

**Table 5:
Controlled Neurofeedback Studies in Treating ADHD**

Study	Subjects/Design	Key Findings
Carmony et al. 2001 ⁶³	16 children ages 8-10, 8 with and 8 without ADHD. Children were randomly assigned to 2 groups of 4 matched pairs. The 1st group (4 with & 4 without ADHD) received 36 - 48 NFB training sessions at school. The 2nd group served as a wait-list control group. All children were unmedicated. Outcome measures included teacher-completed ADDES and the TOVA. All measures were administered before NFB training, at the midpoint, and after training.	<ol style="list-style-type: none"> 1) Only the children with ADHD that were trained with NFB had significantly reduced hyperactivity/ impulsivity as assessed by the TOVA. 2) Significant TOVA improvements occurred on the Commission Errors ($p < .01$) and Anticipatory Scores ($p < .03$) Scales. 3) Due to study design, TOVA results cannot be attributed to maturation, time of year, repeated testing, or the training setting/experience. 4) Teachers' ratings on the ADDES Inattention scale were significantly ($p < .002$) improved for the NFB group.
Monastra, Monastra, & George, 2002 ⁵⁵ Long-term follow-up study described in Monastra, 2005 ⁶⁵	100 ADHD children and adolescents ages 6-19 who demonstrated cortical EEG slowing from a central site. 51 subjects received an average of 43 NFB sessions, 49 did not. All patients received stimulant medication & academic support at school (IEP/504 plan with school accommodations) and their parents received a 10-week parenting program. The outcome measures were the Home & School versions of the ADDES, the TOVA, parenting style, and QEEG Attention Index. All pretreatment measures were administered when patients were unmedicated. Post treatment measures were administered 1-year later while medicated, after 1-week off medication, and 3 years after the initial evaluation	<ol style="list-style-type: none"> 1) Only NFB training resulted in significant improvements on behavioral, TOVA, and QEEG Attention Index measures when medications were withdrawn. 2) On the ADDES, parent & teacher ratings revealed significant ($p < .001$) improvements in hyperactive/impulsive & inattentive behaviors post-training, 1-week after medications were withdrawn. 3) Post NFB training, all TOVA scales were improved to the unimpaired range when measured 1- week after medication withdrawal. 4) Post NFB training, the QEEG Attention Index dropped into the normal range when measured 1-week after medication withdrawal. 5) 3-year follow-up after initial evaluation revealed that the NFB group alone sustained gains on all measures while unmedicated and 80% of the NFB group had reduced their medications by 50% or more. 6) None of the children who did not receive NFB had been able to reduce their dosage of stimulant medication in the follow-up assessment and 85% had increased their dosage.
Fuchs et al., 2003 ⁵⁶	34 ADHD children ages 8-12 were assigned based on parental preference to NFB ($n=22$) or stimulant medication ($n=12$). NFB consisted of 30 60-min sessions with sessions administered 3x's per week. The NFB protocol was either theta/beta or	<ol style="list-style-type: none"> 1) Both groups showed significant improvement in each of the outcome measures with no significant differences between groups. 2) The authors conclude "These findings suggest that neurofeedback was efficient in improving some of the behavioral concomitants of ADHD in children whose parents favored a nonpharmacological treatment"

	SMR training dependent the child's subtype of ADHD. The doses for the medication group were adjusted during study based on need and ranged between 10 and 60 mg/day. The outcome measures were the TOVA, Attention Endurance Test, parent & teacher rated CBRS, and the WISC.	
Heinrich et al. 2004 ⁵⁷	22 ADHD children ages 7-13 were assigned to NFB (n=13) and a wait-list control group (n=9). The NFB children received 25 SCP training sessions over the course of 3 weeks. Starting at week 2, the NFB children were instructed to practice their strategies at home. The outcome measures were the parent rated FBB-HKS, CPT, and event-related potential (P300) during CPT.	<p>1) SCP training resulted in significant reductions in core ADHD symptoms as rated by parents.</p> <p>2) SCP training resulted in significant improvements in the more objective laboratory measures compared to those children in the wait-list control group.</p> <p>3) The authors concluded that <i>"this study provides first evidence for both positive behavioral and specific neurophysiological effects of SCP training in children with ADHD."</i></p>
Rossiter, 2004 ⁵⁸	62 ADHD children and adults ages 7-55 were matched to NFB (n=31) or stimulant medication (n=31) based on patient or parent preference. Patients were matched by (in order) age, sum of 4 baseline TOVA scores, IQ, gender, and ADHD subtype. The medication patients were titrated based on TOVA results and maintained on the dose that maximized TOVA scores. The NFB patients received either 40 sessions in office or 60 at home over 3-3.5 months. The NFB theta/beta protocol was on the left hemisphere for those patients reporting inattention, daydreaming, poor sustained attention, and/or lack of motivation whereas those also reporting impulsivity, distractibility, and/or stimulus-seeking received left and right hemisphere training. The outcome measures were the TOVA for both groups and for the NFB group only either a child or adult ADHD rating scale	<p>1) Both the NFB and stimulant medication groups had similar significant improvements in attention, impulsivity, and processing speed on the TOVA with no significant differences between groups.</p> <p>2) The NFB group demonstrated statistically and clinically significant improvement on behavioral measures (Behavior Assessment System for Children, ES = 1.16, and Brown Attention Deficit Disorder Scales, ES = 1.59).</p> <p>3) The author concluded that <i>"confidence interval and nonequivalence null hypothesis testing confirmed that the neurofeedback program produced patient outcomes equivalent to those obtained with stimulant drugs."</i></p>
deBeus, 2006; ⁵¹ deBeuss & Kaiser,	53 ADHD children ages 7-11 were randomly assigned in a cross-over design to first receive	1) NFB was superior to sham feedback on the IVA's response control and attention scales, on the CPRS's inattentive scale, and the CTRS's inattentive &

2011 ⁵²	either 20 30-minute theta/beta NFB sessions or 20 sham NFB sessions. After these sessions, the children who had received active NFB received 20 sham sessions & those who had received sham NFB received 20 sessions of theta/beta NFB. Children were assessed after each block of 20 sessions. Outcome measures included the IVA, parent-rated CPRS, and teacher-rated CTRS.	hyperactive-impulsive scales. 2) Of the 42 children who completed all 40 sessions, 31 were classified as NFB-learners because their theta/beta EEG ratio improved in the desired direction by one-half a standard deviation or more following active NFB and 11 were classified as NFB non-learners. 3) NFB-learners were superior to non-learners on the IVA's response control and attention scales and the CTRS's inattentive, hyperactive-impulsive, and ADHD total score scales.
Levesque et al, 2006 ⁵⁹	20 ADHD children ages 8-12 were randomly assigned on a 3:1 ratio basis. The 15 NFB children received 40 sessions of theta/beta training while 5 children were waitlisted. Outcome measures included pre/post changes in fMRI, Digit Span subtest of the WISC, IVA, CPRS Inattention and hyperactivity scales, Counting Stroop and Go/No-Go Tasks.	1) On the fMRI, NFB resulted in significant activation of the right anterior cingulate cortex (ACC), right ventrolateral prefrontal cortex, right dorsal ACC, left caudate nucleus, and left substantia nigra whereas no significant changes were seen in the control group. 2) NFB was superior on each of the other outcome measures. 3) The authors concluded that NFB "has the capacity to functionally normalize the brain systems mediating selective attention and response inhibition."
Strehl et al, 2006 ⁵³	25 ADHD children ages 8-13 received 30 SCP NFB sessions lasting 60 minutes in 3 phases of 10 sessions each. Transfer trials without SCP feedback were intermixed with feedback trials to foster generalization of treatment effects. In addition to the NFB sessions, in the third phase children practiced their SCP self-regulation strategy during homework. Outcome measures included parent and teacher ratings of ADHD symptoms (DSM questionnaire for ADHD; Eyberg Child Behavior Inventory; CPRS, and CTRS), IQ (WISC), and a computerized measure of attention.	1) Children with ADHD can learn to regulate slow negative cortical potentials. 2) Children's ability to successfully produce SCP shifts in trials without feedback had better clinical outcomes than those children who were less successful. 3) Parents and teachers reported significant behavioral and cognitive improvements for the children following SCP training. 4) After SCP training, significant improvements in attention and performance IQ score were also observed. 5) The positive changes in parent and teachers ratings, attention, and IQ continued when reassessed 6 months after SCP treatment ended. While this is was not a controlled study, it was included because of its report of 6-month follow-up results and correlating the children's improvement in learning to regulate SCP and to having better clinical outcomes.
Drechsler et al, 2007 ⁵⁴	30 ADHD children age 7-13 were partially randomized to NFB (n=17) and a group for cognitive behavioral training CBT (n=13). The randomization allowed therapeutic/practical aspects to be accounted for (e.g., limited age range for children in each group, gender-mixed groups had to have at least 2 of each gender,	1) NFB was superior to CBT in the parent and teacher ratings, particularly in the attention and cognition-related domains. 2) Children in both groups showed similar improvement on the neuropsychological measures, however only about half of the NFB group learned to regulate cortical activation during the transfer condition without direct feedback. Behavioral improvements of this subgroup were moderately related to NFB training performance, whereas effective parental support

	<p>children/parents of the NFB group had to be available during vacation for intense training, and some children/parents expressed strong preference for one type of training or wanted to participate in both groups—in these latter cases only the data from the 1st treatment was included for analysis). The CBT groups had 15 90-min sessions, once or twice per week and included social skills training, self-management, metacognitive skill training, and training to enhance self-awareness. Parents were invited to participate in the last 15-minutes of each session. The NFB group had 30 45-minute SCP training sessions twice per day for 2 weeks, followed by a 5-week break, then 5 double sessions, once or twice per week for 3 weeks. Parents and children were taught how to practice generalizing SCP activation/deactivation to real life situations. Outcome measures included parent and teacher rated ADHD symptoms (FBB-HKS, CPRS, CTRS, BRIEF), neuropsychological measures for alertness, inhibitory control, selective attention, sustained attention, and switching attention using the TAP and subtest scores from TEA-ch). Learning cortical self-regulation was evaluated by computing the difference between activation during sessions 2 and 3 vs 13 and 14. Parent involvement was assessed via self-report and involvement in CBT and NFB training opportunities.</p>	<p>accounted better for some advantages of NFB training compared to CBT group therapy according to parents' and teachers' ratings 3) The authors concluded that <i>“there is a specific training effect of neurofeedback of slow cortical potentials due to enhanced cortical control. However, non-specific factors, such as parental support, may also contribute to the positive behavioral effects induced by the neurofeedback training.”</i></p>
<p>Leins et al, 2007⁴⁹ Gani et al, 2008 for 2-year follow-up⁶⁶</p>	<p>38 ADHD children age 7-13 were matched by age, sex, IQ, dx, and medication status and then randomly assigned either theta/beta NFB (n=19) or SCP NFB (n=19). NFB training for both groups consisted of 30 60-minute sessions divided into 3 2-week phases of 10-session each separated by a</p>	<p>1) Both NFB groups learned how to intentionally regulate cortical activity consistent with their training and significantly improved in attention and IQ. 2) Parents and teachers reported significant behavioral and cognitive improvements for the children in both NFB groups. 3) The NFB groups did not differ in behavioral or cognitive outcomes. 4) The clinical effects for both NFB groups remained stable six months after</p>

	<p>4 to 6 week break for home practice. For both groups, 23% of the NFB sessions were spent on transfer trials in which the subjects attempted to activate the targeted EEG via self-regulation only without real-time feedback and only learned if they were successful after the end of the transfer trial. Both groups also were taught transfer exercises to practice at home during the four to six week breaks between the first two blocks of 10 NFB sessions. The children were taught how to use their self-regulation strategies for EEG activation in everyday life situations especially in problematic ones such as doing homework or in school where sustained attention and concentration are required. The home training exercises included the use of memory aids. During the third block of 10 sessions, the subjects practiced exercising activation while doing their homework at the end of each NFB session under the supervision of the NFB trainer. Three booster sessions were also administered as part of the 6-month and 2-year follow-up assessments and used to calculate EEG self-regulation skills. Outcome measures included parent and teacher ratings of ADHD symptoms (DSM questionnaire for ADHD; Eyberg Child Behavior Inventory; CPRS, and CTRS), IQ (WISC), and for the SCP NFB group, SCP amplitude during activation and deactivation tasks; and for the theta/beta group the theta/beta ratio during activation and deactivation tasks.</p>	<p>treatment termination.</p> <p>5) In the 2-year follow-up, all improvements in behavior and attention that had been observed at previous assessments remained stable with further significant reductions in the number of reported problems and significant improvement in attention.</p> <p>6) EEG-self regulation skills were maintained for the children in both groups when reassessed 2 years after NFB treatment ended.</p> <p>7) In each NFB group, half of the children no longer met the criteria for ADHD and only 22% were taking medication for ADHD.</p> <p>8) The authors concluded that, "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."</p>
Holtmann et al, 2009 ⁶⁰	<p>34 ADHD children, age 7 to 12, were randomly assigned on a 3:2 ratio basis to receive either 20 theta/beta NFB sessions (N=20) or 20 sessions of Captain's Log (N=14), a cognitive training software program. All children also received a 2-week intensive behavioral day clinic, weekly parent</p>	<p>1) Only NFB resulted in normalization of a key neurophysiologic correlates of response inhibition.</p> <p>2) Only NFB resulted in a significant reduction in impulsivity errors on the Stop-Signal test.</p> <p>3) There were no differential effects on parent ratings.</p> <p>4) The combination of both groups receiving intensive all-day behavior therapy</p>

	training, and 79% were on medication for their ADHD. Outcome measures included pre/post change on Stop-Signal test, a neurophysiologic measure of response inhibition (Go/NoGo-N2), and the parent-rated SNAP-IV.	and 79% of the children being on medication may have attenuated the ability to show differences between treatment groups on the parent ratings.
Gevensleben et al., 2009a ⁴⁸ ; 2009b ⁵⁰ ; Wangler et al, 2011 ⁷² ; Gevensleben et al., 2010 for 6-month follow-up ⁶⁴	102 ADHD children , age 8 to 12, were randomly assigned on a 3:2 ratio basis to receive either 36 sessions of NFB or 36 sessions of Skillies, an award-winning German cognitive training software program. The 62 NFB children were further randomized to receive first either a block of 18 theta/beta training sessions OR 18 slow cortical potential (SCP) training sessions and to switch protocols for the second block of 18 NFB sessions. Outcome measures were German rating scales (FBB-HKS and FBB-SSV) blindly administered to teachers and parents at baseline, after 18, and 36 sessions. Pre/Post changes in EEG were assessed along with 6-month follow-up data for the two-thirds of children who had not dropped out or started some other treatment.	<p>1) Only NFB produced significant changes in EEG and these changes were specific to each form of NFB training and furthermore, were associated with improvements on the ADHD rating scales.</p> <p>2) On the parent and teacher rating scales, improvements in the NFB group were superior to the Skillies group for reducing:</p> <ul style="list-style-type: none"> • Overall ADHD symptoms ($p < .005$ & $p < .01$, both respectively) • Inattention ($p < .005$ & $p < .05$, both respectively) • Hyperactivity/Impulsivity ($p < .05$ & $p < .1$, both respectively) • Oppositional Behavior ($p < .05$, parent rating only) Delinquent & Physical Aggression ($p < .05$, parent rating only). <p>3) No significant differences in effects were found between the two NFB protocols (theta/beta training & SCP training).</p> <p>4) Overall, at the 6-month follow-up the NFB group continued their improvements compared to the Skillies group.</p> <p>5) Finally, as only 50% of the NFB group was classified as treatment responders, the authors concluded that “<i>though treatment effects appear to be limited, the results confirm the notion that NFB is a clinically efficacious module in the treatment of children with ADHD.</i>”</p>
Bakhshayesh et al, 2011 ⁶¹	35 ADHD children , age 6 to 14, were randomly assigned to receive either 30 theta/beta NFB sessions (N=18) or 30 sessions of electromyography (EMG) biofeedback (N=17). Single-blinded RCT. Outcome measures included pre/post change on parent and teacher ratings using the FBB-HKS; CPT; The bp and d2 attention tests; and changes in the theta/beta ratio and EMG amplitude.	<p>1) Training effectively reduced theta/beta ratios and EMG levels in the NF and BF groups, respectively.</p> <p>2) Compared to EMG biofeedback, NFB significantly reduced inattention symptoms on the parent rating scale and reaction time and concentration on the neuropsychological measures.</p> <p>3) While children in both groups made significant improvements on most measures thereby making it difficult with such a small N for NFB to separate from EMG biofeedback, in ALL 11 outcome measures (and subscales thereof), the level of improvement was greater for NFB and a non-parametric binomial test would find this highly significant.</p> <p>4) Besides lowering muscular tension, EMG biofeedback teaches attention, which may further reduce the difference in outcomes.</p>

<p>Duric et al, 2012⁶²</p>	<p>130 ADHD children and adolescents, ages 6 to 18, were randomly assigned to receive either 1) NFB, 2) methylphenidate, or 2) combined NFB/medication. After randomization 39 dropped out (36 immediately after randomization) 13 from the NFB group, 15 from the medication group, 11 from the combined group resulting in 91 completing the study; NFB (n=30), methylphenidate (n=31), and combined (n=30). The NFB group received 30 40-minute theta/beta sessions 3 times per week for 10 weeks. The subjects in the medication and combined group took methylphenidate) twice per day at the recommended dose of 1 mg per kg with the final medication doses from 20 to 60 mg daily. Outcome measures were the inattention and hyperactivity subscales of the parent-rated CMADBD-P (& total score) with the post ADBD-P administered one week after the final NFB session for those in the NFB and combined groups.</p>	<p>1) The parents reported highly significant effects of the treatments in reducing the core symptoms of ADHD, but no significant differences between the treatment groups were observed.</p> <p>2) Although not significant, the NFB group showed more than double the pre-post change in attention compared with the other two treatments (3.1 vs. 1.1 and 1.5 for the means) and NFB’s effect size was larger than the other two treatments on both the inattention and hyperactivity subscales and total score measures.</p> <p>3) The authors conclude that, <i>“NFB produced a significant improvement in the core symptoms of ADHD, which was equivalent to the effects produced by methylphenidate, based on parental reports. This supports the use of NFB as an alternative therapy for children and adolescents with ADHD.”</i></p>
---------------------------------------	--	---

Abbreviations

Behavior Rating Scales	Tests of Attention	Tests of Intelligence
<p>ADDES=Attention Deficit Disorder Evaluation Scale BRIEF=Behavior Rating Inventory for Executive Function CBRS=Conners Behavior Rating Scale CMADBD-P=Clinician’s Manual for the Assessment of Disruptive Behavior Disorders – Rating Scale for Parents CPRS= Conners Parent Rating Scale CTRS=Conners Teacher Rating Scale FBB-HKS=German Rating Scale for ADHD FBB-SSV=German Rating Scale for Oppositional Defiant/Conduct Disorders</p>	<p>CPT=Continuous Performance Test IVA=Integrated Visual and Auditory continuous performance task TOVA=Test of Variables of Attention TAP=Test for Attentional Performance; TEA-ch</p>	<p>WISC=Wechsler Intelligence Scale for Children</p>