Appl Psychophysiol Biofeedback (2007) 32:73–88
DOI 10.1007/s10484-007-9031-0

ORIGINAL PAPER

Neurofeedback for Children with ADHD: A Comparison of SCP and Theta/Beta Protocols

Ulrike Leins · Gabriella Goth · Thilo Hinterberger · Christoph Klinger · Nicola Rumpf · Ute Strehl

Abstract 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.

U. Leins (✉)
Department of Psychiatry and Psychotherapy, University Hospital of Tübingen,
Osianderstrasse 24,
72076 Tübingen, Germany
e-mail: Ulrike.leins@med.uni-tuebingen.de

G. Goth · T. Hinterberger · C. Klinger · N. Rumpf · U. Strehl
Institute of Medical Psychology and Behavioral Neurobiology,
University of Tübingen,
Tübingen, Germany

Keywords ADHD · Neurofeedback · Slow cortical potentials · Theta-Beta · Self-regulation

Introduction

ADHD is one of the most common childhood disorders with a cumulative incidence of 7.5% by 19 years of age (Barbaresi et al., 2004). The effects of pharmacological and behavioral approaches to treat ADHD have been criticized as being limited, especially regarding long term effects (Beelmann & Schneider, 2003; Döpfner & Lehmkuhl, 2002).

The percentage of children diagnosed with ADHD who are treated with stimulants is about 86.5% for “definite” ADHD and 40.0% for “probable” ADHD (Barbaresi et al., 2002). Stimulants work quickly and, in about 70% off all children, they improve attention and reduce hyperactivity and impulsivity (Conners, 2002; Wagner, 2002). However, the effects on academic achievement, family relations and the childrens social life are small (Conners, 2002; Spencer et al., 1996). Long term benefits of pharmacotherapy for ADHD have not been established (Goldman, Genel, Bezman, & Slanetz, 1998; Spencer, Biederman, Wilens, & Faraone, 2002). Several concerns regarding side effects, e.g., reduced growth (MTA Cooperative Group, 2004), sleep disorders and several vegetative disturbances (Schachter, Pham, King, Langford, & Moher, 2001) may contribute to decreased compliance in both patients and parents.

Behavioral therapy has been demonstrated to reduce symptoms of ADHD (Döpfner & Lehmkuhl, 2002). However, a significant number of children exhibit even after behavioral interventions ADHD-symptoms and the long term efficacy has been characterized as marginal (Döpfner & Lehmkuhl, 2002). The limitations of pharmacotherapy and behavioral therapy underscore the need for alternative and/or complementary therapies for ADHD with long-lasting effects and minimal side effects. Neurofeedback appears to be such a promising alternative, as reduced behavioral ADHD-symptoms and improved cognitive variables have been consistently reported in the literature after neurofeedback-treatment.

The primary symptoms of ADHD—inattentiveness, impulsiveness, and hyperactivity—are ensured to be the result of pathological neurophysiology and are reflected in specific electrophysiological patterns. The spontaneous EEG activity of children with ADHD is characterized by increased Theta and decreased Alpha and Beta (Monastra et al., 1999; Monastra & Lubar, 2001). Event-related potentials, particularly the P 300, are marked by decreased amplitudes and prolonged latencies (Johnstone, Barry, & Anderson, 2001; Satterfield, Schell, & Nicholas, 1994).

One special type of event-related potentials are slow cortical potentials (SCPs). SCPs are slow DC-shifts of the EEG that reflect the excitation threshold of large cortical cell assemblies: SCP shifts in the electrical negative direction indicate a reduction of the excitation threshold, whereas shifts in the electrical positive direction reflect an increase of the excitation threshold (Rockstroh, Elbert, Canavan, Lutzenberger, & Birbaumer, 1989). Rockstroh, Elbert, Lutzenberger, and Birbaumer (1990) found that children with attentional problems had an impaired ability to regulate their SCPs.

The first neurofeedback studies in ADHD were conducted in the mid 1970s (Lubar & Shouse, 1976; Shouse & Lubar, 1979). Currently, there are about 20 published studies reporting the effects of neurofeedback treatment for children with ADHD. As Vernon, Frick, and Gruzelier (2004) summarize, there are three main neurofeedback parameters utilised for children with ADHD, which include training in decreasing power of Theta (4–8 Hz) and increasing power of Beta (15–20 Hz) and increasing power of the sensorimotor rhythm (SMR, 12–15 Hz). The majority of research groups combine two or more treatment parameters, e.g., inhibiting Theta and enhancing Beta (Lubar, Swartwood, Swartwood, & O'Donnell, 1995) or inhibiting Theta, enhancing Beta and enhancing SMR (Alhambra, Fowler, & Alhambra, 1995). There are only two studies that trained self regulation of SCPs (Heinrich, 2004; Strehl, Leins, Goth, Klinger, & Birbaumer, 2006).

The results of studies that aim at self-regulation of Theta, Beta and/or SMR consistently suggest that neurofeedback treatment reduces ADHD symptoms. Cognitive measures improve, e.g., variables of attention and intelligence (e.g., Alhambra et al., 1995; Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Monastra, Monastra, & George, 2002). Parents and teacher report behavioral improvements in everyday life, such as decreased impulsivity, hyperactivity and distractibility (Fuchs et al., 2003; Monastra et al., 2002). Alhambra et al. (1995) demonstrated a reduction or discontinuation of stimulant medications. Post-analysis of QEEG reveal changes in treatment parameters (e.g., Monastra et al., 2002). Monastra et al. (2005) summarized that significant clinical improvement was reported in nearly 75% of the patients treated with neurofeedback. No study has reported negative side effects following neurofeedback treatment. Research groups that used SCPs as treatment parameters report a significant reduction of ADHD-symptoms and improved attentional variables (Heinrich, 2004; Strehl et al., 2006). In addition Heinrich (2004) reported a marked CNV (Contingent Negative Variation) increase. Strehl et al. (2006) examined EEG during SCP-treatment. The results indicate that children with ADHD are able to control SCPs and that this ability remains stable six months after treatment.

Despite of these promising results, neurofeedback treatment is not yet accepted as standard therapy for children with ADHD. This is due to several methodological problems that question the reported positive effects of neurofeedback treatment on children with ADHD: First of all, there is a lack of adequate controls and a failure to control for possible confounds, such as the trainer-patient-interaction. Consequently, there is no evidence to show that the positive effects attributed to neurofeedback are a specific consequence of the manipulation of the electrophysiological variables. Second, follow-ups are missing to examine long-term effects. Third, the follow-up data are incomplete, e.g., EEG-data and information about academic performance are absent (Othmer, Othmer, & Clifford, 1991). Vernon, Frick, and Gruzelier (2004) summarize, that "at this moment evidence for the long-term efficacy of neurofeedback remains equivocal." Fourth, many neurofeedback studies comprise small sample sizes, e.g., Lubar and Shouse (1976, $N = 1$), Shouse and Lubar (1979), Tansey and Bruner (1983) and Lubar and Lubar (1984). It is unclear which parameters were used to choose Theta, Beta or SMR or their combination. Information regarding the differential effects on different ADHD-subtypes are missing. It remains unclear if one treatment protocol is more effective than another and if different protocols for different subtypes should be used. Comparison studies of Neurofeedback with behavior therapy do not exist. Only a few studies compared Neurofeedback with drug treatment (Fuchs et al., 2003; Monastra et al., 2002; Rossiter & La Vaque, 1995).

In this study we randomly assigned children diagnosed with ADHD into SCP or Theta/Beta-therapy. This is the first study that compares the effects of SCP-treatment and Theta-Beta-treatment. Confounding variables, such as parental expectancies regarding therapy, parental satisfaction with therapy, and parenting style were assessed. A comprehensive diagnostic assessment that included subjective and objective information from teachers and parents (b) confounding variables (see above), (c) changes in cognition and behavior at

Table 1 Diagnostic instruments and outcome measures

Instrument	Assessment	Diagnostic purpose
Parents		
Semi structured questionnaire to assess developmental and health history of the child.	t0	B
DSM-IV—questionnaires for parents to assess DSM-IV-criteria for ADHD.	t0, t1, t2	B, O
Eyberg Child Behavior Inventory (Eyberg & Pincus, 1999) measures frequency of problems at home on a 7-point-rating-scale (1 = never, 7 = very often) and their impact on a dichotomous scale (yes vs. no).	t0, t1, t2	B, O
German Translation of Conners' Rating Scale (Conners, 1997). Parents rate several behavioral aspects of their child (e.g., affect, hyperactivity, aggression) during three days on a 3-point-rating scale from (0 = not at all, 3 = very often, very).	t0, t1, t2	B, O
Questionnaire to assess parenting style, German version (Miller, 2000).	t0, t1, t2	B, C
7-point rating scale (0 to 6) to assess the parental satisfaction with therapy. These measures were recorded anonymously.	last day of each treatment phase	C
7-point rating scale (0 to 6) to assess the parental expectancies towards the therapy. These measures were recorded anonymously.	first day of each treatment phase	C
Teacher		
DSM-IV—questionnaires for teachers to asses DSM-IV-criteria for ADHD.	t0, t1, t2	B, O
Child		
Testbatterie zur Aufmerksamkeitsprüfung, Version 1.7 (Zimmermann & Fimm, 1997)—a computerized test battery that measures several aspects of attention.	t0, t1, t2	B, O
Wechsler Intelligence Scale for Children: Hamburg-Wechsler-Intelligenztest für Kinder HAWIK-III; (Tewes, Rossmann, & Schallberger, 1999). To avoid retest-effects, we conducted the HAWIK-III only at t0 and t2. Retest-interval between t0 and t2 was between 9 and 10 months (interval between t0 and t1: 3 to 4 months, interval between t1 and t2: 6 months).	t0, t2	B, O

Note. Assessment: t0: baseline, t1: end of the treatment, i.e. after the 30th session, t2: follow-up 6 month after the end of treatment. Diagnostic purpose: B: baseline, O: evaluation of outcome, C: evaluation of confounding variables.

the end of the treatment and six months later, and (d) EEG-data during course of treatment and during follow-up were measured.

Strehl et al. (2006) reported on the SCP-therapy of the present neurofeedback-study. In this paper results from *both* treatments—SCP and Theta/Beta—are reported. Some patients of the SCP-group from Strehl et al. (2006) are identical with patients of the SCP-group of this report.

This study aimed at answering following questions: First, whether patients were able to demonstrate learning of cortical self-regulation. Second, if treatment leads to an improvement in cognition (i.e., attention, intelligence) and behavior (i.e., hyperactivity, impulsivity). Third, if the two experimental groups differ in cognitive and behavioral outcome variables and fourth, if they differ in the stability of cortical self regulation and clinical effects.

Methods

Participants

Participants were children aged 8 to 13 years, who had

(a) Attention Deficit Disorder inattentive type or hyperactive type or combined type according to the DSM IV criteria
(b) no additional neurological or psychiatric disorder and
(c) a full-scale IQ $>$ 80.

Participants were recruited from the outpatient clinic for psychotherapy of the university and from local psychiatric practicing physicians and psychologists.

Participants of both groups were blind to group assignment and assessment. Instruments used for diagnosis and evaluation of outcome are shown in Table 1.

The study was conducted according to the convention of Helsinki and approved by Ethics Committee of the Faculty of Medicine of the University of Tuebingen.

Groups were matched regarding age, sex, IQ, diagnosis and medication (see Table 2). Success of matching was examined with an independent samples t-test (age: $t[36]$, p = 1,000, full scale IQ: $t[36]$, p = .642).

Neurofeedback

The training was introduced as a computer game in which one can get points by using one's brain. Participants were advised to be attentive to the feedback and to find the most successful mental strategy to get as much points as possible. No specific instruction was given. Participants were only told that the aim of training is to "speed" up their brain in order to improve certain abilities, such as

Table 2 Demographic and initial assessment information by treatment group

	Theta/Beta-group	SCP-group
Age		
Mean	9.16	9.16
Range	8–12	8–13
SD	1.46	1.53
Sex		
Boys	16	16
Girls	3	3
IQ		
Full Scale IQ		
Mean	100.31	101.78
Range	82–113	85–123
SD	7.98	11.15
Verbal-IQ		
Mean	104.10	107.57
Range	92–127	87–140
SD	9.60	13.492
Performance-IQ		
Mean	96.94	95.63
Range	71–117	81–118
SD	10.99	12.42
Diagnosis		
ADHS	15	15
ADS	4	4
Comorbidity	2 (1 emotional disorder, 1 eunresis)	7 (4 learning disorders, 1 enuresis, 1 coordination disorder)
Medication	1 (Ritalin, 28 mg per day)	1 (Ritalin, 28 mg per day)

concentration, that are necessary for doing their homework or exams.

Participants in both groups were placed 50 in. from a notebook in a comfortable chair. As shown in Fig. 1, participants saw one rectangle on the top and one at the bottom of the screen. Dependent upon which of the two rectangles was highlighted, the participant was requested to either "activate" or "deactivate" the brain (see Fig. 1).

Participants of both groups received feedback about their brain activity by a moving yellow ball (Fig. 1). During each trial, the ball (cursor) moved from the left corner of the screen to the right corner. Successful trials were rewarded by a smiley face that appeared at the end of the trial (Fig. 1). Unsuccessful trials were indicated by a black screen at the end of the trial. If a trial was invalid, e.g., because of eye movements, a red cross appeared after the end of the trial (Fig. 1).

As feedback-program an application of the Thought Translation Device, TTD (Hinterberger et al., 2000) was used. The TTD-software was custom-built at the Institute of Medical Psychology and Behavioral Neurobiology (University of Tuebingen) for research purpose. The feedback-program was controlled by a computer that was connected with an EEG-amplifier (EEG 8, Contact Precision Instruments).

All patients received additional auditory feedback. This was given with a tone that varied in pitch. A harmonious jingle was introduced as positive reinforcement. After each session the total number of smiley faces was exchanged for tokens. Participants collected these tokens and exchanged them for small gifts, e.g., books or toys.

Participants were trained in 3 treatment phases with a break of 4 to 6 weeks between each phase. A phase comprised two weeks and consisted of 10 sessions. One session lasted about 1 hr—preparation time included—and consisted of four runs with 38 trials. According to the participants demands short breaks were made between the trials.

In session 1 to 15, trials with required activation and deactivation were randomly distributed and comprised 50% of all trials. In sessions 16 to 33, the proportion of activation to deactivation trials changed to 75%/25% in favor to activation.

In order to help the regulatory skills generalizing to everyday life situations transfer trials and transfer exercises were included. During the treatment, 23% of all trials were so called transfer trials. In these trails no cursor was shown and no tone was given during the active phase. At the end of each of these trials, participants were informed by the smiley face and the jingle whether or not the trial was successful. Transfer exercises were done (1) in the weeks between the treatment

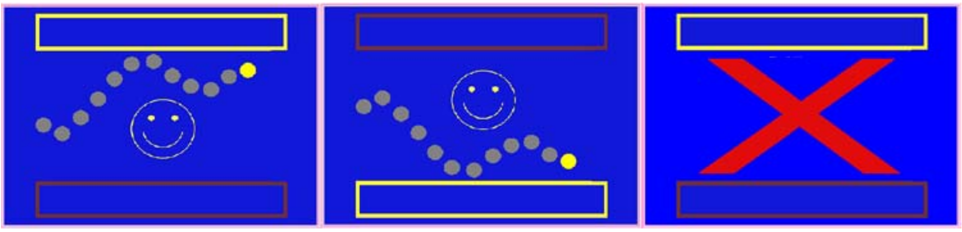


Fig. 1 Feedback-screen: (*left*) smiley face at the end of a successful *activation* trial; (*middle*) smiley face at the end of a successful *deactivation* trial, (*left*) red cross at the end of an *invalid* trial

phases 1 and 2, between the treatment phases 2 and 3 and (2) in the third treatment phase. Participants were instructed to use their strategies for *activation* in everyday life situations. As a memory aid, a 15 × 5 in. picture of a computer screen with ball and goal box (see Fig. 1, left and middle graph) was given to each child. Children were instructed to produce the "activation" especially in problem situations, e.g. doing the homework, in which attention and endurance are required. In the third treatment phase children exercised activation while doing their homework after the end of each training session under the supervision of the trainer. The trainer guided the child only in using the activation-strategy and did not assist in solving the particular cognitive tasks.

Treatment and assessment procedures were implemented either by a licensed clinical psychologist or by graduate students under the psychologist's supervision.

SCP-treatment

SCPs were recorded at Cz. To calculate the feedback-signal, the Cz-signal was referenced against the two mastoids and averaged.

For detailed information about signal processing and artifact correction see Strehl et al. (2006), Hinterberger et al. (2004) and Kotchoubey, Blankenhorn, Fröscher, Strehl, and Birbaumer (1997).

One SCP-trial lasted 8 seconds and consisted of three phases (see Fig. 2): A baseline phase (seconds 0–2), an active phase (seconds 2–7.5) and a reinforcement phase (seconds 7.5–8). At the end of the baseline phase, participants were cued by a highlighted upper rectangle to "activate" their brain and by a highlighted lower rectangle to "deactivate" their brain. "Activation" in the SCP-group meant to produce a SCP-shift in the electrically negative direction, "deactivation" means to produce a SCP-shift in the electrically positive direction. The vertical movement of the ball reflected the degree of the participants' SCP-shifts: The ball moved upwards as the result of a negative SCP-shift and downwards in the case of a positive SCP-shift. At the end of each trial the SCP-power of the whole trial was integrated and subtracted from the baseline. A trial was successful if the integrated electrical activity was—compared to the baseline—negative in activation tasks and positive in deactivation tasks respectively.

Theta/Beta-neurofeedback-treatment

Results from several studies support a frontal electrode position for a theta/beta-neurofeedbacktraining as they found more theta and less beta activity in frontal regions of patients with ADHD (Lubar et al., 1995; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992; Chabot & Serfontein, 1996). But, if electrodes are fixed frontally, there is a risk of artefacts caused by eye movements. A possibility to minimize this risk is to choose a more central electrode position. Besides, a central position for a theta/beta-neurofeedbacktraining is supported by results from a validation study of Monastra et al. (1999). He observed a significant increased theta/beta-ratio in children with ADHD aged 6–11 years. For those reasons electrodes in the Theta/Beta-group were placed at C3f (= halfway between C3 and F3) and C4f (= halfway between C4 and F4).

The Theta/Beta-feedback-signal was calculated by referencing the averaged Theta/Beta-ratio, recorded at C3f and C4f, against the averaged ratio, recorded at the mastoids (A1, A2). Hence, training was done with an unipolar EEG-recording.

As Theta- and Beta-frequencies fluctuate more than the SCPs, baseline and feedback phases were extended. At the beginning of each treatment session, a "pre-baseline" was taken, lasting 8 s. One Theta/Beta-trial lasted 10 s (see Fig. 3)

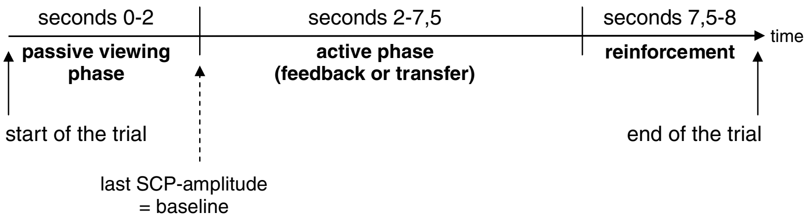


Fig. 2 Trial structure, SCP-group

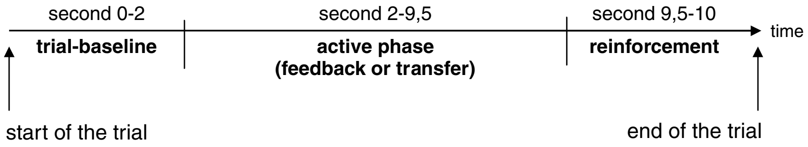


Fig. 3 Trial structure, Theta/Beta-group

with a trial-baseline phase (seconds 0–2), a feedback phase (seconds 2–9.5) and a reinforcement phase (seconds 9.5–10). The Theta/Beta-ratio, measured during the pre-baseline and the ratio, measured during the trial-baseline were integrated, resulting in an "overall-baseline-ratio," which was used as reference for the first trial. With ongoing treatment this reference was updated by each new trial-baseline-ratio.

During activation-tasks participants had to decrease the Theta/Beta-ratio, i.e., to decrease the power in the Theta-band and/or to increase the power in the Beta-band. In deactivation-tasks participants had to decrease the Theta/Beta-ratio. The vertical direction of the feedback ball reflected the participants Theta/Beta-ratio: The ball moved upwards in case of a decreasing ratio and downwards in case of an increasing ratio. At the end of each trial the Theta/Beta-ratio of the active phase was averaged and subtracted from the overall-baseline-ratio. A trial was successful if the averaged ratio was—compared to the overall-baseline-ratio—lower in activation tasks and higher in deactivation tasks respectively.

As electrode placement and trial construction differed between groups, therapists could differentiate between them. This means they were not blind and knew which child participated in which group.

Data analysis

EEG-data

EEG-data were analyzed to determine

(a) if participants of both treatment groups were able to differentiate between activation- and deactivation tasks at the beginning of treatment (sessions 2 + 3), at the end of treatment (sessions 29 + 30) and at follow-up (sessions 32 + 33),
(b) if the difference between activation- and deactivation tasks changed during treatment, i.e., between the beginning of treatment (sessions 2 + 3), the end of treatment (sessions 29 + 30) and follow-up (sessions 32 + 33), and
(c) if the power of SCP-amplitudes and Theta/Beta-ratios respectively changed in activation and deactivation tasks during treatment, i.e., between the beginning of treatment (sessions 2 + 3), the end of treatment (sessions 29 + 30) and the follow-up (sessions 32 + 33).

Session 1 and session 31 were discarded as habituation sessions.

SCP-group

SCP-amplitudes were calculated for both tasks (activation/deactivation), conditions (feedback/transfer) and the three assessment points (sessions 2 + 3, sessions 29 + 30, sessions 32 + 33). After testing for normal distribution of SCP-amplitudes, the differences between SCP-amplitudes in activation and deactivation tasks were analyzed separately for each assessment point with an independent samples *t*-test (Kirley et al., 2002). Whether the difference of SCP-amplitudes between activation and deactivation tasks changed over time (Kirley et al., 2002) was analyzed by an ANOVA with repeated measures. The ANOVA was computed for both feedback and transfer conditions. In case of a significant result, post-hoc paired samples *t*-tests compared the three assessment-times separately. The change of SCP-amplitudes during the treatment (Kirley et al., 2002) was examined by an ANOVA with repeated measures, computed for both tasks (activation/deactivation) and both conditions (feedback/transfer). In case of a significant result, post-hoc paired samples t-tests compared the three assessment-times separately.

Theta/Beta-group

Because of the above mentioned special features of baseline computation, EEG-data-analysis of the Theta/Beta-group differed from the analysis of the SCP-group. The difference between the baseline ratio and the ratio during the feedback phase was computed for each participant, for both tasks (activation/deactivation), both conditions (feedback/transfer) and the three assessment points (sessions 2 + 3, sessions 29 + 30, sessions 32 + 33).

After testing for normal distribution of Theta/Beta-ratios the difference between the Theta/Beta-ratios measured during the activation-tasks and during the deactivation tasks was examined for activation and deactivation tasks separately for each assessment point with an independent samples *t*-test (Kirley et al., 2002). Whether the difference between ratios in activation tasks and deactivation tasks changed over time (Kirley et al., 2002) was analyzed in two steps: First, an ANOVA with repeated measures examined effects of time (sessions 2 + 3, sessions 29 + 30, sessions 32 + 33) and task (activation/deactivation) for for both conditions (feedback/transfer). Second, in case of a significant result, post-hoc paired samples tests compared measurement-times separately. The change of Theta/Beta-ratios during the treatment (Kirley et al., 2002) was examined by an ANOVA with repeated measures. ANOVA was computed for both tasks (activation/deactivation) and both conditions (feedback/transfer). In case of a significant result, post-hoc paired samples *t*-tests compared measurement-times separately.

Psychometric test data

After testing for normal distribution, all data of tests and questionnaires were examined with the same procedure: Effects of time (baseline, end of the treatment, follow-up) and group (SCP-group, Theta/Beta-group) were analyzed by an ANOVA with repeated measures. In case of a significant result, assessment points were compared separately with post-hoc paired samples *t*-tests.

ANOVA-results were corrected with Greenhouse-Geisser, post-hoc tests with Bonferoni. Effect sizes (ES) were calculated were assessed with Cohen's *d* (Cohen, 1988) for each significant result after correction with Bonferoni. Cohen's *d* is computed as the difference between the means, $M_1 - M_2$, divided by the pooled standard deviation $\sigma_{\text{pooled}} = \sqrt{[\sigma_1^2 - \sigma_2^2/2]}$.

Results

Self regulation of SCPs

Differences of SCP-amplitudes between activation and deactivation tasks

Differences between SCP-amplitudes in activation and deactivation tasks in the feedback condition were close to significance after Bonferoni-correction (see Fig. 4). Differences between SCP-amplitudes in activation and deactivation tasks were significant in the transfer condition at the end of the treatment (sessions 29 + 30) ($t[36] = 2.48, p = .036$, $ES = .81$) and at follow-up (sessions 32 + 33) ($t[30] = 2.55$, $p = .048$, $ES = .90$) as can bee seen in Fig. 5.

The difference between SCP-amplitudes in activation and deactivation tasks increased significantly over time (sessions 2 + 3, sessions 29 + 30, sessions 32 + 33) in feedback conditions ($F[2,60] = 5.08$, $p = .020$), but not in transfer conditions. Interaction between time × task was significant in both feedback conditions ($F[2,60] = 5.93, p = .012$) and transfer conditions ($F[2,60] = 4.37, p = .017$). Between-tasks effects (activation/deactivation) did not reach significance. A post-hoc paired samples test for the feedback condition showed that the difference between SCP-amplitudes of activation and deactivation tasks increased significantly between sessions 2 + 3 and sessions 29 + 30 ($t[18] = 3.51$, $p = .006, ES = 1.09$) as well as between sessions 2 + 3 and sessions 32 + 33 ($t[14] = 3.07, p = .016, ES = 1.05$).

SCP-amplitudes in activation and deactivation tasks

SCP-amplitudes in activation tasks changed significantly with time in feedback-conditions ($F[2,30] = 14.57, p < .001$) and transfer conditions ($F[2,30] = 6.90, p = .005$). Change of SCP-amplitudes in deactivation tasks in both conditions did not reach significance (see figure 4 + 5).

A post hoc paired samples test showed, that the SCP-amplitude in feedback conditions between sessions 2 + 3 and sessions 29 + 30 differed significantly ($t[18] = 3.67$, $p = .004$, $ES = 1.03$) as well as between sessions 2 + 3 and sessions 32 + 33 ($t[15] = 5.28$, $p < .001$, $ES = 1.07$). In transfer conditions there were significant

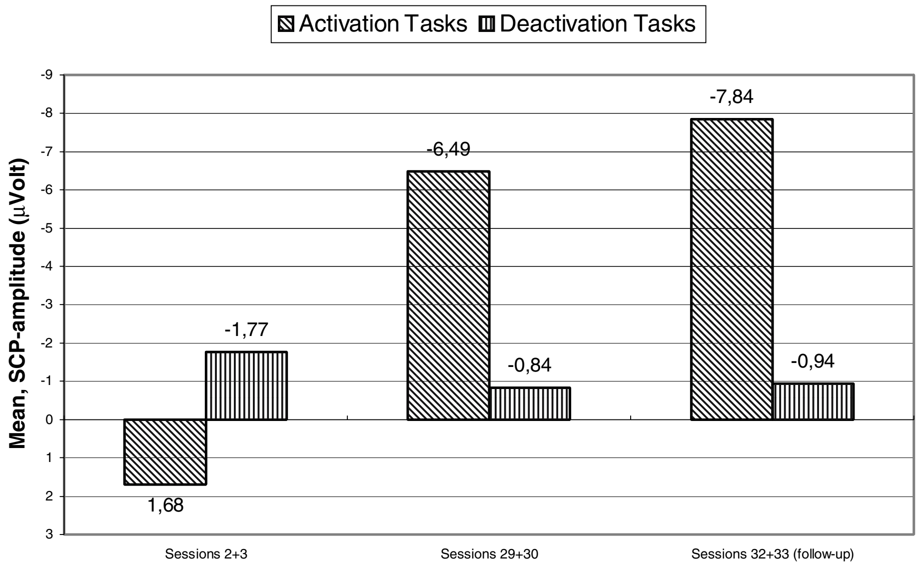
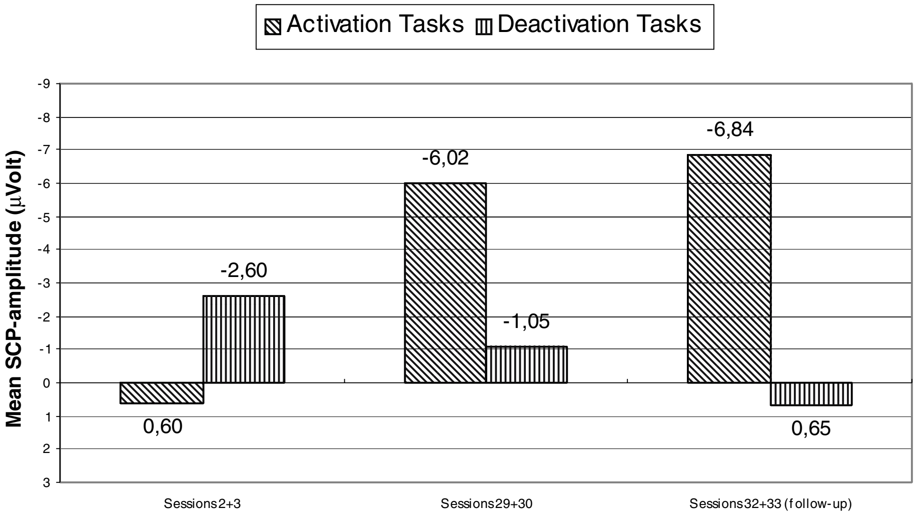


Fig. 4 SCP-group, mean amplitudes in negativity trials and positivity trials; feedback condition

Fig. 5 Mean amplitudes in negativity trials and positivity trials; transfer condition



shifts between sessions $2+3$ and sessions $29+30$ ($t[18] = 3.10$, $p = .012$, $ES = .98$) as well as between sessions $2+3$ and sessions $32+33$ ($t[15] = 24.13$, $p = .006$, $ES = 1.04$).

Self regulation of Theta/Beta

Differences of Theta/Beta-ratios between activation and deactivation tasks

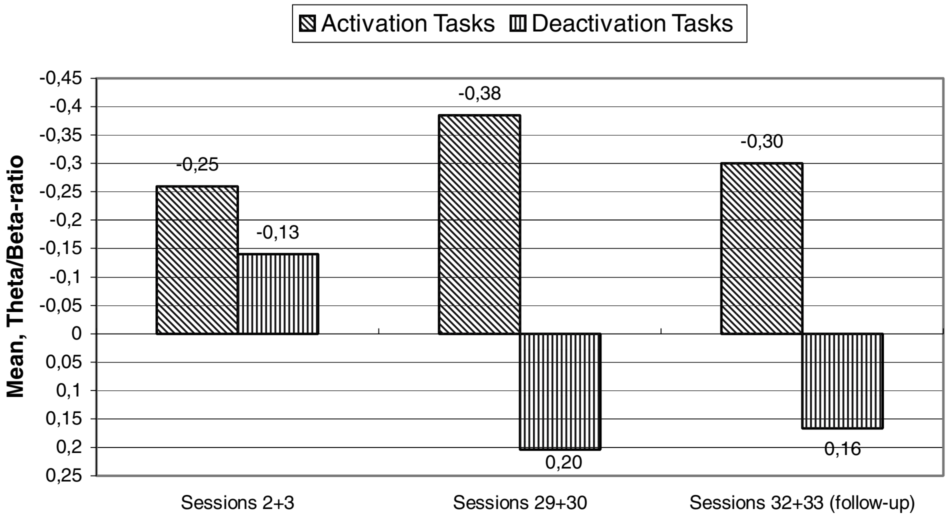
Differences between Theta/Beta-ratios in activation and deactivation tasks were significant at the end of treatment (sessions $29+30$) for the feedback ($t[36] = 4.224$, $p < .001$, $ES = 1.37$) and transfer condition ($t[36] = 3.003$, $p = .010$, $ES = 2.25$). Differences were also significant at follow-up (sessions $32+33$) for the feedback ($t[34] = 3.956$, $p < .001$, $ES = 1.32$) and transfer condition ($t[34] = 3.131$, $p = .012$, $ES = 1.04$). Interaction between time × task was significant for feedback condition ($F[2,68] = 7.19$, $p = .002$). Tests of between-tasks effects (activation/deactivation) reached significance for both feedback ($F[1,34] = 18.53$, $p < .001$) and transfer condition ($F[1,34] = 10.19$), $p = .003$) (see Figs. 6 and 7).

A post-hoc paired samples test for the feedback condition showed that the difference between Theta/Beta-ratios in activation and deactivation tasks increased significantly between sessions $2+3$ and sessions $29+30$ ($t[17] = 3.91$, $p = .003$, $ES = .96$) as well as between sessions $2+3$ and sessions $32+33$ ($t[15] = 2.94$, $p = .020$, $ES = .74$).

Theta/Beta-ratios in activation and deactivation tasks

Changes of mean Theta/Beta-ratios were computed separately for activation and deactivation tasks with a General Linear Model for repeated measures. Theta/Beta-ratios in deactivation tasks changed significantly over time for feedback-condition ($F[2,34] = 11.77$, $p < .001$), but not for transfer-condition. There was no change of Theta/Beta-ratios

Fig. 6 Theta/Beta-group, Theta/Beta-ratio in negativity trials and positivity trials; feedback condition



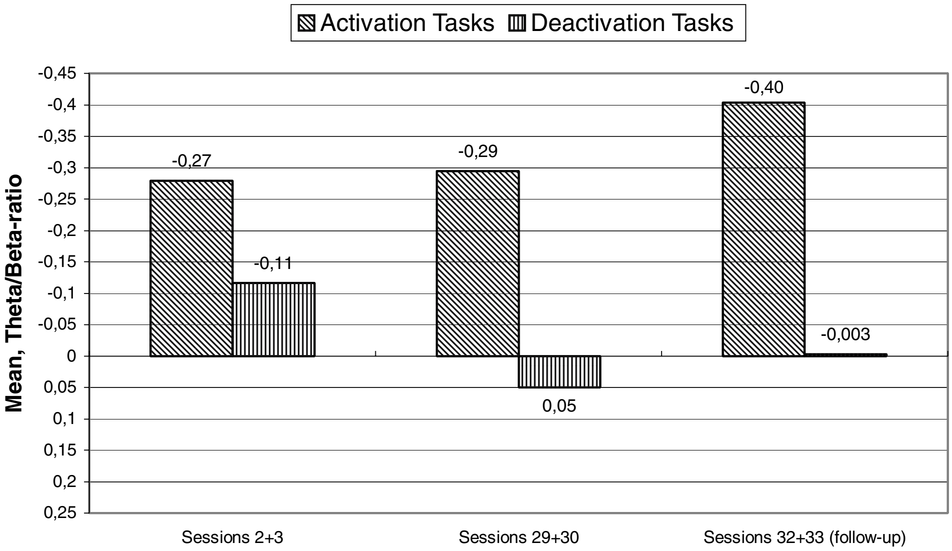


Fig. 7 Theta/Beta-group, Theta/Beta-ratio in negativity trials and positivity trials; transfer condition

in activation tasks in both conditions. A post hoc paired samples test for deactivation tasks in feedback conditions showed a significant increase of Theta/Beta-ratios between sessions $2+3$ and sessions $29+30$ ($t[18] = 4.03, p = .003$, $ES = 1.00$) and between sessions $2+3$ and sessions $32+33$ ($t[17] = 4.17, p = .002, ES = .90$) (see figure $6+7$).

Behavior

Parental ratings

According to parental ratings, DSM IV criteria were reduced significantly over time for both inattention ($F[2,68] = 9.15$, $p = .001$) and hyperactivity ($F[2,68] = 10.08, p < .001$). Interaction of group × time and difference between groups did not reach significance. Post-hoc paired samples tests result in significant changes only for the Theta/Beta-group: Attention improved between baseline and the end of treatment ($t[18] = 3.49$, $p = .009$, $ES = .80$) and between baseline and follow-up ($t[17] = 2.783$, $p = .026$, $ES = .78$). Hyperactivity decreased between baseline and the end of the treatment ($t[18] = 3.52$, $p = .006$, $ES = .34$) and between baseline and follow-up ($t[17] = 3.69$, $p = .002$, $ES = .61$). In both groups means for hyperactivity were below the cut-off-value of 6 at follow-up (SCP-group: 5.78; Theta/Beta-group: 5.28) (see Fig. 8).

Frequency of problems at home, as assessed by the Eyberg questionnaire, decreased significantly over time ($F[2,66] = 9.24$, $p = .001$). Both time × group interaction and difference between groups was not significant. A post-hoc paired samples test showed that the frequency of problems in the SCP-group decreased significantly between baseline and the end of the treatment ($t[18] = 2.84$, $p = .033$, $ES = .43$) and between baseline and follow-up ($t[17] = 2.48, p = .048, ES = .45$) (see Fig. 9).

Impact of problems at home, as assessed by the Eyberg questionnaire, decreased significantly over time ($F[2,66] = 4.83$, $p = .013$). There was no significant

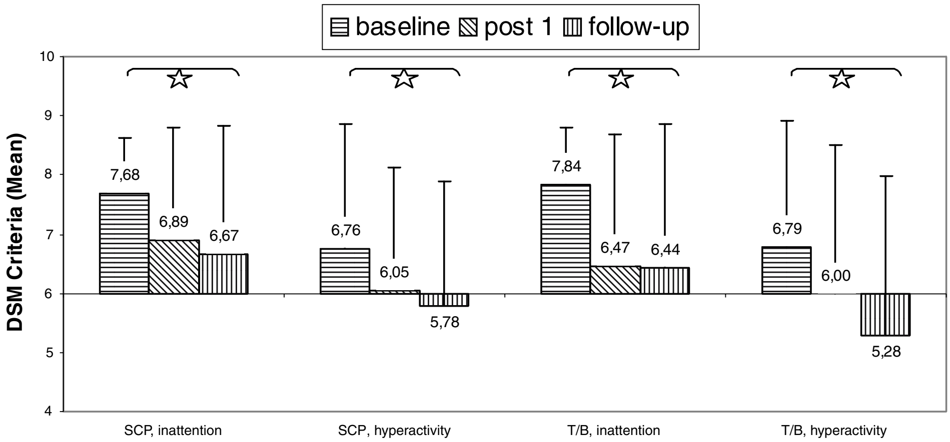
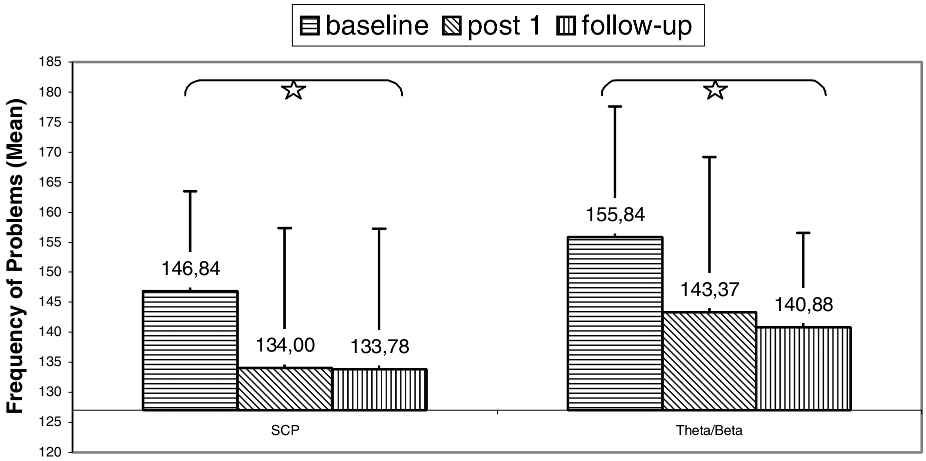


Fig. 8 DSM Criteria, Parents' ratings; scores below 6 are normal

Fig. 9 Frequency of problems, parents' ratings (Eyberg-Questionnaire); Scores below 127 are normal



time × group interaction and no significant difference between groups. Post-hoc paired samples test showed after Bonferoni-correction no significant change for both groups.

Scores of the Conners rating scale were significantly reduced over time ($F[2,62] = 7.75$, $p = .001$). There was no interaction of time × group and no difference between groups. As can be seen in Fig. 10, post-hoc paired samples test yielded a significant improvement in the Theta/Beta-group between baseline and follow-up ($t[16] = 3.45$, $p = .009$, $ES = 1.02$). At each assessment point, parents rated frequency of problems at three days in succession. Mean values of the SCP-group decreased from 17.6 (baseline) to 15.5 (end of the treatment) and 13.9 (follow-up). Mean values of the Theta/Beta-group decreased from 18.2 (baseline) to 16.7 (end of the treatment) an 12.2 (follow-up). Thus, mean values of both groups fell below the cut-off-value at follow-up (see Fig. 10).

Teacher ratings

Teacher ratings improved significant with time for the scales hyperactivity ($F[2,64] = 6.58$, $p = .003$), impulsivity ($F[2,64] = 5.43$, $p = .008$) and social behavior (Civelli, 1995) = 5.14, $p = .010$). There was no significant time × group interaction and no significant difference between groups. For hyperactivity, post-hoc paired samples tests yielded a significant improvement in the SCP-group from baseline to follow-up ($t[17] = 4.02$, $p = .003$, $ES = .56$) and in the Theta/Beta-group from post 1 to follow-up ($t[16] = 3.26$, $p = .015$, $ES = .50$). For impulsivity, post-hoc paired samples tests showed a significant improvement in the Theta/Beta-group, from post 1 to follow-up ($t[16] = 3.73$, $p = .006$, $ES = .56$). For social behavior, post-hoc paired samples tests showed a significant improvement in the SCP-group from baseline to follow-up ($t[17] = 3.25$, $p = .015$, $ES = .59$). Hyperactivity and impulsivity of the Theta/Beta-group deteriorate

Fig. 10 Frequency of problems, parents' ratings (Conners-Questionnaire); Scores below 45 are normal

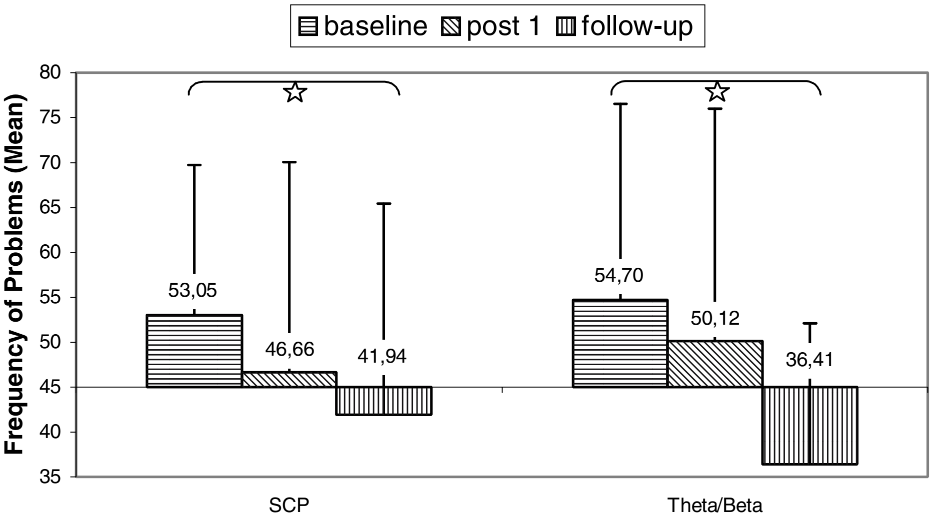
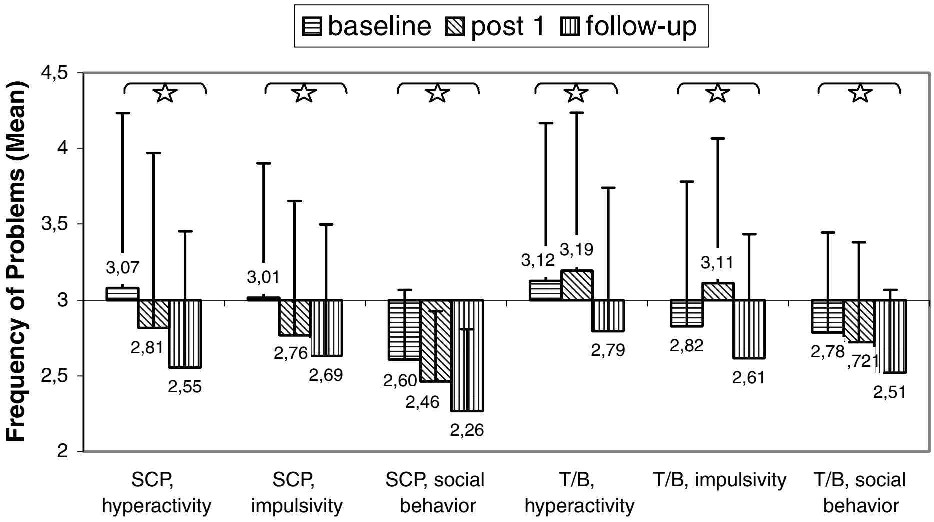


Fig. 11 Behavior, teacher ratings; scores below 3 are normal



from baseline to post 1, before they improve significantly between post 1 and follow-up. Results are presented in Fig. 11.

No significant changes between assessment points were found for inattention, emotionality and academic achievement.

Cognitive measures

IQ

IQ was assessed with HAWIK-III. To minimize retest-effects it was only administered at baseline and follow-up. As can be seen in Fig. 12, both full scale IQ and the performance IQ improved with time (performance IQ: $F[1{,}35] = 31.11$, $p = .002$; full scale IQ: $F[1{,}35] = 11.39, p = .002$). There was no time × group effect and no significant difference between groups. Post-hoc samples tests for the full scale IQ showed a significant improvement only for the Theta/Beta-group ($t[17] = 3.26, p = .015, ES = .62$). Post-hoc samples tests for the performance IQ showed a significant improvement for both groups (SCP: $t[18] = 3.24, p = .008$, $ES = .54$; Theta/Beta: $t[17] = 4.59, p < .001, ES = .82$).

Attention

Attention assessed with 7 subtests of the TAP. The TAP evaluates percent ranges for speed, omissions and commissions. To prevent an Alpha-fault the single test variables were combined to the frequency of results with a below-average achievement (below 25th percentile) and to the frequency of results with an above-average achievement (above 75th percentile). The changes of the number of below- and above-average achievements were analyzed with the General Linear Model for repeated measures and, in case of a significant result, with post-hoc paired samples tests. The number of below-average achievements decreased significantly over time ($F[2{,}68] = 20.10, p < .001$), whereas the number of above-average achievements increased significantly over time ($F[2{,}68] = 12.38$, $p < 001$). Post-hoc paired samples tests for below-average achievements yielded following results: The SCP-group improved significantly both from

Fig. 12 HAWIK-III, IQ

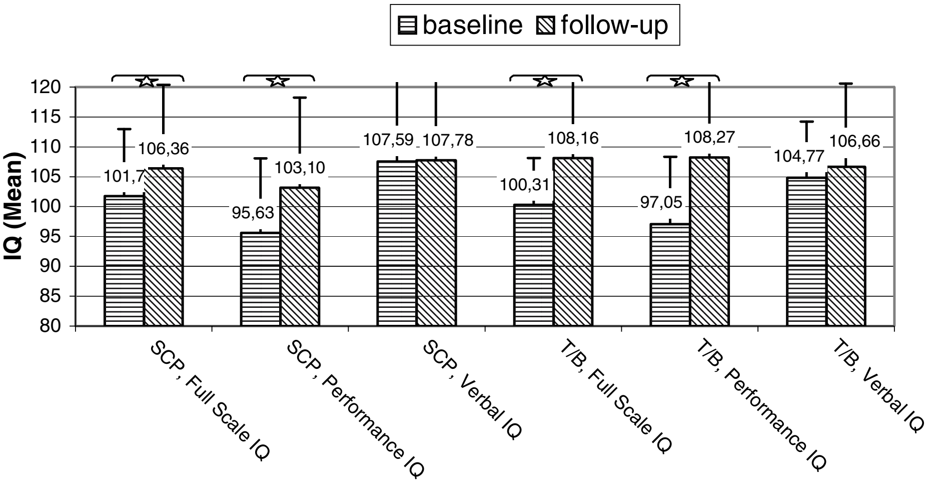
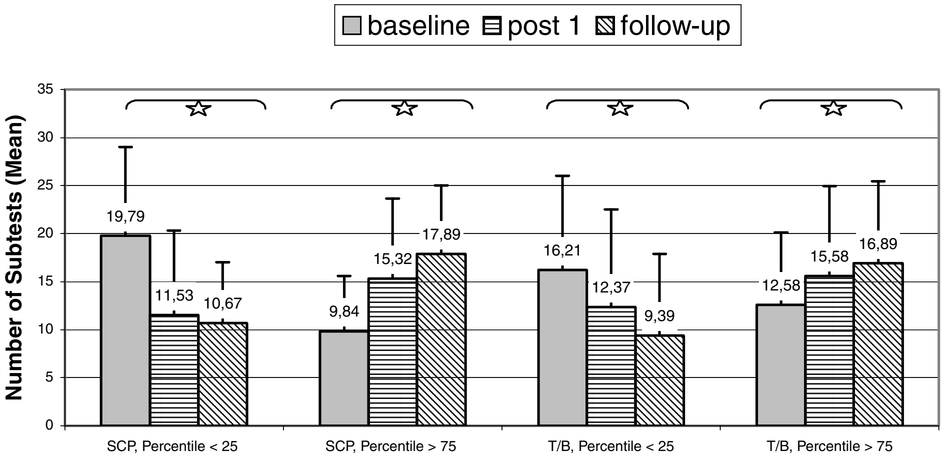


Fig. 13 TAP, Test of attention



baseline to post 1 ($t[18] = 5.20$ $p < .001$, $ES = .92$) and from baseline to follow-up ($t[17] = 6.09$, $p < .001$, $ES = 1.09$). The Theta/Beta-group improved significantly between baseline and follow-up ($t[17] = 3.03$, $p = .021$, $ES = .66$). Post-hoc paired samples tests for above-average achievements showed, that the SCP-group improved significantly between baseline and post 1 ($t[18] = 3.70, p = .004$, $ES = .77$) and post 1 and follow-up ($t[17] = 25.18$, $p < .001, ES = .119$). Results are presented in Fig. 13.

Confounding variables

Parenting style

Parenting style aimed at ensuring our diagnostic decision. As a dysfunctional parenting style may cause behavioral problems that can be misdiagnosed as ADHD-symptoms, the parenting style should always be considered in an ADHD-diagnostic-process. Changes of the parenting style throughout the treatment may influence the childrens behavior and therefore confound outcome variables.

The parenting style questionnaire assessed three different categories: indulgence, over-reaction and an average value. At baseline, mean values of both groups in all categories were below cut-off-values. As assessed with the General Linear Model for repeated measures, there were no effects of time, no time × group interaction and no difference between groups.

Parental expectancies and satisfaction with therapy

Parental ratings of expectancies ranged between 0 and 6 in both groups with a total mean of 4,078 (SCP-group) and 3,886 (Theta/Beta-group) respectively. Parental expectancies increased over time regarding improvements at school ($F[2,80] = 4.84$, $p = .012$), homework ($F[2,82] = 4.10$, $p = .020$), distractibility ($F[2,80] = 4.84$), $p = .011$) and attention ($F[2,80] = 3.19$, $p = .049$). Parental expectancies differed significantly between groups regarding childrens' behavior ($F[1,41] = 4.46$, $p = .041$), attention ($F[1,40] = 4.89, p = .033$) and homework ($F[1,41] = 5.98$, $p = .019$). In these categories parental expectancies of the SCP-group were stronger than those of the Theta/Beta-group. Post-hoc paired samples tests showed a significant increase of parental expectancies of the SCP-group regarding homework between the first and the third treatment phase

Fig. 14 Parental expectancies

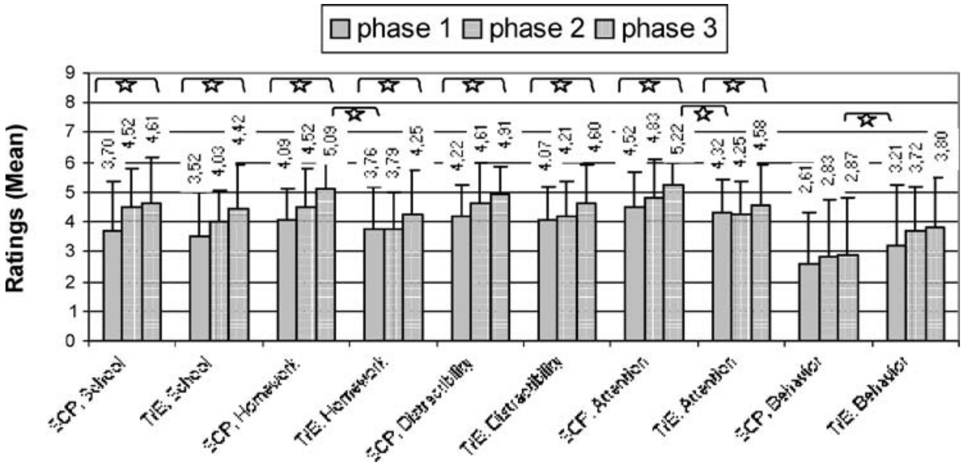
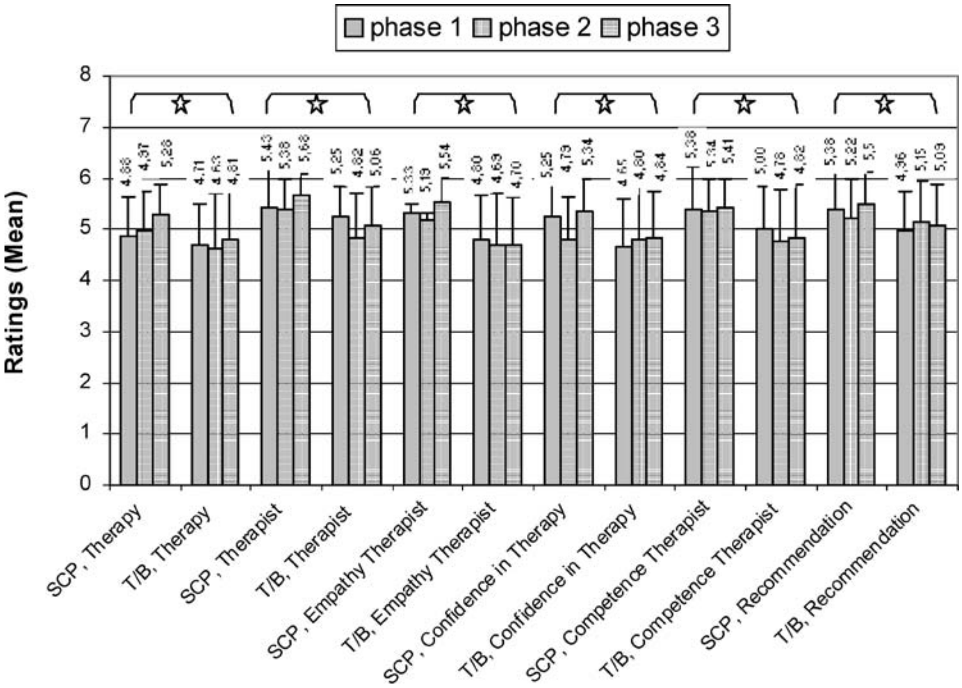


Fig. 15 Parental satisfaction



(t[22], $p = .006$, $ES = 1.03$). Changes over time and differences between groups can be seen in Fig. 14.

Parental ratings of satisfaction with therapy ranged between 3 and 6 (SCP-group) and 2 and 6 (Theta/Beta-group), with a total mean of 5,172 (SCP-group) and 4,849 (Theta/Beta-group) respectively. Parental satisfaction with the therapy gets stronger over time regarding the trainer (F[2,84] $= 3.36$, $p = .043$) and differed significantly between groups in all categories, i.e. satisfaction with therapy (F[1,42] $= 6.89$, $p = .012$), satisfaction with trainer (F[1,42] $= 17.92$, $p < .001$) empathy of trainer (F[1,41] $= 25.79$, $p < .001$), confidence in the therapy (F[1,42] $= 7.85$, $p = .008$), the competence of trainer (F[1,39] $= 11.82$, $p = .001$) and recommendation of the therapy (F[1,42] $= 5.53$, $p = .023$). In these categories parental satisfaction with the SCP-therapy was stronger than parental satisfaction with the Theta/Beta-therapy. For the SCP-group, post-hoc paired samples tests showed a significant increase of parental satisfaction regarding the empathy of trainer between the second and the third treatment phase (t[24], $p = .039$, $ES = .72$). Changes over time and differences between groups can be seen in Fig. 15.

Discussion

EEG-data

As already shown for the SCP-group (Strehl et al., 2006) children with ADHD learn to self regulate SCPs and this skill remains stable at least until six months after the end of the treatment. Participants were able to produce shifts in the electrically negative direction and to differ between tasks with required positivity and negativity. However, they did not consistently produce significant shifts in the electrically positive direction. One reason could be the relative frequency of activation and deactivation trials, that changed from 50%:50% in the first 15 sessions to 75% (activation tasks):25% (deactivation tasks) for the remaining sessions. Thus, participants had more often the chance to exercise negativity. To examine this assumption, an interim analysis of EEG-data was done for session 15. At this time achievements regarding required negativity already exceeded achievements regarding required positivity. As patients are able to produce positive SCP-shifts (Kotchoubey et al., 2001) it raises the question, whether our result is due to the childrens disorder and associated neurological pathologies. In the absence of studies of SCPs in children we can only speculate about this.

Participants of the Theta/Beta-group learned to differentiate between activation and deactivation tasks and improved in deactivation tasks in feedback conditions during the treatment. In fact, achievements in activation tasks improved too but not significantly. It is important to note, that the Theta/Beta-ratios in activation tasks were already negative within the *first* sessions of the treatment. Thus, the fact, that achievements in activation tasks did not improve significantly does not mean, that participants did not learn to activate: They did learn at a very early stage of the training but showed no improvement during the following sessions. Despite the missing improvement in activation tasks participants of the Theta/Beta-group improved significantly in cognitive and behavioral variables. This indicates that the degree of learned activation within the first sessions is sufficient to cause clinical effects. Consequently one should prove if the number of activation tasks could be reduced in order to shorten the length of the training.

As there is no significant improvement both in activation and deactivation tasks during transfer conditions, more transfer trials seem to be necessary.

There are only a few neurofeedback studies who meet basic methodological standards and report EEG-data (Lubar et al., 1995; Monastra et al., 2002; Thompson & Thompson, 1998), but treatment protocols of those studies differ from the present study. Lubar et al. (Thompson & Thompson, 1998) reported an improved Theta/Beta-ratio after the treatment, Monastra et al. (2002) and Thompson and Thompson (1998) found a significant improved post-QEEG and a decreased post-Theta/Beta-ratio in the treatment group. No changes were observed in the control group (Monastra et al., 2002). Our results confirm their findings insofar, as they show that there are pre-post differences regarding some aspects of the EEG.

Effect sizes for changes of the EEG in the SCP-group and Theta/Beta-group depend on task (activation/deactivation) and condition (feedback/transfer). In the SCP-group they vary between .98–1.09 for sessions $29 + 30$ and between 1.04–1.07 for sessions $32 + 33$. Effect sizes for changes of the EEG-power in the Theta/Beta-group vary between .96–2.25 for sessions $29 + 30$ and between .74 and 1.32 for sessions $32 + 33$. Up to now, there are only guidelines to evaluate the relevance of effect sizes that refer to clinical data, e.g., behavioral changes (Bortz & Döring, 1995). According to the guidelines of Bortz and Döring (1995) the effect-sizes for changes of the EEG of the SCP-group are important and those of the Theta/Beta-group are medium to important. Guidelines for the evaluation of effect sizes of EEG-data are missing and previous neurofeedback studies do not report effect-sizes for EEG-data. As the variability of amplitudes differs between SCPs and Theta/Beta, to compare effect-sizes between groups is not possible. However, we hope that our calculations will be the basis and reference value for further EEG-data-effect-sizes.

The stability of self-control of EEG-parameters in both groups is in line with Kotchoubey et al. (1997) and Neumann et al. (2004). who reported stability of EEG changes as a result of neurofeedback in epilepsy patients and in paralyzed patients. Findings from Neumann et al. (2004) provide evidence that SCP self-regulation may automatize with long-term practice and can therefore be considered a skill. The study reported here indicates that the self-regulation-abilities of ADHD-children may automatize, too.

Behavior and cognitive variables

Ratings from parents and teachers as well as results from TAP and HAWIK confirm the results of previous neurofeedback studies (Alhambra et al., 1995; Fuchs et al., 2003; Monastra et al., 2002): Both parents and teacher reported behavioral and cognitive improvements. There was a significant increase of full-scale-IQ and performance-IQ as well as an improvement of variables of attention. According to the guidelines of Bortz and Döring (1995) the effect sizes of behavioral changes can be interpreted as low to medium for the SCP-group (ES = .43–.59) and low to important for the Theta/Beta-group (ES = .34–1.02). Effect sizes of changes in attention are medium to important for the SCP-group (ES = .77–1.19) and medium (ES = .66) for Theta/Beta-group. Effect sizes of changes in IQ vary between .54 (SCP-group) and .62–.82 (Theta/Beta-group) and can therefore be interpreted as medium for the SCP-group and medium to important for the Theta/Beta-group. Follow-up-results of both groups do not differ significantly from results at the end of the treatment. This is the first time that stability of clinical effects after a neurofeedback treatment is demonstrated six months after the treatment. Statistical analysis of between-groups-differences with the General Linear Model indicate that there are no significant differences regarding outcome variables both at the end of the treatment and the follow-up.

Confounding variables

As parenting style did not change significantly between assessment points or differed between groups, it cannot be responsible for clinical improvements.

Some aspects of parental expectancies increased significantly over time. This may be due to the information the trainer provided: Parents were told, that learning and clinical improvements will take time. This introduction may have caused the low parental expectancies in the first and high expectancies in the last treatment phase.

Parental satisfaction with the trainer increased significantly over time. We attribute this to the changing relation between parents and trainer: As trainer and parents had daily contact during the treatment phases, the relation may have become closer.

Both, parental expectancies and satisfaction differed between groups in several aspects and ratings of the SCP-group exceeded those of the Theta/Beta-group. Setting, instructions, the level of contact between trainer and parents and the daytime of treatment, were almost identical between groups. However, clinical experience of trainers was different between the licensed clinical psychologist and the graduate students. Due to practical reasons, the licensed psychologist trained the majority of participants of the SCP-groups, whereas the majority of participants of the Theta/Beta-group was trained by the graduate students. As all graduate students were under regular supervision, we assume the quality of treatment to be comparable between trainer and between groups. Nevertheless, parents were informed about the trainers academic qualification. Studies indicate, that both perceptions and evaluations of persons are influenced by precedent information (Bruner, 1957; Higgins & Rholes, 1977). Therefore the knowledge of parents about the trainers' academic qualification may have influenced their judgements.

The difference between groups regarding parental expectancies and satisfaction makes it difficult to compare the clinical effects between groups. There are two possible conclusions: First—if we presume that parents expectancies and satisfaction have *no* impact on outcome variables—we may conclude, that the clinical effects of both treatment protocols are equal. Second—if we presume, that parental expectancies and satisfaction *have* an impact on outcome variables—we may conclude, that the efficacy of Theta/Beta-protocol is stronger than the efficacy of SCP-protocol because the Theta/Beta-group shows the same clinical improvements despite reduced expectancies. Teachers ratings did not differ between groups, as assessed by the General Linear Model. As teachers were not informed about the academic qualification of trainer, this indicates that the efficacy of treatment protocols is equivalent and that expectancies of parents have no significant impact on the effects of neurofeedback.

Although this study succeeded in overcoming several of the methodological deficiencies of previous neurofeedback studies, unspecific effects were not completely controlled. A double blind design is not realizable as the trainer has to adjust the feedback-parameters and thus has to know which parameters are trained.

As neurofeedback-trainings consist of a minimum of 30 sessions the use of a placebo-group or waiting-group is incompatible with fundamental ethical principles given by the Declaration of Helsinki. Rossiter and La Vaque (2001) suggested, that active control studies should be conducted instead. Neurofeedback should be compared with an intervention with known clinical efficacy. But, even then skeptics could argue, that the effects of neurofeedback are due to confounding variables. Vernon, Frick, and Gruzelier (2004) summarized, that the development of designs for the use of neurofeedback is fraught with several ethical problems. One possibility to prove the specific efficacy of neurofeedback might be to search for variables predicting clinical outcome (Ramirez, Desantis, & Opler, 2001). If it would be possible to prove, that clinical outcomes could be predicted by improvements in the EEG, we would have an important argument for the specific efficacy of neurofeedback. Lubar et al. (1995) examined behavioral and cognitive outcome variables of responder (children with desired EEG-changes after the treatment) and nonresponder (children without EEG-changes after the treatment). Both, responder and nonresponder showed improvements in behavior and attention, but group differences did not reach significance. As the retest-interval was about 8 to 10 weeks, it remains unclear, if attentional improvements of non-responders and responders are due to confounding variables or retest-effects.

Our study indicates that the clinical effects of neurofeedback are not affected by unspecific expectancy effects. The lack of differences between groups in practically all outcome variables demonstrates that neurofeedback of SCP and Theta/Beta improves behavior, attention and IQ significantly. The test parameters used (IQ, attention variables of TAP) do not improve over time without treatment as they are standardized for large populations and different age groups. The size of the effects found in the present study strongly supports a lasting and positive effect of neurofeedback on ADHD.

Acknowledgments This study was supported by the Förderprogramm der Medizinischen Fakultät Tübingen zur Angewandten Klinischen Forschung (AKF-Programm) and the Deutsche Forschungsgemeinschaft (DFG).

References

Alhambra, M. A., Fowler, T. P., & Alhambra, A. A. (1995). EEG Biofeedback: A new treatment option for ADD/ADHD. *Journal of Neurotherapy*, *2*, 39–43.

Barbaresi, W., Katusic, S., Colligan, R., Weaver, A., Pankratz, V., Mrazek, D., et al. (2004). How common is attention-deficit/hyperactivity disorder? Towards resolution of the controversy: results from a population-based study. *Acta Paediatrica*, *445*, 55–59.

Barbaresi, W. J., Katusic, S. K., Colligan, R. C., Pankratz, S., Weaver, A. L., Weber, K. J., et al. (2002). How common is attention-deficit/hyperactivity disorder? *Archives of Pediatrics and Adolescent Medicine*, *156*, 217–224.

Beelmann, A., & Schneider, N. (2003). Wirksamkeit von Psychotherapie bei Kindern und Jugendlichen. Eine Übersicht und Meta-Analyse zum Bestand und zu Ergebnissen der deutschsprachigen Effektivitätsforschung. *Zeitschrift für Klinische Psychologie und Psychotherapie*, *32*, 129–143.

Bortz, J., & Döring, N. (1995). *Forschungsmethoden und evaluation für sozialwissenschaftler* (2nd ed.). Berlin, Heidelberg: Springer.

Bruner, J. S. (1957). On perceptual readiness. *Psychological Review*, *64*, 123–152.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Conners, C. K. (1997). *Conner' rating scales—revised; technical manual*. North Tonawande, N.Y.: Multi-Health Systems.

Conners, C. K. (2002). Forty years of methylphenidate treatment in attention-deficit/hyperactivity disorder. *Journal of Attention Disorders*, *6*, 17–30.

Döpfner, M., & Lehmkuhl, G. (2002). Evidenzbasierte Therapie von Kindern und Jugendlichen mit Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS). *Prax Kinderpsychol Kinderpsychiat*, *51*, 419–440.

Eyberg, S. M., & Pincus D. (1999). *Eyberg child behavior inventory & sutter-eyberg student behavior inventory—Revised*. Odessa, FL: Psychological Assessment Ressources.

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.

Goldman, L. S., Genel, M., Bezman, R. J., & Slanetz, P. J. (1998). Diagnosis and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Journal of the American Medical Association*, *279*, 1100–1107.

Heinrich, H. (2004). Training of slow cortical potentials in ADHD: Evidence for positive behavioral and neurophysiological effects. *Biological Psychiatry*, *55*, 772–775.

Higgins, E. T., & Rholes, W. S. (1977). Category accessibility and impression formation. *Journal of Experimental Social Psychology*, *13*, 141–154.

Hinterberger, T., Kotchoubey, B., Kaiser, J., Kübler, A., Neumann, N., Perelmouter, J., et al. (2000). Anwendungen der Selbstkontrolle langsamer kortikaler Potentiale. *Verhaltenstherapie*, *10*, 219–227.

Hinterberger, T., Neumann, N., Pham, M., Kubler, A., Grether, A., Hofmayer, N., et al. (2004). A multimodal brain-based feedback and communication system. *Experimental Brain Research*, *154*, 521–526.

Johnstone, S. J., Barry, R. J., & Anderson, J. W (2001). Topographic distribution and developmental time course of auditory event-related potentials in two subtypes of attention-deficit hyperactivity disorder. *International Journal of Psychophysiology*, *42*, 73–94.

Kotchoubey, B., Blankenhorn, V., Fröscher, W., Strehl, U., & Birbaumer, N. (1997). Stability of cortical self-regulation in epilepsy patients. *Neuroreport*, *8*, 1867–1870.

Kotchoubey, B., Strehl, U., Uhlmann, C., Holzapfel, S., König, M., Fröscher, W., et al. (2001). Modification of slow cortical potentials in patients with refractory epilepsy. *Epilepsia*, *42*, 406–416.

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

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

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 TOVA scores, behavioral ratings and WISCR performance. *Biofeedback and Self- Regulation*, *20*, 83–99.

Lubar, J. O., & Lubar, J. F. (1984). Electroencephalographic biofeedback of SMR and Beta for treatment of attention deficit disorders in a clinical setting. *Biofeedback and Self-Regulation*, *9*, 1–23.

Mann, C. A., Lubar, J. F., Zimmerman, A. W., Miller, C. A., & Muenchen, R. A. (1992). Quantitative analysis of EEG in boys with ADHD: controlled study with clinical implications. *Pediatric Neurology*, *8*, 30–36.

Miller, Y. (2000). Erziehung von Kindern im Kindergartenalter. Erziehungsverhalten und Kompetenzüberzeugungen von Eltern und der Zusammenhang zu kindlichen Verhaltensstörungen. *Doktorarbeit an der TU Braunschweig*. (un pub).

Monastra, V. J., Linden, M., VanDeusen, P., Green, G., Wing, W., Phillips, A., et al. (1999). Assessing attention deficit hyperactivity disorder via quantitative electrencephalography. *Neurophysiology*, *13*, 424–433.

Monastra, V. J., & Lubar, J. F. L. M. (2001). The development of a quantitative electroencephalographic scanning process for attention deficit—Hyperactivity disorder reliability and validity studies. *Neuropsychology*, *15*, 136–144.

Monastra, V. J., Monastra, D. M., & George, S. (2002). The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary smptoms of attention-deficit/Hyperactivity disorder. *Applied Psychophysiology and Biofeedback*, *27*, 231–249.

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

MTA Cooperative Group. (2004). National institute of mental health multimodal treatment study of ADHD follow-up: Changes in effectiveness and growth after the end of treatment. *Pediatrics*, *113*, 762–769.

Neumann, N., Hinterberger, T., Kaiser, J., Leins, U., Birbaumer, N., & Kübler, A. (2004). Automatic processing of self-regulation of slow cortical potentials: evidence from brain-computer communication in paralyzed patients. *Clinical Neurophysiology*, *115*, 628–635.

Othmer, S., Othmer, S. F., & Clifford, S. M. (1991). EEG biofeedback training for attention deficit disorder, specific learning disabilities, and associated conduct problems. *EEG Spectrum* (http://www.eegspectrum.com/Applications/ADHD-ADD/).

Ramirez, P. M., Desantis, D., & Opler, L. A. (2001). EEG biofeedback treatment of ADD. A viable alternative to traditional medical intervention? *Annals of the New York Academy of Science*, *931*, 342–358.

Rockstroh, B., Elbert, T., Canavan, A., Lutzenberger, W., & Birbaumer, N. (1989). *Slow cortical potentials and behavior*. Baltimore, München, Wien: Urban & Schwarzenberg.

Rockstroh, B., Elbert, T., Lutzenberger, W., & Birbaumer, N. (1990). Biofeedback: Evaluation and therapy in children with attentional dysfunctions. In A. Rothenberger (Ed.), *Brain and behavior in child psychiatry* (pp. 345–355). Berlin: Springer.

Satterfield, J. H., Schell, A. M., & Nicholas, T. (1994). Preferential neural processing of attended stimuli in attention-deficit hyperactivity disorder and normal boys. *Psychophysiology*, *31*, 1–10.

Schachter, M., Pham, B., King, J., Langford, S., & Moher, D. (2001). How efficacious and safe ist short-acting methylphenidate for the treatment of attention-deficit disorder in children and adolsecents? A meta-analysis. *Canadian Medical Association*, *165*, 1475–1488.

Shouse, M. N., & Lubar, J. F. (1979). Operant conditioning of EEG rhythms and ritalin in the treatment of hyperkinesis. *Biofeedback and Self- Regulation*, *4*, 299–312.

Spencer, T. J., Biederman, J., Wilens, T. E., & Faraone, S. V. (2002). Novel treatments for ADHD in children. *Journal of Clinical Psychiatry*, *63*, 16–22.

Spencer, T., Biederman, J., Wilens, T., Harding, M., O'Donnell, D., & Griffin, S. (1996). Pharmacotherapy of attention-deficit hyperactivity disorder across the life. *Journal of the American Academy of Child and Adolescent*, *35*, 409–432.

Strehl, U., Leins, U., Goth, G., Klinger, C., & Birbaumer, N. (2006). Physiological regulation of slow cortical potentials—a new treatment for children for ADHD. *Pediatrics*.

Tansey, M. A., & Bruner, R. L. (1983). EMG and EEG biofeedback training in the treatment of a 10-year-old hyperactive boy with a developmental reading disorder. *Biofeedback and Self- Regulation*, *8*, 25–37.

Tewes, U., Rossmann, P., & Schallberger, U. (1999). *Hamburg wechsler intelligenztest für kinder—Dritte Auflage (HAWIK III)*. Bern: Huber.

Thompson, L., & Thompson, M. (1998). Neurofeedback combined with training in meta cognitive strategies: Effectiveness in students with ADD. *Applied Psychophysiology and Biofeedback*, *23*, 243–263.

Vernon, D., Frick, A., & Gruzelier, J. (2004). Neurofeedback as a treatment for ADHD: A methodological review with implications for future research. *Journal of Neurotherapy*, *8*, 53–82.

Wagner, K. D. (2002). Management of treatment refractory attention-deficit/hyperacitivity disorder in children and adolescents. *Psychopharmacology-Bulletin*, *36*, 130–142.

Zimmermann, P., & Fimm, B. (1997). *Testbatterie zur aufmerksamkeitsprüfung (TAP), Version 1.7*. Herzogenrath: PsyTest.