J. H. (2005). The effects of alpha/theta neurofeedback on personality and mood. ***Cognitive Brain Research,*** **23, 287-292.** Alpha/theta neurofeedback has been shown to be successful both in treating addictions and in enhancing artistry in music students. How its effects are mediated are not yet clear. The present study aimed to test the hypothesis that alpha/theta neurofeedback works inter alia by normalizing extreme personality and raising feelings of well-being. 12 participants with high scores for Withdrawal (as measured by the PSQ) were given either alpha/theta neurofeedback or mock feedback and their personality and mood were assessed. Withdrawal scores on the PSQ-80 were not found to change in either group but significant effects were found for the Profile Of Mood States (POMS), with real feedback producing higher overall scores than mock feedback ($P = 0.056$). Real feedback caused participants to feel significantly more energetic ($P < 0.01$) than did mock feedback. Sessions of real feedback made participants feel more composed ($P < 0.01$), agreeable ($P < 0.01$), elevated ($P < 0.01$) and confident ($P < 0.05$), whilst sessions of mock feedback made participants feel more tired ($P < 0.05$), yet composed ($P < 0.01$). These findings suggest that, whilst 9 sessions of alpha/theta neurofeedback was insufficient to change personality, improvements in mood may provide a partial explanation for the efficacy of alpha/theta neurofeedback.

Saxby, E., & Peniston, E. G. (1995). Alpha-theta brainwave neurofeedback training: an effective treatment for male and female alcoholics with depressive symptoms. ***Journal of Clinical Psychology,*** **51, 685-693.** This was an experimental study of 14 alcoholic outpatients using the Peniston and Kulkosky (1989, 1991) brainwave treatment protocol for alcohol abuse. After temperature biofeedback pretraining, experimental subjects completed 20 40- minute sessions of alpha-theta brainwave neurofeedback training (BWNT). Experimentally treated alcoholics with depressive syndrome showed sharp reductions in self-assessed depression (Beck's Depression Inventory). On the Millon Clinical Multiaxial Inventory-I, the experimental subjects showed significant decreases on the BR scores: schizoid, avoidant, dependent, histrionic, passive-aggression, schizotypal, borderline, anxiety, somatoform, hypomanic, dysthymic, alcohol abuse, drug abuse, psychotic thinking, and psychotic depression. Twenty-one-month follow-up data indicated sustained prevention of relapse in alcoholics who completed BWNT.

PEAK PERFORMANCE & THE ARTS

Egner, T. & Gruzelier, JH. (2003). Ecological validity of neurofeedback: modulation of slow wave EEG enhances musical performance. ***NeuroReport,*** **14(9) 1221-1224.** Biofeedback-assisted modulation of electrocortical activity has been established to have intrinsic clinical benefits and has been shown to improve cognitive performance in healthy humans. In order to further investigate the pedagogic relevance of electroencephalograph (EEG) biofeedback (neurofeedback) for enhancing normal function, a series of investigations assessed the training's impact on an ecologically valid real-life behavioral performance measure: music performance under stressful conditions in conservatoire students. In a pilot study, single-blind expert ratings documented improvements in musical performance in a student group that received training on attention and relaxation related neurofeedback protocols, and improvements were highly correlated with learning to progressively raise theta (5-8 Hz) over alpha (8-11 Hz) band amplitudes. These findings were replicated in a second experiment where an alpha/theta training group displayed significant performance enhancement not found with other neurofeedback training protocols or in alternative interventions, including the widely applied Alexander technique.

Gruzelier, JH. (2014). EEG-neurofeedback for optimizing performance. II: Creativity, the performing arts and ecological validity. Neurosci Biobehav Rev: Jul:44. 142-158. As a continuation of a review of evidence of the validity of cognitive/affective gains following neurofeedback in healthy participants, including correlations in support of the gains being mediated by feedback learning (Gruzelier, 2014a), the focus here is on the impact on creativity, especially in the performing arts including music, dance and acting. The majority of research involves alpha/theta (A/T), sensory-motor rhythm (SMR) and heart rate variability (HRV) protocols. There is evidence of reliable benefits from A/T training with advanced musicians especially for creative performance, and reliable benefits from both A/T and SMR training for novice music performance in adults and in a school study with children with impact on creativity, communication/presentation and technique. Making the SMR ratio training context ecologically relevant for actor's enhanced creativity in stage performance, with added benefits from the more immersive training context. A/T and HRV training have benefitted dancers. The neurofeedback evidence adds to the rapidly accumulating validation of neurofeedback, while performing arts studies offer an opportunity for ecological validity in creativity research for both creative process and product.

Gruzelier, JH. (2014). EEG-neurofeedback for optimizing performance. I: A review of cognitive and affective outcome in healthy participants. Neurosci Biobehav Rev: Jul:44. 124-141. A re-emergence of research on EEG- neurofeedback followed controlled evidence of clinical benefits and validation of cognitive/affective gains in healthy participants including correlations in support of feedback learning mediating outcome. Controlled studies with healthy and elderly participants, which have increased exponentially, are reviewed including protocols from the clinic: sensory-motor rhythm, beta1 and alpha/theta ratios, down-training theta maxima, and from neuroscience: upper-alpha, theta, gamma, alpha desynchronization**.** Outcome gains include sustained attention, orienting and executive attention, the P300b, memory, spatial rotation, RT, complex psychomotor skills, implicit procedural memory, recognition memory, perceptual binding, intelligence, mood and well-being. Twenty-three of the controlled studies report neurofeedback learning indices along with beneficial outcomes, of which eight report correlations in support of a meditation link, results which will be supplemented by further creativity and the performing arts evidence in Part II. Validity evidence from optimal performance studies represents an advance for the neurofeedback field demonstrating that cross fertilization between clinical and optimal performance domains will be fruitful. Theoretical and methodological issues are outlined further in Part III.

Gruzelier, JH, Foks, M, Steffert, T, Chen, MJ. & Ros, T. (2013). Beneficial outcome from EEG-neurofeedback on creative music performance, attention and well-being in school children. ***Biol Psychol.*** **2013 Apr 25. pii: S0301- 0511(13)00099-9. doi: 10.1016/j.biopsycho.2013.04.005. [Epub ahead of print].** We earlier reported benefits for creativity in rehearsed music performance from alpha/theta (A/T) neurofeedback in conservatoire studies (Egner & Gruzelier, 2003) which were not found with SMR, Beta1, mental skills, aerobics or Alexander training, or in standby controls. Here the focus was the impact on novice music performance. A/T and SMR training were compared in 11- year old school children along with non-intervention controls with

outcome measures not only of rehearsed music performance but also of creative improvisation, as well as sustained attention and phenomenology. Evidence of effective learning in the school setting was obtained for A/T and SMR/betA2 ratios. Preferential benefits from A/T for rehearsed music performance were replicated in children for technique and communication ratings. Benefits extended to creativity and communication ratings for creative improvisation which were shared with SMR training, disclosing an influence of SMR on unrehearsed music performance at a novice level with its greater cognitive demands. In a first application of A/T for improving sustained attention (TOVA), it was found to be more successful than SMR training, with a notable reduction in commission errors in the children, 15/33 of whom had attention indices in the ADHD range. Phenomenological reports were in favor of neurofeedback and well-being benefits. Implementing neurofeedback in the daily school setting proved feasible and holds pedagogic promise.

Hanslmayer, S., Sauseng, P., Doppelmayr, M., Schabus, M., & Klimesch, W. (2005). Increasing individual upper alpha by neurofeedback improves cognitive performance in human subjects. ***Applied Psychophysiology & Biofeedback*****, 30(1), 1-10.**The hypothesis was tested of whether neurofeedback training (NFT)—applied in order to increase upper alpha but decrease theta power—is capable of increasing cognitive performance. A mental rotation task was performed before and after upper alpha and theta NFT. Only those subjects who were able to increase their upper alpha power (responders) performed better on mental rotations after NFT. Training success (extent of NFT- induced increase in upper alpha power) was positively correlated with the improvement in cognitive performance. Furthermore, the EEG of NFT responders showed a significant increase in reference upper alpha power (i.e. in a time interval preceding mental rotation). This is in line with studies showing that increased upper alpha power in a prestimulus (reference) interval is related to good cognitive performance.

Hatfield, B, Haufler, A. (2009). Brain processes and neurofeedback for performance enhancement of precision motor behavior. ***NeuroImage*****, 5638 810-817.** Based on a number of empirical investigations of cerebral cortical dynamics during precision aiming tasks (i.e. marksmanship) employing electroencephalography (EEG) refinement of cortical activity and attenuation of nonessential cortico-cortical communication with the motor planning regions of the brain results in superior performance. Employment of EEG neurofeedback during the aiming period of target shooting designed to reduce cortical activation resulted in improved performance in skilled marksmen. Such an effect implies that refinement of cortical activity is causally related to performance. Recently, we examined cerebral cortical dynamics during the stress of competitive target shooting and observed increased activation and cortico- cortical communication between non-motor and motor regions relative to a practice-alone condition. As predicted, this finding was associated with degradation of shooting performance. These findings imply that neurofeedback targeted to brain regions related to emotional responding may preserve the cortical dynamics associated with superior performance resulting in improved accuracy of precision aiming performance.

Kober, SE., Witte, M., Stangl, M., Vaijarnae, A., Neuper, C. & Wood, G. (2014). Shutting down sensory motor interference unblocks the networks for stimulus processing: An SMR neurofeedback training study. Clinical Neurophysiology:April 13. OBJECTIVE: In the present study, we investigated how the electrical activity in the sensorimotor cortex contributes to improved cognitive processing capabilities and how SMR (sensorimotor rhythm, 12-15Hz) neurofeedback training modulates it. Previous evidence indicates that higher levels of SMR activity reduce sensorimotor interference and thereby promote cognitive processing. METHODS: Participants were randomly assigned to two groups, one experimental (N=10) group receiving SMR neurofeedback training, in which they learned to voluntarily increase SMR, and one control group (N=10) receiving sham feedback. Multiple cognitive functions and electrophysiological correlates of cognitive processing were assessed before and after 10 neurofeedback training sessions. RESULTS: The experimental group but not the control group showed linear increases in SMR power over training runs, which was associated with behavioral improvements in memory and attentional performance. Additionally, increasing SMR led to a more salient stimulus processing as indicated by increased N1 and P3 event-related potential amplitudes after the training as compared to the pre-test. Finally, functional brain connectivity between motor areas and visual processing areas was reduced after SMR training indicating reduced sensorimotor interference. **CONCLUSIONS:** These results indicate that SMR neurofeedback improves stimulus processing capabilities and consequently leads to

improvements in cognitive performance. SIGNIFICANCE: The present findings contribute to a better understanding of the mechanisms underlying SMR neurofeedback training and cognitive processing and implicate that SMR neurofeedback might be an effective cognitive training tool.

Kober, SE., Witte, M., Ninaus, M., Neuper, C. & Wood, G. (2013). Learning to modulate one's own brain activity: The effect of spontaneous mental strategies. Frontiers in Human Neuroscience: Oct 18(7). 695. Using neurofeedback (NF), individuals can learn to modulate their own brain activity, in most cases electroencephalographic (EEG) rhythms. Although a large body of literature reports positive effects of NF training on behavior and cognitive functions, there are hardly any reports on how participants can successfully learn to gain control over their own brain activity. About one third of people fail to gain significant control over their brain signals even after repeated training sessions. The reasons for this failure are still largely unknown. In this context, we investigated the effects of spontaneous mental strategies on NF performance. Twenty healthy participants performed either a SMR (sensorimotor rhythm, 12-15 Hz) based or a Gamma (40-43 Hz) based NF training over ten sessions. After the first and the last training session, they were asked to write down which mental strategy they have used for self-regulating their EEG. After the first session, all participants reported the use of various types of mental strategies such as visual strategies, concentration, or relaxation. After the last NF training session, four participants of the SMR group reported to employ no specific strategy. These four participants showed linear improvements in NF performance over the ten training sessions. In contrast, participants still reporting the use of specific mental strategies in the last NF session showed no changes in SMR based NF performance over the ten sessions. This effect could not be observed in the Gamma group. The Gamma group showed no prominent changes in Gamma power over the NF training sessions, regardless of the mental strategies used. These results indicate that successful SMR based NF performance is associated with implicit learning mechanisms. Participants stating vivid reports on strategies to control their SMR probably overload cognitive resources, which might be counterproductive in terms of increasing SMR power.

Leach, J., Bulpin, K., Khan, S., Rass, A., ChammoropPremuzic, T., Nelson, C., Gruzelier, J. (2006). Controlled study of neurofeedback with novice singers. *Society of Applied Neuroscience Conference presentation*. Swansea. This is a pilot for a larger study with the aim of extending with novice musicians the findings of Egner and Gruzelier (2003) with elite musicians. **They demonstrated professionally significant gains in artistry in music performance following alpha/theta training, but not with SMR or beta 1training, nor with aerobic exercise or mental** skills/rehearsal training or the Alexander technique. Here are presented the results of 12 novice singers from London music colleges who were randomly assigned in equal numbers to ten sessions over two months of alpha/theta (A/T) training or SMR training. The study and analysis are ongoing. Results are presented for pre and post training assessment of music performance, attention, memory, mood and processes associated with creativity. There was evidence of significant within and between session learning in increasing the theta/alpha ratio ($p<0.001$ & $p<0.047$), but not in elevating the SMR/theta ratio. Despite the latter limitation semantic cued memory increased in the SMR group in support of Vernon et al (2003) ($p<0.049$, one tailed). Otherwise there were several suggestive differential effects advantaging the A/T group over the SMR group in music performance, creativity and attention, the latter in the direction of the results of Egner and Gruzelier (2004) though not reaching significance in their study. The Test of Variables of Attention (TOVA) showed an increase in sensitivity (d') with A/T ($p<0.04$) and the reverse with SMR (Group x Time $p<0.04$), largely due to a reduction in omission errors with A/T and the opposite mean change in the SMR group (G x T, $p<0.066$). There was also a reduction in RT variability ($p<0.012$). Support for associations with creativity followed improvement in flexibility on the Guildford Alternative Uses Test ($p<0.055$), and the rule breaking subscale of the Adaptor/Innovator Test ($p<0.022$). The Baddeley Sentence Checking Test which involves working memory and reasoning was also advantaged ($p<0.047$) by A/T training. Finally blind lay evaluations from video clips of expressiveness, confidence and stage presence disclosed improvement following A/T (all $p<0.001$) in contrast to SMR training (G x T, all $p<0.002$).

Markovska-Simoska S, Pop-Jordanova N, Georgiev D. (2008). Simultaneous EEG and EMG biofeedback for peak performance in musicians. *Prilozi*, 29(1): 239-252. The aim of this study was to determine the effects of alpha neurofeedback and EMG biofeedback protocols for improvement of musical performance in violinists. The sample consisted of 12 music students (10 violinists and 2 viola players) from the Faculty of Music, Skopje (3 males, mean age of 20 +/- 0 and 9 females, mean age = 20.89 +/-

2.98). Six of them had a low alpha peak frequency (APF) (< 10 Hz), and six a high APF (> 10 Hz). The sample was randomized in two groups. The students from the experimental group participated in 20 sessions of biofeedback (alpha/EMG), combined with music practice, while the students from the control group did only music practice. Average absolute power, interhemispheric coherence in the alpha band, alpha peak frequency (APF), individual alpha band width (IABW), amount of alpha suppression (AAS) and surface forehead integrated EMG power (IEMG), as well as a score on musical performance and inventories measuring anxiety, were assessed. Alpha-EEG/EMG-biofeedback was associated with a significant increase in average alpha power, APF and IABW in all the participants and with decreases in IEMG only in high- APF musicians. The biofeedback training success was positively correlated with the alpha power, IcoH, APF, IABW and baseline level of APF and IABW. Alpha-EEG/EMG biofeedback is capable of increasing voluntary self- regulation and the quality of musical performance. The efficiency of biofeedback training depends on the baseline EEG alpha activity status, in particular the APF.

Sokhadze, E. (2012). Peak performance training using prefrontal EEG biofeedback. *Biofeedback*, 39, 7-15. The use of biofeedback training to self-regulate EEG patterns with the aim of recovering or optimizing function and behavioral performance is becoming increasingly established. The most reasonable approach is to learn to generate and maintain optimal brain wave patterns and produce associated peak performance states on demand. We report two studies where 12 sessions of prefrontal EEG feedback were used to improve performance in both clinical and nonclinical populations. Neurofeedback using Focus, Alertness, and 40 Hz (Neureka!) measures resulted in improved selective attention and other cognitive functions. We discuss other potential applications of neurofeedback in the areas of "under-pressure" activity, where peak performance state is an essential part of the job, such as in sports or the performing arts, as well as for human operators, such as air traffic dispatchers and military personnel on duty.

Witte, M., Kober, SE., Ninaus, M., Neuper, C. & Wood, G. (2013). Control beliefs can predict the ability to up- regulate sensorimotor rhythm during neurofeedback training. Frontiers in Human Neuroscience:15(7). 478. Technological progress in computer science and neuroimaging has resulted in many approaches that aim to detect brain states and translate them to an external output. Studies from the field of brain-computer interfaces (BCI) and neurofeedback (NF) have validated the coupling between brain signals and computer devices; however a cognitive model of the processes involved remains elusive. Psychological parameters usually play a moderate role in predicting the performance of BCI and NF users. The concept of a locus of control, i.e., whether one's own action is determined by internal or external causes, may help to unravel inter-individual performance capacities. Here, we present data from 20 healthy participants who performed a feedback task based on EEG recordings of the sensorimotor rhythm (SMR). One group of 10 participants underwent 10 training sessions where the amplitude of the SMR was coupled to a vertical feedback bar. The other group of ten participants participated in the same task but relied on sham feedback. Our analysis revealed that a locus of control score focusing on control beliefs with regard to technology negatively correlated with the power of SMR. These preliminary results suggest that participants whose confidence in control over technical devices is high might consume additional cognitive resources. This higher effort in turn may interfere with brain states of relaxation as reflected in the SMR. As a consequence, one way to improve control over brain signals in NF paradigms may be to explicitly instruct users not to force mastery but instead to aim at a state of effortless relaxation.

SEIZURE DISORDERS & EPILEPSY

Andrews, D. J., & Schonfeld, W. H. (1992). Predictive factors for controlling seizures using a behavioral approach. *Seizure*, 1(2), 111-116. A behavioral approach using EEG biofeedback for controlling complex-partial seizures has been successful at the Andrews/Reiter Epilepsy Research Program. Records for a random sample of 83 patients with uncontrolled seizures, one third of those receiving care between 1980 and 1985, document that 69 (83%) achieved control by completion of the program. Additional data about initial age of seizure onset, number of years seizures had been uncontrolled and seizure frequency when treatment started were collected to determine whether these factors predicted seizure control. Only frequency was significantly related to whether seizures were controlled when treatment ended. Further study using discriminant analysis showed that earlier onset age and higher seizure frequency were associated with a significantly greater number of treatment sessions required. Thus, these two factors predicted difficulty in controlling seizures, as measured by number of sessions, although onset age did not predict whether control was eventually achieved. Since even the subgroup achieving the lowest rate of control (i.e., patients having daily seizures when treatment started) had 67% success, these results suggest that a behavioral approach can be useful for many people with currently uncontrolled complex-partial seizures regardless of their characteristics on factors examined in this study.

Finley, W. W. (1976). Effects of sham-feedback following successful SMR training in an epileptic: A follow-up study. *Biofeedback & Self-Regulation*, 1, 227-235. After 1 year of SMR biofeedback training of a severe epileptic teenage male, incidence of atonic seizures decreased from 8/hr to less than 1/3 hr. SMR increased from 10% to 70%. Epileptiform discharges decreased from 45% to 15%. Unknown to the patient, his family, or certain members of our research staff, noncontingent feedback was introduced on 7/22/74, ending 9/11/74. A significant decrease occurred for SMR (down 8%), and a significant increase for epileptiform discharges (up 4%). Rate of seizures increased, but was not statistically significant over preceding months of contingent feedback. Incidence of seizures associated with urine loss increased from approximately 6/month to 23/month during noncontingent feedback, a significant increase. Urine-loss results suggest that although seizures did not become more frequent, those the patient did experience were "harder," i.e., more severe. Contingent feedback was reinstituted following the 7-wk sham, and recovery of all variables to their former levels (prior to sham) occurred.

Finley, W. W. (1977). Operant conditioning of the EEG in two patients with epilepsy: Methodologic and clinical considerations. *Pavlovian Journal of Biological Science*, 12(2), 93-111. Methodologic and clinical considerations are discussed in sensorimotor rhythm (SMR) biofeedback research on two dissimilar but severe epileptic males. The first case, an akinetic epileptic who prior to feedback training experienced 80-100 clinical seizures every 10 hours, showed considerable seizure reduction after 6 months of SMR and epileptiform training. A number of methodologic and instrumentation advances were pioneered with the akinetic patient: (1) development of and ultra-sharp band-pass filter; (2) use of epileptiform inhibit and feedback circuitry; (3) use of monetary rewards as additional incentive; (4) use of correlational analysis for evaluation of acquisition in the major dependent variables and; (5) use of noncontingent feedback and reinforcement as control techniques. The second case, a psychomotor epileptic, also showed therapeutic benefit from SMR training. Clinical information regarding the effect of anticonvulsant medications on the course and therapeutic outcome of SMR training are described. In conjunction with operant conditioning of 12 Hz activity, corresponding changes for other EEG parameters are examined.

Finley, W. W., Smith, H. A., & Etherton, M. D. (1975). Reduction of seizures and normalization of the EEG in a severe epileptic following sensorimotor biofeedback training: Preliminary study. *Biological Psychiatry*, 2, 189-203. Sensorimotor rhythm (SMR) biofeedback training was attempted in a 13-year-old male with frequent epileptic seizures. Prior to training the subject was averaging almost eight clinical seizures an hour. The SMR filter was tuned sharply to 12 plus or minus 1 Hz. Feedback was conducted over approximately six months and continues to the present. In that time the subject's percentage of SMR increased from about 10%, prior to training, to 65% after the 34th training session. Correspondingly, his rate of clinical seizures decreased

by a factor of 10 and a significant reduction in percentage of epileptiform discharges was noted. Beginning with trial 35, the subject was provided feedback of epileptiform activity in combination with 12 Hz activity. The combined effect of these two treatment variables was to reduce the trial-to-trial variance in the dependent variables of interest.

Hanson, L. M., Trudeau, D. L., & Grace, D. L. (1996). Neurotherapy and drug therapy in combination for adult ADHD, personality disorder, and seizure disorder: A case report. *Journal of Neurotherapy*, 2(1) 6-14. This is a case report of an adult female patient with ADHD, temporal seizure disorder, and Borderline Personality Disorder treated with 30 weekly sessions of SMR neurofeedback and carbamazepine. Post-treatment measures showed improvements in T.O.V.A., self-report, and QEEG. Both neurofeedback and carbamazepine showed the most effect in early treatment. Progress continued after discontinuance of the drug.

Kaplan, B. J. (1975). Biofeedback in epileptics: Equivocal relationship of reinforced EEG frequency to seizure reduction. *Epilepsia*, 16, 477-485. It has been reported that biofeedback training of 12- to 14-Hz activity recorded over Rolandic cortex was accompanied by a reduction in seizure incidence in four human epileptics (Sterman et al., 1974). Biofeedback training of 12- to 14-Hz activity was provided for two epileptics and had no effect on clinical EEGs, seizure incidence, or proportion of EEG spectral power in the frequency range being trained. Subsequently, biofeedback training of 6- to 12-Hz Rolandic activity was provided for three epileptics. Two patients experienced reductions in seizure not accompanied by medication changes. Since no learning of 6- to 12-Hz activity was detected, the changes in seizure incidence are not attributed to EEG biofeedback. It is suggested that the experience in the feedback setting provided these two patients with new techniques of relaxation. In view of the lack of statistical evidence of EEG changes following EEG biofeedback and the small number of patients trained to date, it appears wise to maintain a cautious attitude until the issue of causality is clear.

Kuhlman, W. N. (1978). EEG feedback training of epileptic patients: Clinical and electroencephalographic analysis. *Electroencephalography & Clinical Neurophysiology*, 45(6), 699-710. To evaluate the clinical efficacy and mechanisms underlying EEG feedback training of epileptic patients, 5 adult patients with poorly controlled seizures were studied for 4--10 months during which quantitative analysis of seizures, the EEG, and serum anticonvulsant levels was conducted. Sustained seizure reduction did not occur during the first 4--5 weeks in which feedback signals were presented randomly in relation to the EEG. When feedback was then made contingent upon central 9-- 14 c/sec activity, seizures declined by 60% in 3 patients. Power spectral analysis showed upward shifts in EEG frequency, decreases in abnormal slow activity, and enhancement of alpha rhythm activity as a function of contingent training, but no specific EEG change was associated with seizure reduction in all patients. No evidence was obtained for the hypothesized involvement of a 'sensorimotor rhythm' or motor inhibition in the training effects. The lack of effect in two patients could not be attributed to insufficient training, lack of motivation, or to differences in seizure classification. A second phase of research showed that continued laboratory training was both sufficient and necessary for maintaining clinical and EEG effects. Results indicate that: (1) significant seizure reductions can occur with EEG feedback training which are not related to placebo effects, non-specific factors or to changes in medication; (2) EEG changes associated with such training can best be described as 'normalization'; (3) continued clinical investigation of EEG feedback training as a non-pharmacological adjunct to conventional therapy appears justified.

Kuhlman, W. N., & Allison, T. (1977). EEG feedback training in the treatment of epilepsy: Some questions and some answers. *Pavlovian Journal of Biological Science*, 12(2), 112-122. A basic question in EEG feedback training of epileptic patients is whether the decrease in seizures is specifically due to the training or to other factors. Questions may also be raised as to what EEG changes are involved. Preliminary results in five patients suggest that seizure reductions can occur with training which are not due to placebo or nonspecific effects or to changes in medication compliance. These changes occurred rapidly during EEG-contingent feedback training but not when feedback was random in relation to the EEG. Reliable changes in the EEG were also observed, but the question of which mechanism accounts for these results has yet to be answered.

Lantz, D., & Sterman, M. B. (1988). Neuropsychological assessment of subjects with uncontrolled epilepsy: Effects of EEG biofeedback training. *Epilepsia*, 29(2), 163-171. A battery of neuropsychological tests was administered at baseline, post-control period, and post-training period to 24 drug-refractory subjects with epilepsy participating in a study of sensorimotor electroencephalographic (EEG) normalization feedback training. Results revealed the following. First, subjects exhibited significant baseline deficits in psychosocial, cognitive and motor functioning. Second, certain tests discriminated subjects before training who were subsequently above and below the median in seizure reduction following EEG training. Subjects who showed the greatest seizure reduction performed better on a test of general problem-solving ability but not on other cognitive tests and worse on tests involving strong motor components and were more intact psychosocially. These subjects also took significantly fewer medications in combination than did less successful subjects. Third, improvement on several measures occurred following participation in the study. Cognitive and motor functioning improved only in subjects with the greatest seizure reduction and only after actual training as opposed to control conditions. Psychological functioning, as measured by the Minnesota Multiphasic Personality Inventory (MMPI) improved in both outcome groups. MMPI improvement, unlike cognitive improvement, was as likely to occur after control conditions, when seizure reduction had not yet occurred, as after EEG training. Thus, MMPI changes apparently reflected the nonspecific benefits of participation in this study.

Lubar, J. F., & Bahler, W. W. (1976). Behavioral management of epileptic seizures following EEG biofeedback training of the sensorimotor rhythm. *Biofeedback & Self-Regulation*, 7, 77-104. Eight severely epileptic patients, four males and four females, ranging in age from 10 to 29 years, were trained to increase 12-14 Hzeta EEG activity from the regions overlying the Rolandic area. This activity, the sensorimotor rhythm (SMR), has been hypothesized to be related to motor inhibitory processes (Sterman, 1974). The patients represented a cross-section of several different types of epilepsy, including grand mal, myoclonic, akinetic, focal, and psychomotor types. Three of them had varying degrees of mental retardation. SMR was detected by a combination of an analog filtering system and digital processing. Feedback, both auditory and/or visual, was provided whenever one-half second of 12-14-Hz activity was detected in the EEG. Patients were provided with additional feedback keyed by the output of a 4-7-Hz filter which indicated the presence of epileptiform spike activity, slow waves, or movement. Feedback for SMR was inhibited whenever slow-wave activity spikes or movement was also present. During the treatment period most of the patients showed varying degrees of improvement. Two of the patients who had been severely epileptic, having multiple seizures per week, have been seizure free for periods of up to 1 month. Other patients have developed the ability to block many of their seizures. Seizure intensity and duration have also decreased. Furthermore, the successful patients demonstrated an increase in the amount of SMR and an increase in amplitude of SMR during the training period. Spectral analyses for the EEGs were performed periodically. The effectiveness of SMR conditioning for the control of epileptic seizures is evaluated in terms of patient characteristics and type of seizures.

Lubar, J. F., Shabsin, H. S., Natelson, S. E. et al. (1981). EEG operant conditioning in intractable epileptics. *Archives of Neurology*, 38, 700-704. Eight epileptic patients with mixed seizures refractory to medical control participated in a double-blind crossover study to determine the effectiveness of operant conditioning of the EEG as an anticonvulsant procedure. Baseline levels of seizures were recorded for four months prior to the beginning of treatment. Participants then received false (noncontingent) feedback for two months followed by an ABA-patterned training program lasting a total of ten months. Subjects were assigned to three treatment groups based on different schedules of EEG feedback. They were first trained (A1 phase) either to suppress slow activity (3 to 8 Hz), to enhance 12- to 15-Hz activity, or to simultaneously suppress 3- to 8-Hz and enhance 11- to 19-Hz activity. This was followed by a B phase, in which patients were trained to enhance slow activity (3 to 8 Hz). In the final phase (A2), the initial training contingencies were reinstated. Neuropsychological tests were performed before and after training, and changes in EEG activity as determined by Fast Fourier spectral analyses were analyzed. Five of eight patients experienced a decrease in their mean monthly seizure rate at the completion of feedback training as compared with their initial baseline level.

Seifert, A. R.,& Lubar, J. F. (1975). Reduction of epileptic seizures through EEG biofeedback training. *Biological Psychology*, 3, 157-184. Biofeedback training of the sensorimotor rhythm (SMR) was carried out in three male and three female adolescent

epileptics and in two normal controls. The patients represented a cross-section of epilepsies including grand mal, myoclonic, afocal and psychomotor types. Three of the cases were mentally retarded. 12-14 Hz (SMR) activity was detected by a combination of sharp analog filtering and digital processing. The patients were provided with feedback whenever they produced 0.5 sec of 12-14 Hz activity of a specified amplitude. Additional feedback was provided for epileptiform activity slow waves or movement. Furthermore, feedback for SMR production was inhibited by digital logic circuitry when movement, slow waves or spikes were present. Seizure reduction was obtained in five of the six epileptics. Several patients showed increased percentage of SMR when feedback was provided and varying degrees of normalization in their EEG as demonstrated by fast Fourier, crossed power spectral density and coherence analyses.

Sterman MB, Egner T. (2006). Foundation and practice of neurofeedback for the treatment of epilepsy. ***Appl Psychophysiology & Biofeedback.*** **2006 Mar;31(1):21-35.**This review provides an updated overview of the neurophysiological rationale, basic and clinical research literature, and current methods of practice pertaining to clinical neurofeedback. It is based on documented findings, rational theory, and the research and clinical experience of the authors. While considering general issues of physiology, learning principles, and methodology, it focuses on the treatment of epilepsy with sensorimotor rhythm (SMR) training, arguably the best established clinical application of EEG operant conditioning. The basic research literature provides ample data to support a very detailed model of the neural generation of SMR, as well as the most likely candidate mechanism underlying its efficacy in clinical treatment. Further, while more controlled clinical trials would be desirable, a respectable literature supports the clinical utility of this alternative treatment for epilepsy. However, the skilled practice of clinical neurofeedback requires a solid understanding of the neurophysiology underlying EEG oscillation, operant learning principles and mechanisms, as well as an in-depth appreciation of the ins and outs of the various hardware/software equipment options open to the practitioner. It is suggested that the best clinical practice includes the systematic mapping of quantitative multi-electrode EEG measures against a normative database before and after treatment to guide the choice of treatment strategy and document progress towards EEG normalization. We conclude that the research literature reviewed in this article justifies the assertion that neurofeedback treatment of epilepsy/seizure disorders constitutes a well-founded and viable alternative to anticonvulsant pharmacotherapy. Correlational analysis confirmed this relationship. The pattern, duration and topographic specificity of these changes suggested a normalization of sensorimotor EEG substrates related to the EEG feedback training.

Swingle, P. G. (1998). Neurofeedback treatment of pseudo seizure disorder. ***Biological Psychiatry*****, 44(11), 1-4.** BACKGROUND: Previous research has shown that the suppression of theta wave activity and the enhancement of sensorimotor rhythm (SMR) through electroencephalographic (EEG) biofeedback is an effective treatment for epilepsy. The current research reports the results of EEG biofeedback treatment for patients presenting with seizure behaviors in the absence of eliptiform EEG activity. METHODS: In addition to psychotherapy, 3 patients, 2 women and 1 man, were trained, using EEG feedback once per week, to reduce the ratio of theta band to SMR band EEG amplitudes. RESULTS: The results showed that reductions in seizure activity were related to reductions in the theta-SMR ratio. CONCLUSIONS: These findings support the view that theta-SMR feedback training, in conjunction with psychotherapy, is an effective adjunctive treatment for pseudo seizure disorder.

Tan, G., Thornby, J., Hammond, D. C., Strehl, U., Canady, B., Arnemann, K., & Kaiser, D. K. (2009). Meta- analysis of EEG biofeedback in treating epilepsy. ***Clinical EEG & Neuroscience*****, 40(3), 173-179.** About one third of patients with epilepsy do not benefit from medical treatment. For these patients electroencephalographic (EEG) biofeedback is a viable alternative. EEG biofeedback, or neurofeedback, normalizes or enhances EEG activity by means of operant conditioning. While dozens of scientific reports have been published on neurofeedback for seizure disorder, most have been case series with too few subjects to establish efficacy. The purpose of this paper is to meta-analyze existing research on neurofeedback and epilepsy. We analyzed every EEG biofeedback study indexed in MedLine, PsychInfo, and PsychLit databases between 1970 and 2005 on epilepsy that provided seizure frequency change in response to feedback. Sixty-three studies have been published, 10 of which provided enough

outcome information to be included in a meta-analysis. All studies consisted of patients whose seizures were not controlled by medical therapies, which is a very important factor to keep in mind when interpreting the results. Nine of 10 studies reinforced sensorimotor rhythms (SMR) while 1 study trained slow cortical potentials (SCP). All studies reported an overall mean decreased seizure incidence following treatment and 64 out of 87 patients (74%) reported fewer weekly seizures in response to EEG biofeedback. Treatment effect was mean log (post/pre) where pre and post represent number of seizures per week prior to treatment and at final evaluation, respectively. Due to prevalence of small groups, Hedges's g was computed for effect size. As sample heterogeneity was possible (Q test, p=.18), random effects were assumed and the effect of intervention was -0.233, SE = 0.057, z = -4.11, p<.001. Based on this meta-analysis, EEG operant conditioning was found to produce a significant reduction on seizure frequency. This finding is especially noteworthy given the patient group, individuals who had been unable to control their seizures with medical treatment.

Tansey, M. A. (1985). The response of a case of petit mal epilepsy to EEG sensorimotor rhythm biofeedback training. *International Journal of Psychophysiology*, 3, 81-84. A 14-year-old girl, with a long history of absence seizures, sudden rages, spatial disorientation, and academic difficulties received long-term (33 sessions) EEG sensorimotor rhythm biofeedback training. Operantly conditioned increases in the average amplitude of the 14 Hz neural discharge rhythm, over the central Rolandic cortex and cerebrolongitudinal fissure, resulted in a total cessation of her absence seizures; which had, prior to the EEG sensorimotor rhythm biofeedback training, occurred at the rate of 4-5 absences per hour. Concurrently, her sudden rages, spatial disorientation, and academic functioning all evidenced significant remediation.

Uhlmann, C., & Froscher, W. (2001). Biofeedback treatment in patients with refractory epilepsy: Changes in depression and control orientation. *Seizure*, 10(1), 34-38. Depression is a common and serious interictal problem in patients with epilepsy. The genesis of depressive disorders is multifactorial. One etiological aspect focuses on psychosocial factors. It was hypothesized that uncontrollable, unpredictable chronic aversive events (i.e. epileptic seizures) result in cognitive deficits of external control orientation. If this is true, biofeedback training could represent a possible treatment strategy to lower depression, because biofeedback is known to mediate success experiences and control. Measures of depression and locus of control were administered to 20 patients with refractory partial epilepsy before and after biofeedback treatment. The biofeedback consisted of slow cortical potentials or breathing parameters in 10 patients each. A clear relationship occurred between depression and locus of control in the subjects. After biofeedback training control orientation moved towards a more internal locus of control. Also, depression scores were significantly reduced six months after training. Results show that in patients with refractory epilepsy depression is highly correlated with locus of control, in a way that external control orientation relates to high depression scores. Biofeedback is able to improve internal control orientation through personal success mediation.

Upton, A. R., & Longmere, D. (1975). The effects of feedback on focal epileptic discharges in man: A preliminary report. *Canadian Journal of Neurological Sciences*, 2, 153-167. The history of the control of epileptic disturbances by conditioning techniques is reviewed. The preliminary results of a three year trial of feedback techniques in 13 epileptic patients are presented. Thirteen epileptic patients (age 2.5 leads to 39 mean, 15.1 years) with lateralized focal discharges in the EEG were given repeated trials of feedback, the focal discharges being used to trigger auditory and somatosensory stimuli. Dosages and serum levels of medication were unchanged throughout the experimental period. The number of epileptic spikes per 15 seconds was assessed by automatic trend analysis during 20 to 30 minute control, biofeedback and post-feedback epochs. On-going EEG activity was quantified by 8 channel frequency analysis over 10 second epochs. The patients made efforts to increase and decrease the number of spike discharges with and without feedback and the results of both triggered and random auditory, somatosensory, photic and combined stimulation were compared at various intervals over a period of up to three years. A marked reduction in the number of focal discharges was noted in eight (61.5%) patients during and immediately following the sessions. Intermittent biofeedback sessions were not associated with a serial reduction in the number of focal EEG discharges. There was a reduction in the number of clinical epileptic disturbances in six patients (46%) and possible reasons for this improvement are discussed. One

patient suffered an increase in focal temporal lobe discharges during triggered and random auditory stimulation whereas there was a marked reduction in the number of discharges during minimal electrical stimulation of the contralateral arm. The need for careful assessment of each patient to determine appropriate feedback stimulation is stressed. One aim of this research has been to assess the feasibility of using miniature units for continuous feedback of focal discharges in epileptic patients.

Walker, J. E. (2008). Power spectral frequency and coherence abnormalities in patients with intractable epilepsy and their usefulness in long-term remediation of seizures using neurofeedback. ***Clinical EEG & Neuroscience*****, 39(4), 203-204.** Medically intractable seizures appear to be highly correlated with focal slow activity (delta or theta). They also correlate highly with decreases in the coherence of theta. Normalization of focal slowing and of decreased theta coherence will probably be the neurofeedback approaches most likely to decrease or eliminate seizures in future cases. Neurofeedback has been used for over 35 years to reduce the incidence and severity of seizures. With power training to decrease theta and increase the sensorimotor rhythm (12-15 Hz), an average of 82% of patients experienced a significant reduction in seizure frequency, and occasional remissions were seen. Recent improvements using QEEG to guide neurofeedback training have made it possible to eliminate seizures in most patients, even those with intractable seizures. Following our previous study in 2005, we report an additional 25 patients so treated. We also report an analysis of the frequency of QEEG abnormalities in this patient group. All of the intractable epileptic patients had one or more slow foci (excessive theta or delta compared with the normal database). One third had a relative deficiency of beta power. One fourth had a deficiency of absolute delta. Eighteen percent had excessive absolute alpha power, 18% had deficient absolute alpha power, 18% percent had excessive absolute beta power, and 18% percent had deficient absolute beta power. Hypocoherence of theta was found in 75%, and decreases in alpha coherence were noted in 42%. Hypocoherence of beta was found in 50%, and hypocoherence of delta was found in 25%. Increases in alpha coherence were noted in 33%. Seventeen percent had no coherence abnormalities. When most of the power and coherence abnormalities were normalized with neurofeedback training, all the patients became seizure-free; 76% no longer required an anticonvulsant for seizure control.

Walker, J. E., & Kozlowski, G. P. (2005). Neurofeedback treatment of epilepsy. ***Child & Adolescent Psychiatric Clinics of North America*****, 14(1), 163-176.** With electroencephalographic (EEG) biofeedback (or neurofeedback), it is possible to train the brain to de-emphasize rhythms that lead to generation and propagation of seizure and emphasize rhythms that make seizures less likely to occur. With recent improvements in quantitative EEG measurement and improved neurofeedback protocols, it has become possible in clinical practice to eliminate seizures or reduce the amount of medication required to control them. In this article, the history of neurofeedback for epilepsy is presented followed by discussions of the relevant neurophysiology of epilepsy. A model of how neurofeedback might raise the seizure threshold is then presented. Clinical experience using a quantitative EEG- guided approach is described, including a representative case study.

Zhao, L., Liang, Z., Hu, G., & Wu, W. (2005). Nonlinear analysis in treatment of intractable epilepsy with EEG biofeedback. ***Conference Proceedings IEEE Engineering, Medical, & Biological Science*****, 5, 4568-4571.** About 25% epilepsy patients are suffering from medically intractable epileptic seizure. Many studies have shown that electroencephalogram (EEG) biofeedback therapy has the exciting potential for seizure control. In this paper, five patients with intractable epilepsy were trained to increase the production of sensorimotor (12~15Hz) activity and decrease the production of slow theta (4~7Hz) activity. Nonlinear analyses are proposed to evaluate the effect of biofeedback training. In all the five patients, the complexity and approximate entropy of EEG increased significantly ($P<0.05$) after (about 1-month) the biofeedback treatment.

SLEEP DISORDERS

Arns, M., Kenemans, JL. (2012). Neurofeedback in ADHD and insomnia: Vigilance stabilization through sleep spindles and circadian networks. Neuroscience Biobehavioral Review. In this review article an overview of the history and current status of neurofeedback for the treatment of ADHD and insomnia is provided. Recent insights suggest a central role of circadian phase delay, resulting in sleep onset insomnia (SOI) in a sub- group of ADHD patients. Chronobiological treatments, such as melatonin and early morning bright light, affect the suprachiasmatic nucleus. This nucleus has been shown to project to the noradrenergic locus coeruleus (LC) thereby explaining the vigilance stabilizing effects of such treatments in ADHD. It is hypothesized that both Sensori-Motor Rhythm (SMR) and Slow-Cortical Potential (SCP) neurofeedback impact on the sleep spindle circuitry resulting in increased sleep spindle density, normalization of SOI and thereby affect the noradrenergic LC, resulting in vigilance stabilization. After SOI is normalized, improvements on ADHD symptoms will occur with a delayed onset of effect. Therefore, clinical trials investigating new treatments in ADHD should include assessments at follow-up as their primary endpoint rather than assessments at outtake. Furthermore, an implication requiring further study is that neurofeedback could be stopped when SOI is normalized, which might result in fewer sessions.

Bell, J. S. (1979). The use of EEG theta biofeedback in the treatment of a patient with sleep-onset insomnia.
***Biofeedback & Self-Regulation*, 4(3), 229-236**. In this report, the treatment of a 42-year-old female with a complaint of chronic sleep-onset insomnia is described. Following the unsuccessful use of relaxation training, treatment consisted of 11 sessions of EEG theta rhythm (4--7 Hz) biofeedback. Theta density and five sleep indices were monitored throughout baseline, placebo, and treatment sessions. A significant increase in theta density was accompanied by reports of a decrease in sleep latency and an increase in total sleep time. This improvement was maintained after withdrawal of medication and at 3-month follow-up.

Berner, I., Schabus, M., Wienerroither, T., & Klimesch, W. (2006). The significance of sigma neurofeedback training on sleep spindles and aspects of declarative memory. *Applied Psychophysiology & Biofeedback,* 31(2), 97-114. The functional significance of sleep spindles for overnight memory consolidation and general learning aptitude as well as the effect of four 10-minute sessions of spindle frequency (11.6-16 Hz, sigma) neurofeedback-training on subsequent sleep spindle activity and overnight performance change was investigated. Before sleep, subjects were trained on a paired-associate word list task after having received either neurofeedback training (NFT) or pseudofeedback training (PFT). Although NFT had no significant impact on subsequent spindle activity and behavioral outcomes, there was a trend for enhanced sigma band-power during NREM (stage 2 to 4) sleep after NFT as compared to PFT. Furthermore, a significant positive correlation between spindle activity during slow wave sleep (in the first night half) and overall memory performance was revealed. The results support the view that the considerable inter-individual variance in sleep spindle activity can at least be partly explained by differences in the ability to acquire new declarative information. We conclude that the short NFT before sleep was not sufficient to efficiently enhance phasic spindle activity and/or to influence memory processing. NFT was, however, successful in increasing sigma power, presumably because sigma NFT effects become more easily evident in actually trained frequency bands than in associated phasic spindle activity.

Hammer, BU., Colbert, AP., Brown, KA., Llioi, EC. (2011). Neurofeedback for insomnia: a pilot study of Z-score SMR and individualized protocols. Applied Psychophysiology and Biofeedback, 36(4): 251-264. Insomnia is an epidemic in the US. Neurofeedback (NFB) is a little used, psychophysiological treatment with demonstrated usefulness for treating insomnia. Our objective was to assess whether two distinct Z-Score NFB protocols, a modified sensorimotor (SMR) protocol and a sequential, quantitative EEG (sQEEG)-guided, individually designed (IND) protocol, would alleviate sleep and associated daytime

dysfunctions of participants with insomnia. Both protocols used instantaneous Z scores to determine reward condition administered when awake. Twelve adults with insomnia, free of other mental and uncontrolled physical illnesses, were randomly assigned to the SMR or IND group. Eight completed this randomized, parallel group, single-blind study. Both groups received fifteen 20-min sessions of Z-Score NFB. Pre-post assessments included sQEEG, mental health, quality of life, and insomnia status. ANOVA yielded significant post-treatment improvement for the combined group on all primary insomnia scores: Insomnia Severity Index (ISI $p<.005$), Pittsburgh Sleep Quality Inventory (PSQI $p<.0001$), PSQI Sleep Efficiency ($p<.007$), and Quality of Life Inventory ($p<.02$). Binomial tests of baseline EEGs indicated a significant proportion of excessively high levels of Delta and Beta power ($p<.001$) which were lowered post-treatment (paired z-tests $p<.001$). Baseline EEGs showed excessive sleepiness and hyperarousal, which improved post-treatment. Both Z- Score NFB groups improved in sleep and daytime functioning. Post-treatment, all participants were normal sleepers. Because there were no significant differences in the findings between the two groups, our future large scale studies will utilize the less burdensome to administer Z-Score SMR protocol.

Reiner, M., Rozengurt, R. & Barnea, A. (2014). Better than sleep: Theta neurofeedback training accelerates memory consolidation. Biological Psychology:Jan;95(45). 45-53. Consistent empirical results showed that both night and day sleep enhanced memory consolidation. In this study we explore processes of consolidation of memory during awake hours. Since theta oscillations have been shown to play a central role in exchange of information, we hypothesized that elevated theta during awake hours will enhance memory consolidation. We used a neurofeedback protocol, to enhance the relative power of theta or beta oscillations. Participants trained on a tapping task, were divided into three groups: neurofeedback theta; neurofeedback beta; control. We found a significant improvement in performance in the theta group, relative to the beta and control groups, immediately after neurofeedback. Performance was further improved after night sleep in all groups, with a significant advantage favoring the theta group. Theta power during training was correlated with the level of improvement, indicating a clear relationship between memory consolidation, and theta neurofeedback.

Schabus, M., Heib DP., Lechinger J., Griessenberger H., Klimesch W., Pawlizki A., Kunz AB., Sterman BM. & Hoedlmoser K. (2014). Enhancing sleep quality and memory in insomnia using instrumental sensorimotor rhythm conditioning. Biological Psychology Jan;95. 126-134. EEG recordings over the sensorimotor cortex show a prominent oscillatory pattern in a frequency range between 12 and 15 Hz (sensorimotor rhythm, SMR) under quiet but alert wakefulness. This frequency range is also abundant during sleep, and overlaps with the sleep spindle frequency band. In the present pilot study we tested whether instrumental conditioning of SMR during wakefulness can enhance sleep and cognitive performance in insomnia. Twenty-four subjects with clinical symptoms of primary insomnia were tested in a counterbalanced within-subjects-design. Each patient participated in a SMR- as well as a sham-conditioning training block. Polysomnographic sleep recordings were scheduled before and after the training blocks. Results indicate a significant increase of 12-15 Hz activity over the course of ten SMR training sessions. Concomitantly, the number of awakenings decreased and slow-wave sleep as well as subjective sleep quality increased. Interestingly, SMR-training enhancement was also found to be associated with overnight memory consolidation and sleep spindle changes indicating a beneficial cognitive effect of the SMR training protocol for SMR "responders" (16 out of 24 participants). Although results are promising it has to be concluded that current results are of a preliminary nature and await further proof before SMR-training can be promoted as a non- pharmacological approach for improving sleep quality and memory performance.

Sterman, MB., Shouse, MN. (1980). Quantitative analysis of training, sleep EEG and clinical response to EEG operant conditioning in epileptics. Electroencephalography and Clinical Neurophysiology, 49(5-6): 558-579. This report is a follow-up to a previous paper which described seizure rate changes with central cortical EEG feedback training in 8 poorly controlled epileptic subjects. Data examined here include associated training compliance and performance, sleep EEG spectra, clinical EEG and anticonvulsant blood levels. The study employed a double-cross- over, single blind ABA design applied to two subgroups of epileptic patients. Both groups had in common two training periods (A1, A2) in which either 12--15 c/sec (subgroup I, n = 4) or 18--23 c/sec (subgroup II, n = 4) was reinforced in the absence of 6--9 c/sec, movement or epileptiform discharge, and one training period (B) in which 6--9 c/sec was reinforced in the absence of 12--15 or 18--23 c/sec as well as movement and epileptiform discharge. Training periods occurred primarily in the home and lasted 3 months. Compliance with training instructions and response acquisition were demonstrated. Overall anticonvulsant blood levels were low and unrelated to EEG or seizure changes.

Clinical EEG findings corresponded to sleep EEG and seizure rate outcomes. Power spectral analysis of sampled non-REM sleep from all-night EEG recordings obtained after each training phase indicated contingency specific changes which were limited to sensorimotor recordings in subgroup I and corresponded to the pattern of seizure rate changes in this group. EEG changes were also limited to sensorimotor cortex in subgroup II, but were linear and paralleled a progressive decrease in seizure rate. Both groups, however, showed the same pattern of EEG changes with seizure reductions; low and high frequencies were reduced and intermediate, rhythmic frequencies increased. Correlational analysis confirmed this relationship. The pattern, duration and topographic specificity of these changes suggested a normalization of sensorimotor EEG substrates related to the EEG feedback training.

SUBSTANCE ABUSE AND ALCOHOL USE DISORDERS

Arani, FD., Rostami, R., Nostratabadi, M. (2012). Effectiveness of neurofeedback training as a treatment for opioid-dependent ***Clinical EEG and Neuroscience*****:41(3). 170-177**. Neurofeedback (NF) training has been employed as a therapeutic method in substance-dependence disorder over the last three decades. The purpose of the present study was to examine the effectiveness of this method on improvement of comorbid neuro-psychological syndromes in opioid-dependence disorder. Psychopathological and craving dimensions and brain activity signals of 20 opioid dependent patients were measured using Symptom Checklist-90-Revised (SCL-90-R), Heroin Craving Questionnaire (HCQ), and Quantitative Electroencephalography (QEEG). All the patients were undergoing pharmacotherapy. They were assigned to two groups that were matched based on SCL-90-R scores, education and age. The experimental group received 30 sessions of NF training in addition to their medicine. The control group received only the usual pharmacotherapy. The probable changes were monitored by reappraisal of all the patients after the treatment. We hypothesized that patients in the experimental group would show more reduction in their comorbid syndromes. The Multivariate Analysis of Covariance (MANCOVA) showed that the experimental group, in comparison with control group, showed significantly more improvement in all three outcome measures. In the SCL-90-R, improvement was noted with the hypochondriacs, obsession, interpersonal sensitivity, aggression, psychosis, and general symptomatic indexes. In the HCQ, improvement was found in the anticipation of positive outcome, desire to use substance, and total average score. Finally, the QEEG showed positive changes in frontal, central and parietal delta, frontal and central theta, parietal alpha and frontal and central Sensory Motor Rhythm (SMR) amplitudes. This study suggests that NF can be used as a therapeutic method to ameliorate abnormalities related to opioid-dependence disorders. The results emphasize the importance of neuropsychological interventions in treatment of substance-dependence disorders.

Burkett, V. S., Cummins, J. M., Dickson, R. M., & Skolnick, M. (2005). An open clinical trial utilizing real-time EEG operant conditioning as an adjunctive therapy in the treatment of crack cocaine dependence. ***Journal of Neurotherapy*****, 9(2), 27-48.** Electroencephalographic (EEG) biofeedback has been employed in substance use disorder (SUD) over the last three decades. The SUD is a complex series of disorders with frequent comorbidities and EEG abnormalities of several types. EEG biofeedback has been employed in conjunction with other therapies and may be useful in enhancing certain outcomes of therapy. Based on published clinical studies and employing efficacy criteria adapted by the Association for Applied Psychophysiology and Biofeedback and the International Society for Neurofeedback and Research, alpha theta training—either alone for alcoholism or in combination with beta training for stimulant and mixed substance abuse and combined with residential treatment programs, is probably efficacious. Considerations of further research design taking these factors into account are discussed and descriptions of contemporary research are given.

Callaway, T.G., Bodenhamer-Davis, E. (2008). Long-term follow-up of a clinical replication of the Peniston Protocol for chemical dependency. ***Journal of Neurotherapy*** **12(4), 243 – 259.** *Introduction*. This study is a long-term follow-up of an early replication of the Peniston EEG biofeedback (EEG-BFB) Protocol for chemical dependency (Peniston & Kulkosky, 1989, 1990). *Method*. This clinical trial included 16 chemically dependent adult participants treated with the Peniston Protocol in a university outpatient clinic between 1993 and 1995. Ten participants were probationers classified as high risk for rearrest. Treatment effects were assessed using pre/posttreatment measures (Beck Depression Inventory, Minnesota Multiphasic Personality Inventory-2) and long-term follow-up of abstinence and rearrest rates. Probationer rearrest rates were compared to an equivalent probation sample (n = 24) that did not receive EEG-BFB. *Results.* Initial Beck Depression Inventory scores indicated mild/moderate depression but were significantly reduced posttreatment to within normal limits. Substantial differences were noted posttreatment on 7 Minnesota Multiphasic Personality Inventory-2 clinical scales suggesting less psychopathology following treatment. Long-term (74–98 months) follow-up indicated that 81.3% (n = 13) participants were abstinent. Rearrest rates and probation revocations for the probationer subgroup were lower than the comparison group (40% vs. 79.16%). *Conclusion*. This study provides evidence of the durability of Peniston Protocol results over time but has the usual limitations of a clinical trial with a small sample, nonrandomized, and uncontrolled design. Implications for further research are discussed including the relevance of recent modifications to the Peniston Protocol and qEEG–based protocols in treating substance abuse.

DeBeus, R. J. (2007). Quantitative electroencephalography-guided versus Scott/Peniston neurofeedback with substance abuse outpatients: A pilot study. *Applied Psychophysiology and Biofeedback*, 35(4), 146-151. Electroencephalographic (EEG) biofeedback has been employed in substance use disorder (SUD) over the last three decades. The SUD is a complex series of disorders with frequent comorbidities and EEG abnormalities of several types. EEG biofeedback has been employed in conjunction with other therapies and may be useful in enhancing certain outcomes of therapy. Based on published clinical studies and employing efficacy criteria adapted by the Association for Applied Psychophysiology and Biofeedback and the International

Society for Neurofeedback and Research, alpha theta training—either alone for alcoholism or in combination with beta training for stimulant and mixed substance abuse and combined with residential treatment programs, is probably efficacious. Considerations of further research design taking these factors into account are discussed and descriptions of contemporary research are given.

Dehghani-Arani F, Rostami R & Nadali H. (2013). Neurofeedback training for opiate addiction: improvement of mental health and craving. Appl Psychophysiol Biofeedback. 2013 Jun;38(2):133-41. doi: 10.1007/s10484-013-9218-5. Psychological improvements in patients with substance use disorders have been reported after neurofeedback treatment. However, neurofeedback has not been commonly accepted as a treatment for substance dependence. This study was carried out to examine the effectiveness of this therapeutic method for opiate dependence disorder. The specific aim was to investigate whether treatment leads to any changes in mental health and substance craving. In this experimental study with a pre-post test design, 20 opiate dependent patients undergoing Methadone or Buprenorphine maintenance treatment were examined and matched and randomized into two groups. While both experimental and control groups received their usual maintenance treatment, the experimental group received 30 sessions of neurofeedback treatment in addition. The neurofeedback treatment consisted of sensory motor rhythm training on Cz, followed by an alpha-theta protocol on Pz. Data from the general health questionnaire and a heroin craving questionnaire were collected before and after treatment. Multivariate analysis of covariance showed that the experimental group achieved improvement in somatic symptoms, depression, and total score in general mental health; and in anticipation of positive outcome, desire to use opioid, and relief from withdrawal of craving in comparison with the control group. The study supports the effectiveness of neurofeedback training as a therapeutic method in opiate dependence disorder, in supplement to pharmacotherapy.

Fahrion, S. L., Walters, E. D., Coyne, L., & Allen, T. (1992). Alterations in EEG amplitude, personality factors and brain electrical mapping after alpha theta brainwave training: A controlled case study of an alcoholic in recovery. Alcoholism: Clinical & Experimental Research, 16, 547-552. A controlled case study was conducted of effects of EEG alpha and theta brainwave training with a recovering alcoholic patient who experienced craving and fear of relapse after 18 months of abstinence. Training consisted of six sessions of thermal biofeedback to increase central nervous system (CNS) relaxation. Effects were documented with pretreatment and post-treatment personality testing, 20-channel digitized EEG evaluations both under relaxed conditions and under stress, minute-by-minute physiologic recordings of autonomic and EEG data during each training session, blood pressure, and heart rate indications taken both during relaxation and under stress, and by clinical observation. Results replicated those of a previous controlled study with chronic alcoholic patients not abstinent prior to treatment. New findings include post-treatment indications of more relaxed CNS functioning under stress, and of reduced autonomic activation both during relaxation and under stress. Brain-mapping indications of anxiety associated with painful cold-pressor stimulation were seen only in the pretest readings; at post-test the brain map indicated pain-associated EEG activity in the contralateral somatosensory area, but no apparent anxiety-associated EEG activity. At 4 months post-treatment the patient's wife and colleagues report the patient appears to function in a more relaxed way under the impact of stress, and he reports no longer experiencing craving for alcohol. Overall, support is provided for the possibility that alpha and theta brainwave training may be a useful intervention for the abstinent alcoholic experiencing stress-related craving and fear of relapse.

Goldberg, R. J., et al. (1976). Alpha conditioning as an adjunct treatment for drug dependence: Part I. *International Journal of Addiction*, 11, 1085-1089. The effects of alpha conditioning on the habits of four methadone-maintained patients were assessed. All four learned some control over alpha activity in the 5-week, 10-session training period. The most striking results, however, related to the subjects' substitution of self- initiated mental states associated with alpha for previously used drug-seeking or self-medicating methods of coping with everyday problem situations. All four subjects reported a decrease in illicit drug usage and an increased feeling of self-control. Verification of improvement in adjustment and drug abuse was shown by counseling reports and narcotic screens from the maintenance program.

Keith, JR., Ragpay, L., Theodore, D., Schwartz, JM & Ross, JL. (2014). An assessment of an automated EEG biofeedback system for attention deficits in a substance use disorders residential treatment setting. Psychology of Addiction Behaviors: Sept 2014 Early e-pub. Attention deficits are prevalent among individuals with substance use disorders and may interfere with recovery. The present study evaluated the effectiveness of an automated electroencephalogram (EEG) biofeedback system in recovering illicit substance users who had attention deficits upon admission to a comprehensive residential treatment facility. All participants (n = 95) received group, family, and individual counseling. Participants were randomly assigned to 1 of 3 groups that either received 15

sessions of automated EEG biofeedback (AEB), 15 sessions of clinician guided EEG biofeedback (CEB), or 15 additional therapy sessions (AT). For the AEB and CEB groups, operant contingencies reinforced EEG frequencies in the 15-18 Hz (β) and 12-15 Hz (sensorimotor rhythm, "SMR") ranges and reduce low frequencies in the 1-12 Hz (Δ, θ, and α) and 22-30 Hz (high β) ranges. The Test of Variables of Attention (TOVA), a "Go-NoGo" task, was the outcome measure. Attention scores did not change on any TOVA measure in the AT group. Reaction time variability, omission errors, commission errors, and d' improved significantly (all p values <.01) in the AEB and CEB groups. AEB and CEB did not differ significantly from each other on any measure. The results demonstrate that automated neurofeedback can effectively improve attention in recovering illicit substance users in the context of a comprehensive residential substance abuse treatment facility.

Kelly, M. J. (1997). Native Americans, neurofeedback, and substance abuse theory: Three year outcome of alpha/theta neurofeedback training in the treatment of problem drinking among Dine' (Navajo) people. ***Journal of Neurotherapy,*** **2(3), 24-60.** This three year follow-up study presents the treatment outcomes of 19 Dine' (Navajo) clients who completed a culturally sensitive, alpha/theta neurofeedback training program. In an attempt to both replicate the earlier positive studies of Peniston (1989) and to determine if neurofeedback skills would significantly decrease both alcohol consumption and other behavioral indicators of substance abuse, these participants received an average of 40 culturally modified neurofeedback training sessions. This training was adjunctive to their normal 33 day residential treatment. According to DSM-IV criteria for substance abuse, 4 (21%) participants now meet criteria for "sustained full remission", 12 (63%) for "sustained partial remission", and 3 (16%) still remain "dependent" (American Psychiatric Association, 1994). The majority of participants also showed a significant increase in "level of functioning" as measured by the DSM-IV Axis V GAF. Subjective reports from participants indicated that their original neurofeedback training had been both enjoyable and self-empowering; an experience generally different from their usual treatment routine of talk-therapy and education. This internal training also appeared to naturally stimulate significant, but subtle, spiritual experiences and to be naturally compatible with traditional Navajo cultural and medicine-ways. At the three-year follow-up interview, participants typically voiced that these experiences, and their corresponding insights, had been helpful both in their ability to cope and in their sobriety. From an outside perspective, experienced nurses also reported unexpected behavioral improvements during the participant's initial training. Additionally, administrators and physicians generally found the objective feedback and verification quality of neurofeedback protocols compatible with their own beliefs. An attempt has also been made to conceptualize the outcome analysis of this study within both a culturally specific and universal socio/bio/ environmental context.

Peniston, E. G., & Kulkosky, P. J. (1989). Alpha-theta brainwave training and beta-endorphin levels in alcoholics. Alcohol: Clinical & Experimental Research, 13(2), 271-279. An alpha-theta brainwave-biofeedback training program was applied as a novel treatment technique for chronic alcoholics. Following a temperature-biofeedback pretraining phase, experimental subjects completed 15 30-min sessions of alpha-theta biofeedback training. Compared to a nonalcoholic control group and a traditionally treated alcoholic control group, alcoholics receiving brainwave training (BWT) showed significant increases in percentages of EEG record in alpha and theta rhythms, and increased alpha rhythm amplitudes. Alcoholics receiving BWT showed a gradual increase in alpha and theta brain rhythms across the 15 experimental sessions. These experimentally treated alcoholics showed sharp reductions in self-assessed depression (Beck's Depression Inventory) compared to the control groups. Alcoholics receiving standard medical treatment (abstinence, group psychotherapy, antidepressants) showed a significant elevation in serum beta-endorphin levels at the conclusion of the experiment. This neuropeptide is an index of stress and a stimulant of caloric (e.g., ethanol) intake. Application of brainwave treatment, a relaxation therapy, appears to counteract the increase in circulating beta-endorphin levels seen in the control group of alcoholics. 13-month follow-up data indicate sustained prevention of relapse in alcoholics that completed alpha-theta brainwave training.

Saxby, E., & Peniston, E. G. (1995). Alpha-theta brainwave neurofeedback training: An effective treatment for male and female alcoholics with depressive symptoms. Journal of Clinical Psychology, 51(5), 685-693. This was an experimental study of 14 alcoholic outpatients using the Peniston and Kulkosky (1989, 1991) brainwave treatment protocol for alcohol abuse. After temperature biofeedback pretraining, experimental subjects completed 20 40-minute sessions of alpha-theta brainwave neurofeedback training (BWNT). Experimentally treated alcoholics with depressive syndrome showed sharp reductions in self-assessed depression (Beck's Depression Inventory). On the Millon Clinical Multiaxial Inventory-I, the experimental subjects showed significant decreases on the BR scores: schizoid, avoidant, dependent, histrionic, passive- aggression, schizotypal, borderline, anxiety, somatoform, hypomanic, dysthymic, alcohol abuse, drug abuse, psychotic thinking, and psychotic depression. Twenty-one-month follow-up data indicated sustained prevention of relapse in alcoholics who completed BWNT.

Watson, C. G., Herder, J., & Passini, F. T. (1978). Alpha biofeedback therapy in alcoholics: An 18-month follow-up. Journal of Clinical Psychology, 34(3), 765-769. In an earlier study on patients with alcohol problems, an experimental group given 10 hour-long alpha biofeedback training sessions showed greater improvement on State and Trait Anxiety scores than did a control sample. In the present study an 18-month follow-up was done on those Ss. The differences between the experimentals and controls in State and Trait Anxiety after 18 months were essentially identical to the differences between them immediately after treatment, which indicates that alpha training had long-range therapeutic effects. A difference between the groups on the Alcohol Rehabilitation Follow up Questionnaire also suggested that alpha training may have been associated with some reduction in alcohol consumption as well.

For additional information about The Efficacy of Neurofeedback, how to become a Brain Trainer, or for any other information please contact:

Brain-Trainer International
+1 (833) 224-5895
info@brain-trainer.com