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Additive effects of neurofeedback on the treatment of ADHD: A randomized controlled study

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ABSTRACT

Neurofeedback (NF) has been identified as a "possibly efficacious" treatment in current evidence-based reviews; therefore, more research is needed to determine its effects. The current study examined the potential additive effect of NF for children diagnosed with ADHD beginning a medication trial first. Thirty-six children (6–12 years) with a DSM-IV-TR diagnosis of ADHD were randomly assigned to an NF with medication (NF condition) or a medication only condition. Children in the NF group attended 20 twice-weekly sessions. Outcome measures included individual cognitive performance scores (ADS, K-WISC-III), ADHD rating scores completed by their parents (ARS, CRS) and brainwave indices of left and right hemispheres before and after NF treatment. Significant additive treatment effect in any of the symptom variables was found and a reduction of theta waves in both the right and left hemispheres was recorded in NF condition participants. However our randomized controlled study could not demonstrate superior effects of combined NF on intelligent functioning compared to the medication treatment only. This study suggested any possible evidence of positive and additive treatment effects of NF on brainwaves and ADHD symptomatology.

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention, impulsivity and hyperactivity and is a common disorder in childhood. The prevalence rate of ADHD worldwide is 2%–9%, and the reported incidence rate of ADHD in the United States ranges from 2% to 20% for elementary school students, with a relatively high incidence rate of 3%–5% for children in the lower elementary school grades (Froehlich et al., 2007). Almost one-half of the children with ADHD exhibit these symptoms chronically, which may continue into adulthood (Holtmann and Stadler, 2006).

So far, the most successful and the most widely used treatment for ADHD is medication, though it has limitations and disadvantages, like side-effects, which has a robust effect in group data, with placebo-controlled effect sizes of 0.7 to 1.5 for methylphenidate and amphetamine (Arnold, 2004; Taylor et al., 2004). European clinical guidelines recommend a multimodal treatment, encompassing medication, cognitive behavioral and family treatments (Taylor et al., 2004). However, even when administered in a careful algorithm and combined with behavior modification, another established treatment for ADHD, 32% of children did not fully benefit from this presumed optimal combination treatment (Swanson et al., 2001). Furthermore, even for those with a good initial response, no study has been able to document the persisting benefit of medication beyond 2 years (Molina et al., 2009). In addition, an unknown percentage of families refuse to try the medications, even though their children might benefit, due to fears about possible side effects or addiction and dependence (Arnold et al., 2013). The 8-year follow-up of the Multimodal treatment Study of ADHD (MTA; 10) noted the disappointing long-term results of current treatments. Therefore, both new and alternative treatments are needed.

One alternative and complementary treatment for ADHD (Duric et al., 2014) is neurofeedback (NF). NF trains the brain by using operant conditioning principles based on real-time measurement and processing of electrical activity using scalp electrodes. It is a kind of behavioral therapy aimed at developing skills for self-regulation of cortical activity (Heinrich et al., 2007). The evidential foundation of NF for the treatment of ADHD is based on the theory that brain waves can be conditioned (Kamiya, 1968) and NF is aiming to normalize the EEG by improving cortical functioning

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(Butnik, 2005). Those with ADHD learns to enhance the EEG needed frequencies and suppress the unneeded ones in the form of a rewards system (Friel, 2007). This may affect the changes of attention or other neurocognitive processes.

In most studies which have performed uncontrolled and non-randomized studies, NF has been shown to provide benefits as an efficacious treatment for ADHD (Duric et al., 2014; Arnold et al., 2013; Bakhshayesh et al., 2011; Lansbergen et al., 2011; Meisel et al., 2013; Lofthouse et al., 2012; Arns et al., 2012; Gevensleben et al., 2009). The 2009 meta-analysis by Arns of 6 peer-reviewed published randomized trials of NF for ADHD found a large effect for inattention and medium effect for hyperactivity and impulsivity (Bakhshayesh et al., 2011). In a more recent review of 9 controlled RCTs that reported Effect Sizes (ESs), there was a medium between-groups mean for overall ADHD symptoms (Lofthouse et al., 2012). Significant improvements of ADHD symptoms over time after NF treatment were found in a double-blind placebo feedback-controlled design by Lansbergen et al. (Lansbergen et al., 2011). Randomized studies from Duric et al. and Meisel et al. found promising evidence of ADHD symptom improvements in treatment with NF (Duric et al., 2014; Meisel et al., 2013) and superiority of the combined NF treatment indicated clinical efficacy of NF in children with ADHD in comparison to those of attention skills training (AST) as a control condition (Gevensleben et al., 2009). Also study by Linden et al. found improved ADHD symptoms and IQ of NF group than normal group (Linden et al., 1996), the results from study by Monastra et al. have reported the improvement of behavioral problem and attention of NF group comparing medication group (Monastra et al., 2002). However, a systematic review and meta-analysis of randomized controlled trials (RCTs) of non-pharmacological interventions in children with ADHD reported no significant results for the blind rating of ADHD symptoms ($p = 0.07$) and did not find any beneficial effect of NF on neurocognitive functioning (Vollebregt et al., 2014; Sonuga-Barke et al., 2013). Better evidence for efficacy of NF is required with blinded assessments.

Several studies provide evidence for positive effects of NF treatment in children with ADHD (Evans et al., 2014; Arns et al., 2009; Duric et al., 2014), however the designed ones have shown absent, such as lack of mixed multiple intervention strategies or an adequate control group, the use of self-reported measures only, the absence of the report of changed brain waves, protocol differences. These shortcomings preclude unambiguous interpretation or generalization of the results (Moriyama et al., 2012; Holtmann et al., 2014; Lofthouse et al., 2012; Duric et al., 2014). More research is needed to determine the efficacy of this treatment. Therefore, the objective of the current study was to examine a possible additive effect of NF on cognitive functions, parental symptom reports, and brainwave activity before and after treatment for children diagnosed with ADHD beginning a medication trial.

2. Methods

2.1. Participants

Thirty-six children who were beginning a medication trial for ADHD (mean age 8.75 years, standard deviation [SD] = 2.12, 27 boys, 9 girls) were enrolled. Participating children were randomly assigned (1:1 assignment using random block sizes of 2), to either NF with medication (combined condition) or medication treatment (control condition) group. The diagnosis of ADHD was based on DSM-IV-TR criteria and determined by child and adolescent psychiatrists. Children were excluded if they (a) used medication for a condition other than ADHD, (b) had a comorbid disorder other than oppositional defiant disorder or anxiety disorder, (c) had a neurological disorder and/or cardiovascular disease, (d) participated in another clinical trial simultaneously, (e) had received NF in the past, or (f) had a full-scale IQ (FSIQ) of below 80. In addition to the diagnosis, the psychiatrist and psychologist performed pre- and post-NF clinical evaluations. All required institutional review board approved consent/assent forms were signed by the participants and a parent. Demographic data, which are collected by means of minimization, including grade, age, sex and diagnosis are presented in Table 1.

2.2. Neurofeedback protocol and data collection

NF training was conducted by an experienced clinical psychologist with extensive background in biofeedback training. Participants were seated in a comfortable armchair in a quiet room. NF protocol in this study was Beta/SMR training using visual feedback reward. During the NF session, brain activity was shown to the participant using visual and auditory feedback and game type was airplane. The ongoing EEG was band-pass filtered in the following four frequency ranges: theta (4–7 Hz), sensorimotor rhythm (SMR, 12–15 Hz), beta (15–18 Hz), and high beta (22–30 Hz). The goal of NF training was to increase the power in the SMR or beta bands ("reward bands") and simultaneously decrease the power in the theta and high beta bands ("inhibit bands"). All EEG signals and training parameters were measured using 3 electrodes; one active electrode was at the specific position of the C3 or C4 site, the second was a reference on the left or right ear, and the third was a ground on the right or left earlobe. All participants received 20 sessions, two times per week for 2.5 months using c3 and c4 placement. The target length of each session was all 60 min (25 min for each site) including break time. Rewards were given if participants could keep theta levels below threshold 70% of the treatment time and keep beta levels above the threshold 20% of the time. Depending on the participant's performance these reward thresholds were manually adjusted by the therapist.

Table 1
Demographic characteristics.

Descriptive characteristics	NF + M ($N = 18$)	M ($N = 18$)	Analysis T, χ^2 p-value
Grade (M and SD)	2.11 (0.32)	1.89 (0.47)	0.108
Age (M and SD)	8.72 (2.42)	8.78 (1.83)	0.939
Sex (N and%)			
Boys	16 (88.9)	11 (61.1)	0.121
Girls	2 (11.1)	7 (38.9)	
FSIQ (M and SD)	100.06(16.60)	100.72(12.06)	0.891
ADHD subtype (N and%)			
Combined	9 (50.0)	7 (38.9)	0.772
Inattentive	7 (38.9)	8 (44.4)	
Hyperactive/impulsive	2 (11.1)	3 (16.7)	

Note. M = mean, SD = standard deviation, N = Number, NF + M = Neurofeedback with medication condition; M = Medication condition. T = t-test, χ^2 = chi-square test, FSIQ = Full scale IQ.