



**Attention &
Achievement Center**

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NEUROFEEDBACK RESEARCH FOR ADHD

Arns, M., Conners, C. K., & Kraemer, H (2012). A decade or EEG Theta/Beta Ratio Research in ADHD: A Meta-Analysis. *Journal of Attention Disorders*; (in press).

Objective: Many EEG studies have reported that ADHD is characterized by elevated Theta/Beta ratio (TBR). In this study we conducted a meta-analysis on the TBR in ADHD. Method: TBR data during Eyes Open from location Cz were analyzed from children/adolescents 6-18 years of age with and without ADHD. Results: Nine studies were identified with a total of 1253 children/adolescents with and 517 without ADHD. The grand-mean effect size (ES) for the 6-13 year-olds was 0.75 and for the 6-18 year-olds was 0.62. However the test for heterogeneity remained significant; therefore these ESs are misleading and considered an overestimation. Post-hoc analysis found a decreasing difference in TBR across years, explained by an increasing TBR for the non-ADHD groups. Conclusion: Excessive TBR cannot be considered a reliable diagnostic measure of ADHD, however a substantial sub-group of ADHD patients do deviate on this measure and TBR has prognostic value in this sub-group, warranting its use as a prognostic measure rather than a diagnostic measure.

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.

Arns, M., Kleinnijenhuis, M., Fallahpour, K., & Bretler, R. (2007). Golf performance enhancement and real-life neurofeedback training using personalized event-locked EEG profiles. *Journal of Neurotherapy*, 11(4), 11-18.

Background. This study reports on a new method for golf performance enhancement employing personalized real-life neurofeedback during golf putting.

Method. Participants ($n = 6$) received an assessment and three real-life neurofeedback training sessions. In the assessment, a personal event-locked electroencephalographic (EEG) profile at FPz was determined for successful versus unsuccessful putts. Target frequency bands and amplitudes marking optimal prefrontal brain state were derived from the profile by two raters. The training sessions consisted of four series of 80 putts in an ABAB design. The feedback in the second and fourth series was administered in the form of a continuous NoGo tone, whereas in the first and third series no feedback was provided. This tone was terminated only when the participants EEG met the assessment-defined criteria. In the feedback series, participants were instructed to perform the putt only after the NoGo tone had ceased.

Results. From the personalized event-locked EEG profiles, individual training protocols were established. The interrater reliability was 91%. The overall percentage of successful putts was significantly larger in the second and fourth series (feedback) of training compared to the first and third series (no feedback). Furthermore, most participants improved their performance with feedback on their personalized EEG profile, with 25% on average. Conclusions. This study demonstrates that the “zone” or the optimal mental state for golf putting shows clear recognizable personalized patterns. The learning effects suggest that this real-life approach to neurofeedback improves learning speed, probably by tapping into learning associated with contextual conditioning rather than operant conditioning, indicating perspectives for clinical applications.

Barabasz, A., & Barabasz, M. (2000). Treating AD/HD with hypnosis and neurotherapy. *Child Study Journal*, 30(1), 25-42.

Eighteen children and one young adult ADHD patients were treated with alert hypnosis as an adjunct to neurotherapy. Posttest means for each subscale (Inattentive, Impulsive, and Hyperactive) of the Attention Deficit Disorders Evaluation Scale-Home Version were significantly lower than pretest scores. No comparison group was used, and outcomes were confined to specific therapist.

Bazanava, O.M., Aftanas, L.I. (2010). Individual EEG alpha activity analysis for enhancement neurofeedback efficiency: Two case studies. *Journal of Neurotherapy* 14(3), 244 – 253.

The hypothesis was tested of whether neurofeedback training applied in order to increase or decrease power of individual EEG frequency ranges is more efficient than neurofeedback training of standard EEG frequency ranges. The sessions of decreasing the theta/beta ratio and reinforcing alpha neurofeedback training were carried out on two outpatients with attention deficit disorder (a schoolboy) and functional pain contraction (a professional musician). The neurofeedback utilizing standard EEG frequency ranges (theta 4-8, alpha 8-12, beta 13-18) was inefficient and even resulted in aggravation of symptoms in both cases. The individualized neurofeedback that utilized individual frequency ranges resulted in substantial clinical improvement.

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, Fernandez 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.

Boyd, W. D., & Campbell, S. E. (1998). EEG biofeedback in the schools: The use of EEG biofeedback to treat ADHD in a school setting. *Journal of Neurotherapy*, 2(4), 65-71.

Six middle school students diagnosed with attention deficit/hyperactivity disorder were selected for sensory motor rhythm (SMR) training with EEG biofeedback. The subjects were evaluated following a 72-hour drug-free period with the WISC-III Digit Span subtest and the Test of Variables of Attention (TOVA). Five of the subjects received 20 sessions of EEG biofeedback and one of the subjects received nine sessions of EEG biofeedback. The subjects were evaluated again following a 72-hour drug-free period. Five of the six subjects improved on their combined Digit Span, TOVA Inattention, and TOVA Impulsivity scores. These results supported previous findings that EEG biofeedback can be effective in the treatment of attention deficit/hyperactivity disorder. More importantly, this study demonstrated that EEG biofeedback could be used in an actual school setting. Recommendations for implementing an EEG biofeedback program in the schools were provided.

Breteler, M. H. M., Arns, M., Peters, S., Giepman, 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 indepth study of the changes in the qEEG power and coherence protocols evidenced no fronto-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.

Budzynski, T. H. (1996). Brain brightening: Can neurofeedback improve cognitive process? *Biofeedback*, 24(2), 14-17.

(Abstract to follow)

Canon, R., Kerson, C., Hampshire, A. & Coleman, G. L. (2013). Assessing the functional integrity of the default network in adult ADHD with fMRI and sLORETA. *Journal of Neurotherapy*; 16(1) (in press)

Intrinsic functional connectivity within the default network (DMN) of the brain has gained growing interest in attention deficit/hyperactivity disorder (ADHD). The DMN is proposed to support such core functions as theory of mind, self-related activities such as autobiographical self, stimulus independent thought, self-projection, self-

reference and introspective processes as well as central features of self-regulation, task compliance and executive functions. The present study recorded brain activity using both EEG and fMRI during rest and task. The rest data were analyzed using sLORETA and a psychophysiological interaction model respectively. Medial prefrontal and left parietal region connectivity showed the greatest difference when comparing ADHD to control in theta, alpha 1 and alpha 2.

Cannon, R., Kerson, C., Hampshire, A. (2011). sLORETA and fMRI Detection of Medial Prefrontal Default Network Anomalies in Adult ADHD. *Journal of Neurotherapy*; 15(4). 358-373

Attention deficit hyperactivity disorder (ADHD) is a developmental psychiatric disorder thought to affect approximately 5 to 10% of school-age children, of whom 30%–65% continue to exhibit symptoms into adulthood. The prevalence of ADHD in adults is also an estimated 4%, second only to depression. Across studies there appear to be significant network dysfunctions involved in ADHD. Typically the foci of interest in ADHD included the insular cortices, frontal lobes, basal ganglia and cerebellum. More recently, attention has been directed to the default network of the brain and its functional integrity in ADHD with focus on the precuneus and parietal lobes and interactions with medial prefrontal cortices. Functional Magnetic Resonance Imaging (fMRI) measures neurovascular coupling as measured by the blood oxygenated level dependent signal (BOLD). Electroencephalogram (EEG) measures brain electrical information. Since fMRI is an indirect measure of neuronal activity and EEG is a direct measure combining the results from these two imaging modalities under the same task conditions may provide a more complete story as to the what (EEG) and where (fMRI) activity exists.

Carmody, D. P., Radvanski, D. C., Wadhvani, S., Sabo, J. J., & Vergara, L. (2001). EEG biofeedback training and attention-deficit/hyperactivity disorder in an elementary school setting. *Journal of Neurotherapy*, 4(3), 5-27.

Method: An experimental group of eight children ages 8-10 completed 35-47 sessions of EEG biofeedback training over a six-month period. Four participants in the experimental group were diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) and four were not diagnosed with ADHD. Eight children in the waitlist control group were matched to the experimental group on age, grade, teacher, and diagnosis. None of the 16 participants were medicated for ADHD.

Results: Attention abilities as measured by the Test of Variables of Attention showed the experimental group of children with ADHD reduced errors of commission and anticipation, indicating a reduction in impulsivity. Teacher reports using the McCarney Scale indicated improvements in attention but no changes in impulsivity and hyperactivity.

Discussion: Several confounds require exploration before attribution of changes are assigned to neurofeedback. Whether the effects are due to the neurofeedback protocols, attendance at individual sessions away from the classroom, the attention of the technician, or the excitement of a special program cannot be determined with this study. It will be necessary to have a placebo group in order to separate systematically the variables in the training program.

Egner, T., & Gruzelier, J. H. (2001). Learned self-regulation of EEG frequency components effects attention and event-related brain potentials in humans. *NeuroReport*, 12, 4155-4159.

Learned enhancement of EEG frequency components in the lower beta range by means of biofeedback has been reported to alleviate attention deficit hyperactivity disorder (ADHD) symptoms. In order to elucidate frequency-specific behavioural effects and neurophysiological mediators, this study applied neurofeedback protocols to healthy volunteers, and assessed impact on behavioural and electrocortical attention measures. Operant enhancement of a 12-15Hz component was associated with reduction in commission errors and improved perceptual sensitivity on a continuous performance task (CPT), while the opposite relation was found for 15-18Hz enhancement. Both 12-15Hz and 15-18Hz enhancement were associated with significant increases in P300 event-related brain potential amplitudes in an auditory oddball task. These relations are interpreted as stemming from band-specific effects on perceptual and motor aspects of attention measures.

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 discrete 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 = 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 'd prime' (d'), and reduced omission errors and reaction time variability. Beta1 training was associated with faster reaction times and increased target P300 amplitudes, 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.

Fehmi, L. G., & Selzer, F. A. (1980). Biofeedback and attention training. Chapter in S. Boorstein (Ed.), *Transpersonal Psychotherapy*. Palo Alto: Science and Behavior Books.

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 behaviour in children with special needs. *Educational & Child Psychology*, 22(3), 67-77.

The current choice of treatment for the remediation of attentional and behavioural difficulties among primary school children with special educational needs (SEN) is, increasingly, pharmacological. If neurofeedback can regulate brain arousal states and thereby improve attention, behaviour 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 behaviour 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 behaviour, plus qualitative feedback as a post-treatment measure of attention/behaviour. Results indicate that neurofeedback may make an important impact on emotions and affect of the SEN individual, leading to improved behaviour 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 behaviour; incorporating neurofeedback as part of the school-based special needs provision is feasible and practicable.

Fritson, K. K., Wadkins, T. A., Gerdes, P., & Hof, D. (2007). The impact of neurotherapy on college students' cognitive abilities and emotions. *Journal of Neurotherapy*, 11(4), 1-9.

Background. In past research, several case studies and five controlled-group studies explored the effect of electroencephalographic (EEG) biofeedback on intelligence, attention, and behavior in children diagnosed with attention deficit hyperactivity disorder, but no studies have explored the effects of EEG biofeedback in nonclinical adults on measures of response control, mood, emotional intelligence, and self-efficacy.

Method. Sixteen nonclinical college students were randomly assigned to receive Beta/Sensory Motor Rhythm EEG biofeedback to increase 12 to 15 Hz activity while inhibiting 4 to 7 Hz and 22 to 36 Hz activity. A control group received placebo EEG biofeedback. All participants completed pre- and postmeasures assessing intelligence scores, attention, impulse control, mood, emotional intelligence, and self-efficacy to assess the effect of EEG biofeedback.

Results. Results showed significant improvements in response control but no improvements in attention.

Measures of intelligence and emotional functioning did not change after EEG biofeedback.

Conclusions. This study indicates that response control may improve in a few as 20 EEG biofeedback sessions.

Implications and shortcomings discussed.

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-Connors 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 nonpharmacological 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.

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.

Hirshberg, L. M. (2007). Place of electroencephalographic biofeedback for attention deficit/hyperactivity disorder. *Expert Review of Neurotherapeutics*, 7(4), 315-319.

Historically, pharmacological treatments for attention-deficit/hyperactivity disorder (ADHD) have been considered to be the only type of interventions effective for reducing the core symptoms of this condition. However, during the past three decades, a series of case-and controlled-group studies examining the effects of EEG biofeedback have reported improved attention and behavioral control, increased cortical activation on quantitative electroencephalographic examination, and gains on tests of intelligence and academic achievement in response to this type of treatment. This review paper critically examines the empirical evidence, applying the efficacy guidelines jointly established by the Association for Applied Psychophysiology and Biofeedback (AAPB) and the International Society for Neuronal Regulation (ISNR). On the basis of these scientific principles, EEG biofeedback was determined to be “probably efficacious” for the treatment of ADHD. Although significant clinical improvement was reported in approximately 75% of the patients in each of the published research studies, additional randomized, controlled group studies are needed in order to provide a better estimate of the percentage of patients with ADHD who will demonstrate such gains in clinical practice.

Jacobs, E. H. (2005). Neurofeedback treatment of two children with learning, attention, mood, social, and developmental deficits. *Journal of Neurotherapy*, 9(4), 55-70.

Neurofeedback is biofeedback training of EEG activity through an operant conditioning process by which the individual strived to increase or inhibit the brain's production of electrical activity in specific frequency ranges. Studies have demonstrated efficacy with a variety of disorders, including attention deficit hyperactivity disorder (ADHD), learning problems, and autistic features. This paper describes the application of neurofeedback in a clinical setting with two complex children who manifested multiple diagnoses, including learning disabilities (LD), ADHD, social deficits, mood disorders, and pervasive developmental disorder (PDD). Both boys had adjusted poorly to school, family, and peers. Methods. Subjects were referred to the author's clinical practice. They received individualized protocols based on their symptoms and functional impairments. They were administered semi-weekly 20-minute sessions of one-channel neurofeedback training for approximately six months. In both cases symptoms were identified and tracked with a parent rating scale and one case, with the Symptom Assessment-45 Questionnaire (SA-45) also.

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.

Kirk, L. (2007). *Neurofeedback protocols for subtypes of attention deficit/hyperactivity disorder*. Chapter in J. R. Evans (Ed.), *Handbook of Neurofeedback*. Binghamton, NY: Haworth Medical Press, pp. 267-299.

Kropotov, J. D., Grin-Yatsenko, V. A., Ponomarev, V. A., Chutko, L. S., Yakovenko, E. A., & Nikishena, I. S. (2007). Changes in EEG spectograms, event-related potentials and event-related desynchronization induced by relative beta training in ADHD children. *Journal of Neurotherapy*, 11(2), 3-11.

Attention-deficit/hyperactivity disorder (ADHD) is a developmental disorder that, by current definition, has onset prior to age 7 years. MRI studies have provided some insight into brain differences associated with ADHD, but thus far have almost exclusively focused on children ages 7 years and older. To better understand the neurobiological development of ADHD, cortical and subcortical brain development should be systematically examined in younger children presenting with symptoms of the disorder. High-resolution anatomical (MPRAGE) images, acquired on a 3.0T scanner, were analyzed in a total of 26 preschoolers, ages 4–5 years (13 with ADHD, 13 controls, matched on age and sex). The ADHD sample was diagnosed using DSM-IV criteria, and screened for language disorders. Cortical regions were delineated and measured using automated methods in Freesurfer; basal ganglia structures were manually delineated. Children with ADHD showed significantly reduced caudate volumes bilaterally; in contrast there were no significant group differences in cortical volume or thickness in this age range. After controlling for age and total cerebral volume, left caudate volume was a significant predictor of hyperactive/impulsive, but not inattentive symptom severity. Anomalous basal ganglia, particularly caudate, development appears to play an important role among children presenting with early onset symptoms of ADHD.

Kropotov, J. D., Grin-Yatsenko, V. A., Ponomarev, V. A., Chutko, L. S., Yakovenko, E. A., Nildshena, I. S. (2005). ERP correlates of EEG relative beta training in ADHD children. *International Journal of Psychophysiology*, 55(1), 23-34.

Kwon, H., Cho, J., Lee, E. (2009). EEG asymmetry analysis of the left and right brain activities during simple versus complex arithmetic learning. *Journal of Neurotherapy* 13(2), 109 – 116.

Repeated practice of simple arithmetic such as addition, subtraction, and multiplication has been widely used for effective math education. Brain activity patterns during simple and complex arithmetic calculation have been explored by several research groups using magnetic resonance images (MRI) and functional MRI (fMRI), and some have reported that the balanced whole brain (both left and right brain) activities during simple arithmetic in contrast to the predominant left brain activities during complex arithmetic.

Methods. In this work, we have identified the characteristic brainwaves and asymmetric activation patterns of the left and right brain during the process of simple and complex arithmetic by measuring theta, alpha, Sensory Motor Response (SMR), and beta brainwaves of 24 participants from the location FP1 (left brain) and FP2 (right brain) using EEG.

Results. Simple statistics analysis showed the significantly different beta activities from the left brain during complex arithmetic compared to simple arithmetic process, and through the asymmetry analysis of the left and right brain activities, less symmetrical brain activation during complex calculation, that is, specifically higher SMR, and beta brainwaves in the left hemisphere more than right hemisphere was identified, which is consistent with recent fMRI findings.

Conclusion. The results imply that simple arithmetic process may improve the whole brain activities in a balanced way while complex arithmetic induce unbalanced activities of the left and right brain.

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 behavioural or cognitive outcome.

Leins, U., Goth, G., Hinterberger, T., Klinger, C., Rumpf, N., & Strehl, U. (2007). Neurofeedback for children with ADHD: A comparison of SCP and theta/beta protocols. *Applied Psychophysiology & Biofeedback, 32*(2), 73-88.

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 behavioural or cognitive outcome.

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 Deficit 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 five 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. F. (2003). *Neurofeedback for the management of attention-deficit / hyperactivity disorders*. Chapter in M. S. Schwartz & F. Andrasik (Eds.), *Biofeedback: A Practitioner's Guide (Third Edition)*. New York, Guilford, 409-437.

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., & Shouse, M. N. (1976). EEG and behavioral changes in a hyperactive child concurrent with training of the sensorimotor rhythm (SMR): A preliminary report. *Biofeedback & Self-Regulation*, 1(3), 293-306.

Reduced seizure incidence coupled with voluntary motor inhibition accompanied conditioned increases in the sensorimotor rhythm (SMR), a 12-14 Hz rhythm appearing over rolandic cortex. Although SMR biofeedback training has been successfully applied to various forms of epilepsy in humans, its potential use in decreasing hyperactivity has been limited to a few cases in which a seizure history was also a significant feature. The present study represents a first attempt to explore the technique's applicability to the problem of hyperkinesis independent of the epilepsy issue. The results of several months of EEG biofeedback training in a hyperkinetic child tend to corroborate and extend previous findings. Feedback presentations for SMR were contingent on the production of 12-14-Hz activity in the absence of 4- 7-Hz slow-wave activity. A substantial increase in SMR occurred with progressive SMR training and was associated with enhanced motor inhibition, as gauged by laboratory measures of muscular tone (chin EMG) and by a global behavioral assessment in the classroom. Opposite trends in motor inhibition occurred when the training procedure was reversed and feedback presentations were contingent on the production of 4-7 Hz in the absence of 12-14-Hz activity. Although the preliminary nature of these results is stressed, the subject population has recently been increased to establish the validity and generality of the findings and will include the use of SMR biofeedback training after medication has been withdrawn.

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. Posttraining 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.

Lutzenberger W, Elbert T, Rockstroh B, Birbaumer N. (1982) Biofeedback produced slow brain potentials and task performance. *Biological Psychology*, 14, 99-111.

Twenty subjects learned to control slow potential (SP) shifts of the brain by means of a biofeedback procedure. Depending upon the pitch of a signal tone, negative SP shifts had to be increased or reduced during intervals of 6 sec each. Visual feedback of the actual SP shift was given. Blocks of training trials alternated with blocks of test trials without any feedback of the SPs. At the end of every test trial a simple arithmetic problem had to be solved by the subjects. Subjects performed the computation in a shorter time interval if an increased negativity preceded task onset as compared to slower response times during suppression of negativity. Results suggest that cortical negativity reflects unspecific preparation for cerebral performance.

Monastra, V. J., (2005). Electroencephalographic biofeedback (neurotherapy) as a treatment for attention deficit hyperactivity disorder: Rationale and empirical foundation. *Child & Adolescent Psychiatric Clinics of North America*, 14(1), 55-82.

During the past three decades, electroencephalographic (EEG) biofeedback has emerged as a nonpharmacologic treatment for attention-deficit/hyperactivity disorder (ADHD). This intervention was derived from operant conditioning studies that demonstrated capacity for neurophysiologic training in humans and other mammals and targets atypical patterns of cortical activation that have been identified consistently in neuroimaging and quantitative EEG studies of patients diagnosed with ADHD. This article presents the rationale for EEG biofeedback and examines the empirical support for this treatment using efficacy guidelines established by the Association for Applied Psychophysiology and Biofeedback and the International Society for Neuronal Regulation. Based on these guidelines, EEG biofeedback is considered to be "probably efficacious" for the treatment of ADHD and merits consideration as a treatment for patients who are stimulant "nonresponders." Although research findings published to date indicate positive clinical response in approximately 75% of patients treated in controlled group studies, additional randomized, controlled trials are needed to provide a better estimate of the robustness of this treatment

Monastra, V. J., Lynn, S., Linden, M., Lubar, J. F., Gruzelier, J., & LaVaque, T. J. (2005). Electroencephalographic biofeedback in the treatment of attention-deficit/hyperactivity disorder. *Applied Psychophysiology & Biofeedback*, 30(2), 95-114.

Historically, pharmacological treatments for attention-deficit/hyperactivity disorder (ADHD) have been considered to be the only type of interventions effective for reducing the core symptoms of this condition. However, during the past three decades, a series of case and controlled group studies examining the effects of EEG biofeedback have reported improved attention and behavioral control, increased cortical activation on quantitative electroencephalographic examination, and gains on tests of intelligence and academic achievement in response to this type of treatment. This review paper critically examines the empirical evidence, applying the efficacy guidelines jointly established by the Association for Applied Psychophysiology and Biofeedback (AAPB) and the International Society for Neuronal Regulation (ISNR). On the basis of these scientific principles, EEG biofeedback was determined to be "probably efficacious" for the treatment of ADHD. Although significant clinical improvement was reported in approximately 75% of the patients in each of the published

research studies, additional randomized, controlled group studies are needed in order to provide a better estimate of the percentage of patients with ADHD who will demonstrate such gains in clinical practice.

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.

Mulholland, T. Goodman, D., & Boudrot, R. (1983). Attention and regulation of EEG alpha-attenuation responses. *Biofeedback & Self-Regulation*, 8(4), 585-600.

Two experiments with 16 normal adults of both sexes tested the hypothesis that inattention to a biofeedback display is associated with increased variability of those physiological processes that had been regulated by the biofeedback. Each experiment was a repeated-measures-on-independent-subjects-design. Dependent variables were the time durations and the mean rms power of two mutually exclusive segments of the parietal-occipital EEG: alpha and not-alpha segments. Independent variables were combination of counting tasks and instructions to look at, listen to, and count visual and auditory flashes and clicks. The durations of alpha and not-alpha segments were controlled or regulated by means of an alpha-contingent visual feedback stimulus; attention to the feedback stimulus was challenged by instructions to count other, noncontingent stimuli. Control of alpha and not-alpha segments was least for conditions of (1) "sham" feedback, and (2) feedback with instructions to count noncontingent auditory clicks, which were presented 3/sec while the feedback visual stimuli were occurring. A new EEG test of attention and distraction was suggested.

Nash, J. K. (2000). Treatment of attention-deficit hyperactivity disorder with neurotherapy. *Clinical Electroencephalography*, 31(1), 30-37.

Significant public health concerns exist regarding our current level of success in treating ADHD. Medication management is very helpful in 60-70% of patients. Side effects, lack of compliance and the fact that stimulant medications cannot be given late in the day limit the benefits largely to school hours. While stimulants improve behavior and attention, less of an effect has been noted on academic and social performance. Continuing concerns exist about long-term safety, and studies on long-term cardiovascular and neurophysiological effects have not been carried out. Neurotherapy for ADHD offers an effective alternate for patients whose treatment is limited by side effects, poor medication response and in cases in which the patients and/or their parents refuse to consider medications. Studies indicate clinical improvement is largely related to measurable improvements in the EEG signature, evidenced by declining theta/beta ratios over frontal/central cortex and/or reduced theta/alpha band amplitudes.

Perreau-Linck, E., Lessard, N., Lévesque, J., Beaugregard, M. (2010). Effects of neurofeedback training on inhibitory capacities in ADHD children: A single-blind, randomized, placebo-controlled study. *Journal of Neurotherapy* 14(3), 229 – 242.

Introduction: Studies performed during the last decades suggest that neurofeedback (NF) training can effectively reduce symptomatology in children with Attention-Deficit/Hyperactivity Disorder (ADHD). Yet, questions remain concerning specific effects of NF training in ADHD children since these studies did not use a randomized, placebo-controlled approach. To address this issue, such an approach was used in the present study to measure the impact of NF training on inhibitory capacities.

Methods: Nine ADHD children (with no comorbidity), aged 8 to 13 years, were randomly assigned to either an experimental group (n = 5) or a placebo group (n = 4). For both groups, training protocols comprised 40 one-hour sessions (20 meetings of two sessions each). SMR/Theta training was used in the experimental group. Pre-recorded sessions of the first author's EEG activity were used in the placebo group. Pre- and post-training assessments consisted of the Conner's Parent Rating Scales (CPRS-R) and neuropsychological tests. A multiple case study strategy was applied for data analysis using a Reliable Change Index (RCI) when applicable.

Results: One experimental subject was a drop-out and one placebo subject had to be discontinued due to adverse effects. The latter subject accepted to undergo post-training evaluations; hence an Intention-To-Treat analysis was performed on this subject's data. Remaining subjects showed significant improvements on the CPRS-R. Improvements were measured on the Variability measure of the CPT-II consistently across the placebo group and on the Inhibition Condition of the Stroop Task for all but one placebo subject. The same trend was found for the Inhibition/Switching Condition (Stroop Task) across the experimental group (n=4).

Pulvermuller, F., Mohr, B., Schleichert, H., & Veit, R. (2000). Operant conditioning of left-hemispheric slow cortical potentials and its effect on word processing. *Biological Psychology*, 53, 177-215.

This study investigated whether language-related cognitive processes can be modified by learned modulation of cortical activity. Study participants received feedback of slow cortical potentials (SCPs) recorded above left-hemispheric language cortices and were reinforced for producing negative and positive shifts upon two different discriminative stimuli. In all subjects who achieved reliable control of left-hemispheric brain responses, substantial modification of word processing was observed. Behavioral modification could be documented in two experiments in which word probes were presented following discriminative stimuli. When negative shifts of the EEG were required, lexical decisions on words were substantially speeded, while they were slowed during positivity conditions. There was no indication for any performance difference between conditions in control subjects who failed to achieve control over SCPs after feedback training. This result was replicated in an experiment using lateralized-tachistoscopic stimulus presentation. Comparisons of word and pseudoword responses in both experiments indicated that behavioral modification was most pronounced for word responses. It was also not seen in a simple reaction time task not involving language materials. This argues against a global effect related to perception, visuo-spatial attention, or motor processes. We conclude that linguistic processes can be influenced by modification of cortical activity due to operant conditioning. In closing, tentative explanations of the present results based on theories of language and attention processes are being discussed

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 measures. 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 measures. 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.

Rockstroh, B., Elbert, T., Lutzenberger, W., & Birbaumer, N. (1990). Biofeedback: Evaluation and therapy in children with attentional dysfunction. Chapter in A. Rothenberger (Ed.), *Brain and Behaviour in Child Psychiatry*. Berlin: Springer Verlag, pp. 345-357.

Background: Learned self-control of slow cortical potentials (SCPs) may lead to behavioral improvement in attention-deficit/hyperactivity disorder (ADHD). Hence, training effects should also be reflected at the neurophysiological level.

Methods: Thirteen children with ADHD, aged 7–13 years, performed 25 SCP training sessions within 3 weeks. Before and after training, the German ADHD rating scale was completed by parents, and event-related potentials were recorded in a cued continuous

performance test (CPT). For a waiting-list group of nine children with ADHD, the same testing was applied.

Results: ADHD symptomatology was reduced by approximately 25% after SCP training. Moreover, a decrease of impulsivity errors and an increase of the contingent negative variation were observed in the CPT task.

Conclusions: This study provides first evidence for both positive behavioral and specific neurophysiological effects of SCP training in children with ADHD.

Rossiter, T. (2002). Neurofeedback for AD/HD: A ratio feedback case study. *Journal of Neurotherapy*, 6(3), 9-35.

Introduction. The case study of a 13-year-old AD/HD male treated with neurofeedback is the subject matter for a tutorial on Ratio feedback.

Method. Neurofeedback was conducted at C3 (increase 15 to 18 Hz, decrease 2 to 10 Hz) and C4 (increase 12 to 15 Hz, decrease 2 to 7 Hz). Protocols provided visual and auditory feedback based on the ratio of slow wave activity to be suppressed divided by fast wave activity to be enhanced (Ratio feedback).

Results. The patient demonstrated marked improvement in processing speed and variability on the Test of Variables of Attention-Auditory, a 19-point increase in IQ on the Kaufman Brief Intelligence Test, significant behavioral improvement based on parental (Behavior Assessment System for Children) and patient (Brown ADD Scale) reports, and a 7.5 grade equivalent increase in reading scores (Kaufman Test of Educational Achievement-Brief Form). At the 17-month follow-up parent questionnaires indicated that the patient's behavioral gains had been maintained or were slightly improved. EEG data showed significant declines in the C4/SMR Ratio (10 to 7 Hz/12 to 15 Hz) and 2 to 7 Hz amplitude, a tendency toward an increase in 12 to 15 Hz amplitude, a significant increase in 8 to 11 Hz amplitude, and a decline in 22 to 30 Hz amplitude. Beta activity (15 to 18 Hz) was unchanged. An unexpected finding was that C3/Beta (10 to 10 Hz/15 to 18 Hz) and C4/SMR protocols had similar effects on the EEG even though they targeted different bands to enhance and suppress. It appears that suppression of slow wave activity (2 to 7 Hz) may be the active component in both Ratio protocols and that fast wave enhancement either plays a minor (12 to 15 Hz) or no role (15 to 18 Hz).

Discussion. The findings cast doubt on the assumption that the C3/Beta and C4/SMR protocols have unique effects on EEG activity. Nevertheless, they may have differential effects on brain functions related to the training sites employed. It would be useful to analyze EEG changes in successfully treated individual AD/HD patients as a first step toward understanding the effects of various treatment protocols. What the protocols are intended to do, and the actual effects on the EEG may be different. If there are active components common to the various AD/HD treatment protocols reported in the literature, this is one way of beginning to recognize them. Brain maps collected before, during, and at the conclusion of treatment would enhance our understanding of treatment effects of various neurofeedback protocols, lead to more focused and productive research, and ultimately facilitate the development of more efficient treatment paradigms.

Rossiter, T. R., & La Vaque, T. J. (1995). A comparison of EEG biofeedback and psychostimulants in treating attention deficit/hyperactivity disorders. *Journal of Neurotherapy*, 1, 48-59.

The study compared the effects of EEG biofeedback and stimulant medication in reducing AD/HD symptoms. Stimulants are the most widely used treatment for AD/HD but have drawbacks. The most serious is that symptom reduction is only temporary unless medication is taken indefinitely. In addition, stimulants may have side effects and long-term compliance with taking the medication is poor, especially among adolescents. The study compared treatment programs with 20 sessions of EEG biofeedback (n

= 23) or stimulants (n = 23) as their primary components. An EEG group (EEG) was matched with a stimulant group (MED) by age, IQ, gender, and diagnosis. The Test of Variables of Attention (TOVA) was administered pre and post-treatment. Both the EEG and MED groups improved ($p < .05$) on TOVA measures of inattention, impulsivity, information processing, and variability but did not differ from each other ($p > 0.3$) on TOVA change scores. The results indicate that the EEG biofeedback program is an effective alternative to stimulants and may be the treatment of choice when medication is ineffective, has side effects, or compliance is a problem. Previous studies suggest that EEG biofeedback leads to lasting symptom reduction. This needs to be confirmed with larger samples using standardized assessment procedures.

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.

Shouse, M. N., & Lubar, J. F. (1979). Operant conditioning of EEG rhythms and Ritalin in the treatment of hyperkinesia. *Biofeedback & Self-Regulation*, 4(4), 299-311.

Enhanced voluntary motor inhibition regularly accompanies conditioned increases in the sensorimotor rhythm (SMR), a 12--14-Hz Rolandic EEG rhythm in cats. A similar rhythm, presumably SMR, has also been identified in the human EEG. The clinical effectiveness of SMR operant conditioning has been claimed for epilepsy, insomnia, and hyperkinesia concurrent with seizure disorders. The present report attempts to follow up and replicate preliminary findings that suggested the technique's successful application to hyperkinesia uncomplicated by a history of epilepsy. SMR was defined as 12--14-Hz EEG activity in the absence of high-voltage slow-wave activity between 4 and 7 Hz. Anticipated treatment effects were indexed by systematic behavioral assessments of undirected motor activity and short attention span in the classroom. EEG and behavioral indices were monitored in four hyperkinetic children under the following six conditions: (1) No Drug, (2) Drug Only, (3) Drug and SMR Training I, (4) Drug and SMR Reversal Training, (5) Drug and SMR Training II, (6) No Drug and SMR Training. All hyperkinetic subjects were maintained on a constant drug regimen throughout the phases employing chemotherapy. Contingent increases and decreases in SMR occurred in three of four training subjects and were associated with similar changes in classroom assessments of motor inactivity. Combining medication and SMR training resulted in substantial improvements that exceeded the effects of drugs alone and were sustained with SMR training after medication was withdrawn. In contrast, these physiological and behavioral changes were absent in one highly distractible subject who failed to acquire the SMR task. Finally, pretraining levels of SMR accurately reflected both the severity of original motor deficits and the susceptibility of hyperkinetic subjects to both treatments. Although the procedure clearly reduced hyperkinetic behavior, a salient, specific therapeutic factor could not be identified due to the dual EEG contingency imposed combined with associated changes in EMG. Despite these and other qualifying factors, the findings suggested the prognostic and diagnostic value of the SMR in the disorder when overactivity rather than distractibility is the predominant behavioral deficit.

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.

Swingle, P. G. (2001). Parameters associated with rapid neurotherapeutic treatment of common ADD (CADD). *Journal of Neurotherapy*, 5(4), 73-84.

Paralysis after stroke or neurotrauma is among the leading causes of long-term disability in adults. The development of brain-computer-interface (BCI) systems that allow online classification of electric or metabolic brain activity and their translation into control signals of external devices or computers have led to two major approaches in tackling the problem of paralysis. While assistive BCI systems strive for continuous high-dimensional control of robotic devices or functional electric stimulation (FES) of paralyzed muscles to substitute for lost motor functions in a daily life environment (e.g. Velliste et al. 2008 [1], Hochberg et al. 2006 [2], Pfurtscheller et al. 2000 [3]), restorative BCI systems aim at normalization of neurophysiologic activity that might facilitate motor recovery (e.g. Birbaumer et al. 2007, 2009 [4,5]; Daly et al. 2008 [6]). In order to make assistive BCI systems work in daily life, high BCI communication speed is necessary, an issue that by now can only be achieved by invasive recordings of brain activity (e.g. via multi-unit arrays, MUA, or electrocorticogram, ECoG). Restorative BCI systems, in contrast, were developed as training tools based on non-invasive methods such as electro- or magnetoencephalography (EEG / MEG). More recently developed approaches use real-time functional magnetic resonance imaging (rtfMRI) or near-infrared spectroscopy (NIRS). Here, we provide an overview of the current state in the development and application of assistive and restorative BCI and introduce novel approaches to improve BCI control with brain stimulation such as transcranial direct current stimulation (tDCS). The outlook of using BCI in rehabilitation of stroke and neurotrauma is discussed.

Tansey, M. A. (1984). EEG sensorimotor rhythm biofeedback training: Some effects on the neurological precursors of learning disabilities. *International Journal of Psychophysiology*, 3, 85-99.

This study presents a clinical treatment regime for pathological interhemispheric dysfunction with respect to a population of learning disabled boys. The results obtained replicate and extend earlier findings with respect to operantly conditioned increases in amplitude of sensorimotor transactions and its positive effect on learning disability. Specifically, the biofeedback, and subsequent conditioning, of increased 14 Hz neural discharge patterns (sensorimotor rhythm-SMR) over the central Rolandic cortex, appeared to increase bilateral

sensorimotor transactions resulting in substantive reduction/remediation in the learning disabilities of the recipients of such EEG biofeedback training.

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 hyperkinesia 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 ratio 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.

Vachon-Preseau, E., Achim, A., Benoit-Lajoie, A. (2009). Direction of SMR and beta change with attention in adults. *Journal of Neurotherapy* 13(1), 22 – 29.

Introduction. The aim of this study was to clarify the interpretation of sensory-motor rhythm (SMR; 13–15 Hz) and beta (16–20 Hz) changes with respect to attention states.

Method. For this purpose, EEG was recorded from 11 participants during (a) a multiple object tracking task (MOT), which required externally directed attention; (b) the retention phase of a visuo-spatial memory task (VSM), which required internally directed attention and avoidance of sensory distraction; and (c) the waiting intervals between trials, which constituted a no-task-imposed control condition. The 2 active tasks were consecutively presented at 2 difficulty levels (i.e., easy and hard). Two analyses of variance were conducted on EEG log spectral amplitudes in the alpha (8–12 Hz), SMR, and beta bands from F3, F4, C3, C4 and P3, P4.

Results. The first 15 analysis compared the MOT to the VSM by difficulty levels and revealed a significant task effect ($p < .0005$) but no effect of difficulty. The results showed that externally directed attention (MOT) resulted in lower values than internally directed attention (VSM) in all three bands. The second analysis averaged the difficulty levels together and added the no-task-imposed reference condition. The results again showed a significant task effect that did not interact with site, hemisphere, or, more important, band. Post hoc tests revealed that both MOT and VSM produced significantly smaller means than the no-task-imposed condition. This pattern of log-amplitude means and the lack of task interaction with any other factor indicate

that task-induced attention reduces EEG power in the same proportion across the 3 bands and the 6 channels studied.

Conclusions. These results contradict a frequent interpretation concerning the relationship between the brain's aptitude to increase low beta in neurofeedback programs and improved sustain attention capacities.

Valdez, M. (1985). Effects of biofeedback-assisted attention training in a college population. *Biofeedback & Self-Regulation*, 10(4), 315-324.

A program of stress management employing open-focus attention-training workshops was developed at Baruch College to bring the benefits of stress reduction to students. The purpose of the research reported here was to evaluate the results of the open-focus attention-training technique. Open-focus technique without biofeedback training was used for two semesters. Biofeedback training was incorporated in the third semester. In the first study, changes in grade point average (GPA), stress-related symptoms, and physiological measures were examined. The experimental subjects' stress data for this study was reported previously (Valdés, 1985). In the second study, changes in the same variables for experimental and control subjects were evaluated. Students in the control group showed decreased GPA, while those who participated in open-focus training showed a trend toward improved GPA. Stress-related symptoms associated with anxiety and management of emotional problems showed significant posttraining improvement, as did physiological measures in all of the biofeedback modalities in which the experimental subjects were specifically trained. The results support the hypothesis that the workshops were successful in reducing stress levels, and suggest that further controlled research be conducted to verify these findings, and to identify the most effective components of the training procedure.

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.

Wadhvani, S., Radvanski, D. C., & Carmody, D. P. (1998). Neurofeedback training in a case of attention deficit hyperactivity disorder. *Journal of Neurotherapy*, 3(1), 42-49.

Electroencephalographic biofeedback, also known as neurofeedback, has been used to improve attention in children with Attention Deficit Hyperactivity Disorder (ADHD). In the present case study, a ten-year-old boy completed 37 sessions of neurofeedback training over a six-month period on-site in a school setting. Beta brainwave training was applied for sessions 1 – 22 and replaced by sensorimotor rhythm training for sessions 23 – 37. A review of his national achievement test scores for four years revealed he improved performance the year he received neurofeedback and the gain was lost the year after treatment was completed. The participant had been receiving methylphenidate for the previous two years and remained on the medication throughout neurofeedback and for the year after neurofeedback treatment. Findings are suggestive of the advantages of

incorporating neurofeedback training as part of a multimodal treatment program in a school setting for children with ADHD

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 obtain a QEEG and a reading difference topograph. 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.