NeuroRegulation

Determination of the Effects of Neurofeedback Training in the Neuropsychological Rehabilitation in Inattentive and Combined Subtypes of Attention Deficit/Hyperactivity Disorder

Mahnaz Moghanloo[1], Maria E Aguilar Vafaie[1], Reza Rostami[2], Hojatollah Farahani[3]*

[1]Tarbiat Modares University, Tehran, Iran
[2]Tehran University, Tehran, Iran
[3]Islamic Azad University, Tehran, Iran

***Address correspondence to:** Mahnaz Moghanloo, Tarbiat Modares University, Islamic Republic of Iran.
Email: Moghanloo12@yahoo.com

Copyright: © 2014 Moghanloo et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (CC-BY).

Abstract

Introduction: The aim of the present study was to compare the effect of neurofeedback in neuropsychological rehabilitation of attention in children with combined (C) and predominantly inattentive (IA) subtypes of ADHD. **Method**: This research is a quasi-experimental study by which, from among 7–12 year old children referred to the Atiyeh Psychiatric Center, 30 children diagnosed with either Combined or predominantly Inattentive subtypes of ADHD (15 children in each subtype) underwent 30 sessions (3 sessions per week) of neurofeedback therapy. For assessing children's cognitive performance, the children in both treatment groups were administered before and after treatment with a time interval of 10 weeks, both the visual and auditory continuous performance tests (IVA). Patient diagnosis for assignment to either of two ADHD subtypes was carried out with the Conner's rating scale, a Clinical Interview Checklist, and Psychiatrist evaluation. **Results**: Neurofeedback training significantly increased all IVA subscales scores, with the exception of the Balance scale, in all subjects, regardless of treatment group (subtype). Results of MANOVA analysis indicated that the two subtypes did not differ in terms of effectiveness of neurofeedback training with the exception of the Readiness scale. **Conclusion**: The present findings supported the efficacy of Neurofeedback training in increasing children's scores on the IVA-CPS battery of tests, regardless of subtype classification. These findings are interpreted within recent theoretical and developments regarding the validity of subtypes and the usefulness of a dimensional approach.

Keywords: neurofeedback, attention-deficit/hyperactivity disorder, combined subtype, predominantly inattentive subtype

Introduction

One of the most common neurodevelopmental disorders is Attention-deficit/hyperactivity disorder (ADHD); it begins in early childhood (between 3 to 7 years of age), usually continues during adolescence, and continues into adulthood in more than half of the cases (Barkley, 1997). Behaviorally, it is most commonly characterized by sustained attention deficits, hyperactivity and impulsivity, and its major determinants include neural (e.g., Casey et al., 1997), cortical (e.g., Makris et al., 2007), neuro-cortical maturational (e.g., Shaw et al., 2007), neurodevelopmental trajectories (Shaw, Gogtay, & Rapoport, 2010), as well as neurocognitive anolamies (Sergeant, Oosterlaan, & van der Meere, 1999; van Mourik, Osterlaan, & Sergeant, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In terms of the prevalence of this disorder, it has been estimated to affect 9% of American school children (Pastor & Reuben, 2008); between 2 and 29% of the general population at international levels (American Psychiatric Association, 2000; Barkley, 2005; Linden, Habib & Radojevic, 1996); and, between 3 and 12% in Iran (Mashhadi, 2009). In most instances, its prevalence is higher among males than females (American Psychiatric Association, 2000).

In past years, with the use of factor analytic techniques, three distinct behavioral symptoms (inattention, hyperactivity and impulsivity) have been reconceptualized in the form of two dimensions: attention deficiency and hyperactivity/impulsivity or disinhibition (Barkley, 2006; Burns, Boe, Walsh, Sommers-Flannagan, & Teegarden, 2001; Pillow, Pelham, Hoza, Molina, & Stulz, 1998) and based on these two dimensions, three different subtypes of ADHD disorder have been identified: (1) ADHD predominantly inattentive subtype (ADHD-IA); (2) ADHD predominantly hyperactive/impulsive subtype (ADHD-HI); and, (3) ADHD combined subtype (ADHD-C; American Psychiatric Association [APA], 2000).

Although there is limited information on the different prevalence rates of these subtypes, the combined subtype has been found to occur with the highest frequency and the hyperactivity/impulsivity subtype with the least. The prevalence of the inattentive subtype falls between the two former subtypes (Millstein, Wilens, Biederman, & Spencer, 1998). For instance, in the Millstein and colleagues study (Millstein et al., 1998), the diagnosis of ADHD among 149 children patients, indicated a prevalence of 2, 37, and 56 percent for the IA, HI and C subtypes, respectively.

The research literature on ADHD subtypes based on DSM-IV criteria indicates that the underlying determinants for the three ADHD subtypes are basically different, including differences in demographic characteristics, nature of functional impairments, level of comorbidity with other disorders, neuropsychological profiles and neurocognitive deficits (Barkley, 1997; Booth, Carlson & Tucker, 2005; Diamond, 2005; Milich, Ballentine, & Lynam, 2001). Some other researchers also believe that the ADHD predominantly inattentive (IA) subtype is a distinctive disorder and should not be considered as an ADHD subtype (Barkley, 2006; Brown, 2006; Diamond, 2005; Geurts, Vert, Oosterlaan, Roeyers, & Sergeant, 2005; Milich et al., 2001; Wilcutt, Doyle, Nigg, Farone, & Penningtone, 2005).

Review of the literature also indicates that there is a clear difference in executive functioning between the C and IA subtypes (Milich et al., 2001), and Barkley (1997, 2005) has, similarly, considered executive function as the main factor discriminating among ADHD subtypes. Moreover, Chemark, Hall and Musiek (1999) have proposed that the combined (C) and predominantly hyperactive/impulsive (HI) subtypes conform an externalizing disorder involving primarily executive function and behavioral regulation deficits, instead of attention deficits per se. In contrast, Chemark and colleagues suggest that the predominantly attention deficiency (IA) subtype is an internalizing disorder with the primary cause being a deficiency of processing and information inputting where attention plays a major role; and thus, executive dysfunction, in this condition should be considered as a secondary cause.

Although the cause of the ADHD is not presently known (Barkley, 2006; Kaplan, Sadoc & Grebb, 2003; Nigg, 2006; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), a very active research agenda is expanding in order to understand the complexity of this disorder and its neuropsychological underpinnings. For instance, recent neuroimaging evidence suggests an important role of the frontal and, especially, the prefrontal cortex (PFC) in executive dysfunctions (Fuster, 2008; Barkley, 1997). For a thorough review of this literature, the readers are recommended to consult Halperin and Healy's (2011) article. Given the role of executive dysfunction in ADHD disorder and its relationship with the prefrontal brain region (Barkley, 1997; 2003; 2006), stimulant medication is considered one of the best-supported interventions for ADHD (Faraone & Buitelaar, 2009). By facilitating the transfer of dopamine neurotransmitter in the PFC, stimulant drugs, improve executive function performance. Although stimulant drugs, such as methylphenidate, can to a great extent, decrease hyperactivity/impulsivity behavior and even in some cases, have significant short-term effects in improving educational performance, the results of evaluation of reading tests and performance in cognitive tests (such as the continuous performance test) show that the long-term effects after treatment with stimulant medication are limited to cortical levels of the brain. However, researchers (e.g., Arnsten & Dudley, 2005; Lubar, Swartwood, Swartwood, & Timmermann 1995; Patoine, 2009) also believe that long-term improvements in subcortical functioning could be possible and should not be discarded.

Despite the positive effects of drug therapy in reducing the symptoms of hyperactivity and impulsivity (two pivotal ADHD symptoms of C and HI subtypes), its effectiveness in decreasing attention deficits has been found to be limited (Barkley & Cunningham, 1979; Camobel, 2003; Chemark et al., 1999). In a review article, Swanson, Nolan, and Pelham (1993) reported that 25 to 40 percent of children with ADHD may not respond to medication. Moreover, ADHD children who respond well to drug therapy (i.e., C and HI subtypes), although they may show a reduction of symptoms of hyperactivity and impulsivity, this improvement is temporary and depends on continuous medication use. Furthermore, the side effects of medication, which include sleep disorders, poor appetite, mild interruption of physical growth, and restlessness, cannot be ignored (Lubar et al., 1995). Some research (e.g., Barkley, McMurray, Edelbrock, & Robbins, 1990) has also provided empirical evidence regarding the fact that the use of medication and stimulant drugs leads to side effects such as decreased appetite, insomnia, stomach aches, and headaches, with a recent study (Goldman, 2010) replicating these findings. In line with this evidence, Molina and colleagues' eight-year longitudinal study (Molina, Hinshaw, Swanson, & Arnold, 2009) investigating the effectiveness of the stimulant drugs in reducing ADHD symptoms concluded that even though medication is an effective treatment, with therapeutic effects of up to about 14 months, long-term effects of drug therapy could not be confirmed. However, long-term effects of drug treatment are required if ADHD symptoms persevere throughout life.

One innovative, recent, non-medicinal training paradigm in the treatment of ADHD is neurofeedback training (Barbaraz & Barbaraz, 1996). Neurofeedback investigations have focused on the study of brain wave activity in people with ADHD in comparison to those without ADHD, and they have shown that those individuals with ADHD have higher slow wave (theta) activity and lesser fast wave (beta) activity (Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992). Neurofeedback is a neurobehavioral treatment aimed at acquiring self-control over certain brain activity patterns and implementing these self-control skills in dailylife situations (Gevensleben et al., 2009). Two well-known training protocols include: (1) training of slow cortical potentials (SCPs); and (2) theta/beta training, which are typically used in children with ADHD. The SCPs training is related to phasic regulation of cortical excitability. Negative SCPs reflect increased excitation and occur during states of behavioral or cognitive activation, while positive SCPs are thought to indicate reduction of cortical excitation of the underlying neural networks and appear during behavioral inhibition. In the theta/beta training, the goal is to decrease activity in the theta band (4–8 Hz) and to increase activity in the beta band (13–20 Hz) of the electroencephalogram (EEG), which corresponds to an alert and focused but relaxed state. Thus, neurofeedback training addresses tonic aspects of cortical arousal. The rationale of applying neurofeedback in the treatment of ADHD is based on findings from EEG and event related potentials (ERP) studies. For the contingent negative variation (CNV; a typical SCP), reduced amplitude was measured during cued continuous performance tests (CPT) in children with ADHD (for a review, see Banaschewski & Brandeis, 2007). This finding may be seen in line with the dysfunctional regulation/allocation of energetically resources model of ADHD (Sergeant, Oosterlaan, & Van der Meere, 1999).

Review of the literature indicates that SCPs training (e.g., Heinrich, Gevenesleben, Freisleder, Moll, & Rothenberger, 2004; Drechsler et al., 2007; Gevensleben, et al., 2009; Strehl et al., 2008) and theta/beta training (e.g., Rossiter & Lavaque, 1995; Monastra, Monastra, & George, 2002; Fuchs, Birbaumer, Lutzenberger, Gruzelier & Kaiser, 2003; Rossiter, 2004; Levesque, Beauregard, & Mensour, 2006; Bakhshayesh, 2007; Holtmann et al., 2009; Xiong, Shi, & Xu, 2005; Leins et al., 2007; Kaiser & Othmer, 2000) have a beneficial influence in the treatment of ADHD symptoms. Skills for the regulation of brain wave activity are learned over the course of neurofeedback training, which may last for a time between of 6 months (e.g., Gevensleben, Holl, Albrecht, Schlamp, & Kratz, 2009; Strehl et al., 2006; Sherlin, 2010) to 2 years (e.g., Gani, Birbaumer, & Strehl, 2009), and, even 10 years (Lubar, 2003).

Lubar (1991) has emphasized the important role of neurofeedback training in reducing ADHD symptoms, especially attention deficiency symptoms. He suggests that the attention disorder observed in the ADHD attention deficiency subtype, which does not respond to drug treatment, will considerably improve with neurofeedback training. In corroboration with Lubar’s suggestion, Levesque and colleagues (Levesque, Beauregard, & Mensour, 2006) have shown that neurofeedback training, via normalizing performance in the anterior cingulate cortex area of the brain, leads to improved performance in selective attention tests. The reason behind the limited effectiveness of stimulant drugs seems to be related to the impact drugs have at the cortical level of brain and neurotherapy is linked directly to changes in cortical functioning such as cognitive processes associated with prefrontal cortex. While medication attempts to rectify neurotransmitter (chemical) imbalances in the subcortical area of brain, neurotherapy attempts to challenge the brain to self-regulate and redress the imbalance (Lubar, Swartwood, Swartwood, & O'Donnell, 1995).

In terms of treatment methods for ADHD management and control, due to the complex and ambiguous nature of this disorder (Sonuga-Barke, Sergeant, Nigg, & Wilcutt, 2008), a wide variety of interventions have been developed by researchers and psychotherapists, including cognitive-behavioral (Young & Amarasinghe, 2010) and behavioral (Sonuga-Barke, Daley, Thompson, Laver-Bradbury, & Weeks, 2001), to mention two. These and other interventions were designed to improve a wide range of deficits, primarily, executive functions (Karatekin, 2006, White & Shah, 2006), and working memory (Klinberg, 2009). In the last two or three decades, these efforts have culminated in the consolidation of EEG Biofeedback, or Neurofeedback, as a viable intervention for the neuro-rehabilitation of ADHD patients.

Review of the literature on the effectiveness of neurofeedback in reducing ADHD symptoms indicates that after Lubar and Shouse's pioneering work (1976), research performed during the period of time from 2004 to 2010 has shown neurofeedback to be efficient in the improvement of cognitive and behavioral difficulties in ADHD patients, especially the improvement of attention skills (e.g., Butinik, 2005). Of particular relevance for the present research are the studies by American researchers, Gouts and Eagle (1994), Lubar and colleagues (Lubar et al., 1995) and by Yaghubi (2007) in Iran, which have provided empirical evidence for the effectiveness of neurofeedback training in improving performance on the TOVA continuous performance test and also have shown that neurofeedback training can increase IQ scores as measured by the Revised Wechsler Intelligence Scale for Children (WISC-R, 1991). More recently, Sherlin and colleagues (Sherlin, Arns, Lubar, & Sokhadz, 2010) have reported in their position paper, evidence regarding the long-term effects of neurofeedback via the regulation of brain waves at cortical levels leading to long-term improvements of behavior. These findings and many more have been summarized in several review studies (e.g., Arns, deRidder, Strehl, Breteler, & Coenon, 2009; Lofthouse, Hersch, Hurt, DeBeus, & Heurt, 2012; Gani, Birbaumer, & Strehl, 2009; Fox, Tharp, & Fox, 2005; Gevensebelen et al., 2009; Monstra et al., 2005).

Contrary to the confidence with which earlier research studies (e.g., Camobel, 2003; Chemark et al., 1999; Loo & Barkley, 2005), emphasized treatment with stimulant drugs, more recent research (e.g., Young, 2010) has shown much caution is warranted regarding the effectiveness of stimulant drugs in the treatment of attention deficit symptoms of ADHD, as stimulant drugs have shown to be effective only in C and HI subtypes. Similarly, many research studies in Iran (Babaei, 2001; Esmaili, Bahreyniyan, & Hashemiyan, 2004; Mashhadi, 2006; KarAhmadi, 2007; Imani, 2009; Shirazi, 2005; Yaghoubi, 2006), as well as Abedi, Jamali, Faramarzi, Aghayi, and Behruz's 2012 meta analysis, have provided support for the facilitating effect of stimulant drugs in the transfer of dopamine neurotransmitter in the prefrontal cortex leading to a considerable decrease of ADHD symptoms; although as noted earlier, this improvement has not been sustained after termination of treatment or cessation of drug intake and has not been supported with the IA subtype.

Based on parental reports of ADHD children regarding the effectiveness of stimulant drugs in reducing their children's symptoms, the evidence indicates that, despite some positive effects of drugs in academic performance, ability to concentrate and reduce aggression and hyperactivity behaviors, children under medication still have difficulties in reading, social skills, and understanding of rules for complying with the underlying reasons of inappropriate behavior (Lubar, 2003).

In general, most studies have shown that neurofeedback training is efficient in reducing symptoms of all three subtypes of ADHD; although, some studies (e.g., Carmody, Radvansik, Wadhwani, Sabo, & Vergara, 2002; Monstra et al., 2005) have shown that the effect of neurofeedback is more efficient in patients with attention deficiency, rather than in those with hyperactivity and impulsivity symptoms, to such an extent that neurofeedback has been considered to be a systematic training of attention (Butinik, 2005). In fact, many research studies (Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) have confirmed the effectiveness of neurofeedback in improving attention and cognitive skills. Sherlin et al. (2010), in a position paper about the effectiveness of neurofeedback on reducing the ADHD symptoms, concluded that neurofeedback training is most efficient in reducing attention and impulsivity symptoms although less so regarding hyperactivity symptoms. Based on a thorough review of the literature, Sherlin and colleagues believe that new research studies are needed for exploring the different mechanisms involved accounting for subtype's differences, which may help explain the cognitive deficits specific to each subtype. Previous research has mainly focused on the effectiveness of neurofeedback training on the decrease of a specific and/or a single clinical symptom; however, ADHD is associated with different phenotypes, each with particular properties related to multiple cognitive deficits (Bidwell, McClernon, & Kollins, 2011).

Review of the literature also indicates that most researches (e.g., Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) have focused on the combined subtype of ADHD, and in follow-up assessments regarding the effectiveness of neurofeedback, on the decline of clinical symptoms; however, these studies have not evaluated the role of neurofeedback in the improvement of cognitive deficits taking into account different subtypes. Hence, given the extreme importance of cognitive deficits in the perseveration and severity of ADHD symptoms (e.g., Butcher et al., 2000; Fischer, Barkley, Smallish, & Fletcher,2005), and given the effectiveness of neurofeedback training in ADHD patients' neuropsychological rehabilitation (e.g., Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monastra et al., 2005; Sherlin et al., 2010; Williams, 2010), the aim of the present research was to determine the effectiveness of neurofeedback training in decreasing cognitive deficits considering C and IA subtypes.

METHOD

Participants

Using a purposeful sampling method, 30 male children (15 patients for each ADHD subtype) were drawn from a larger sample of children (aged 7–12 years) who were consecutive referrals to a psychiatrist in Atiyeh Clinic. In order to secure sound subtype diagnoses in the selected sample of participants in the present study, inclusion criteria involved several assessments for subtype diagnosis: a) a psychiatrist diagnosis for ADHD subtypes, b) the implementation of a clinical interview checklist based on the DSM-IV-TR criteria, and c) the administration of the SNAP-IV questionnaire. Those participants who had used stimulant drugs were excluded from the study, due to drug effects on brain functioning and its interference with the aim of this study of examining neurofeedback training effects only. Additional exclusion criteria included confirmed co-morbid disorders, sensory-motor disability, epilepsy, and IQ scores lower than 85. Age and gender of participants was controlled in this study. Thus, all participants were 7–12 year old male children with an IQ score range of higher than or equal to 85, and had not taken medication for 3 months and two weeks (approximately 100–114 days) prior to participation in this study.

Procedure

The participants performed 40 sessions of neurofeedback (NF) training. The NF training protocol used consisted of theta/beta training. The goal was to decrease activity in the theta band (4–8 Hz) and high beta (18–30 Hz) and to increase activity in the beta band (13–20 Hz) of the EEG in (FZ), and to decrease activity in the theta band (4–8 Hz) and high beta (18–30 Hz) in (CZ). Pre-training assessments encompassed several behavior rating scales (DSM-

IV-TR Clinical Interview Checklist, SNAP-IV, IVA). The IVA scale was performed before and after 40 sessions NF training.

Instruments

DSM-IV-TR Clinical Interview Checklist. The clinical interview checklist based on DSM-IV-TR was used as one measure for the diagnosis ADHD participants. The substance of this checklist is in fact the same diagnostic criteria of DSM-IV-TR for inclusion and exclusion criteria of ADHD. It is structured on a question format and was completed by the mothers of the participating children.

SNAP-IV Rating Scale-Parent Form. The SNAP-IV Rating Scale used in the present study was the revised version of the Swanson, Nolan and Pelham (SNAP) Questionnaire (Swanson, Nolan, & Pelham, 1993). The SNAP-IV consists of Inattention, Hyperactivity/ Impulsivity, and Oppositional subscales (Bussing et al., 2008; Swanson et al., 2001). The SNAP-IV includes items from the DSM-IV (1994) criteria for two ADHD subsets of symptoms: inattention (items # 1–9) and hyperactivity/impulsivity (items # 10–18). Also, items are included from the DSM-IV criteria for Oppositional Defiant Disorder (ODD, items # 19–27) since ODD often is present in children with ADHD. The items are scored on a 4-point response scale, ranging from “0” to “3” (*Not at All* = 0, *Just A Little* = 1, *Quite a Bit* = 2, and *Very Much* = 3). The Chinese version of the SNAP-IV was reported to have satisfactory levels of reliability and concurrent validity (Liu et al., 2006). Results from an Iranian study, examining the psychometric properties of this test reported three orthogonal constructs following factor analysis, criterion validity (.48) and high alpha coefficient for reliability (.82).

Wechsler Intelligence Scale for Children-Revised (WISC-R). In this research, the revised version of WISC-R was used, which has been standardized with Iranian children 6–13 years old by Shahim (1998). Shahim’s (1998) research reported reliability coefficients ranged between .44 and .94.

The Integrated Visual and Auditory (I.V.A.) Test Battery. The Continuous Performance Test (CPT) is a subtest from the Integrated Visual and Auditory (IVA) battery of tests, used as a screening tool in conjunction with other diagnostic procedures (e.g., parent and teacher behavior rating scales, QEEG, T.O.V.A.) to assist in the screening of individuals with Attention Deficit Hyperactivity Disorder (ADHD). The computerized CPT involves the presentation of target and non-target stimuli. The test runs for 14 minutes and primarily assesses attention and impulse control (Conners, 1985; 2004). Briefly, participants are required to respond to the stimuli on a computer screen by pressing a space bar for every letter except for the letter “X”. In addition administration and scoring are computerized, removing the element of human errors. All IVA scores are presented both as raw scores and as quotient scores. The basis for statistical analysis is the same as that used for more IQ tests; all quotient scores have a mean of 100 and a standard deviation of 15 (Conners, 1985; 2004). The CPT was designed to discriminate ADHD populations from individuals with Conduct Disorder and those without behavior problems and is based on extensive research evidence (Chee, 1989; Connors, 2004). It has also been used to monitor the effectiveness of neurofeedback training and/or medication (Riccio, Reynolds, Lowe, & Moore, 2002). Reliability coefficient reported by Seckler, Burns, Montgomery, and Sandford (1995) with the test-retest method was 0/37- 0/75, and IVA was found to be a significantly stable measure of performance both globally and in terms of specific scales. The sensitivity of the IVA in being able to correctly identify ADHD children who were previously diagnosed by health professionals is 92%. The specificity (proportion of non-ADHD children who received a negative finding) was 90%. The positive predictive power is 89% and the number of false negatives 7.7% (lower than most other CPT subscales).

Results

In order to evaluate the effectiveness of neurofeedback training in neurocognitive rehabilitation of children diagnosed with ADHD subtypes IA and C, several steps were followed in data analysis. First of all, a t-test for dependent groups, without considering experimental groups, was computed for all participants between pre- and post-neurofeedback training scores for all IVA subscales. Results indicated that neurofeedback training had a significantly enhancing effect for all participants on all IVA subscales, with exception of one subscale (balance). These findings are depicted in Table 1.

Table 1
Means, Standard Deviations, and Difference Score t-tests for IVA Subscales for All Participant without Considering C and IA Subtypes

	M		***SD***			
Subscale of IVA	**Pre test**	**Post test**	**Pre test**	**Post test**	**Pre-Post t-test**	**Sig.**
Response control	74.00	110.86	42.26	8.58	4.69	0.05
Attention	37.46	76.33	26.15	16.70	8.71	0.001
Prudence	117.68	16.80	52.38	11.90	4.53	0.001
Consistency	122.38	165.40	47.56	14.22	4.76	0.001
Stamina	127.21	158.53	47.64	21.86	3.40	0.001
Vigilance	54.58	132.23	43.25	30.06	10.36	0.001
Focus	131.64	170.08	54.11	21.43	3.99	0.001
Speed	70.00	82.28	30.54	25.23	2.72	0.05
Readiness	134.43	159.53	49.03	16.14	2.88	0.001
Comprehension	70.03	126.53	46.17	26.64	3.35	0.001
Persistence	148.11	156.06	20.32	15.01	1.97	0.05
Sensory/motor	92.06	131.23	28.97	13.00	7.32	0.001
Sustained Attention	50.25	113.26	29.36	27.75	12.19	0.001
Balance	92.16	102.03	38.26	12.34	1.34	0.70
Hyperactivity	92.66	107.23	27.03	5.93	2.93	0.001

A MANCOVA analysis was computed in order to evaluate the effectiveness of neurofeedback training on IVA post-training performance. This analysis enabled a comparison of pre- post-training performance of two experimental groups, controlling for pre-training performance, as well as the simultaneous consideration of multiple IVA dependent measures. Results from this analysis yielded only one significant finding regarding IVA readiness subscale scores. The participants in the IA subtype obtained significantly higher readiness scores (F = 4467/61, P= 0/01) in comparison to participants from the C subtype, indicating a highly specific effect of neurofeedback training when comparisons are made considering these two categories of ADHD. No other results reached significance. Overall indices of significance of the MANOVA analysis are presented in Table 2. Table 3 depicts results from ANCOVA analysis. The result of this table, consistent with Table 2, showed that the effect of neurofeedback training did not differ in the two subtypes, except in the readiness subscale (F= 729/08, P=0/05).

Table 2
MANCOVA Analysis Overall Significance Indices of IVA Pre-Post Test Difference Scores Comparing Two ADHD Subtypes

Test	Value	*F*	df of the error	Sig.	Effect size
Pillai,s trace	1	4467.61	13	0.01	1
Wilk,s lambda	0	4467.61	13	0.01	1
Hotteling,s trace	58078.93	4467.61	13	0.01	1
Roy's Largest Root	58078.93	4467.61	13	0.01	1

Table 3
ANCOVA Analysis of IVA Pre-Post Test Difference Scores Comparing Two ADHD Subtypes

Variable	SS	df	MS	*F*	Sig.
Response control	71.32	1	71.32	2.10	0.17
Attention	24.90	1	24.90	0.08	0.74
Prudence	187.28	1	187.28	2.46	0.14
Consistency	398.51	1	398.51	2.08	0.17
Stamina	23.81	1	23.81	0.03	0.87
Vigilance	1007.21	1	1007.21	0.79	0.39
Focus	1193.14	1	1193.14	2.46	0.14
Speed	519.60	1	519.60	0.75	0.40
Readiness	729.08	1	729.08	3.97	0.05
Comprehension	609.96	1	609.96	0.75	0.40
Persistence	431.69	1	431.69	1.48	0.24
Sensory- motor	25.47	1	25.47	0.14	0.71
Sustained attention	81.58	1	81.58	0.10	0.75
Balance	100.79	1	100.79	0.51	0.48
Hyperactivity	4.16	1	4.16	0.15	0.70

Discussion

The main finding of the present study refers to the effectiveness of neurofeedback training in enhancing the neurocognitive rehabilitation of ADHD children, regardless of subtype classification. More specifically, participant children 7 to 12 years of age, who were diagnosed with ADHD, either IA or C subtypes, and who underwent neurofeedback training, showed improved performance on all IVA sub-scales, with exception of the readiness subscale (Table 1 and Table 3). An extensive number of research studies (Arns et al., 2009; Fox et al., 2005; Gani et al., 2009; Gevensebelen et al., 2009; Lofthouse et al., 2010; Monstra et al., 2005; Sherlin et al., 2010; Williams, 2010) support the effectiveness of neurofeedback training on decreasing the clinical symptoms associated with ADHD. In particular, the literature review performed by Sherlin and colleagues (2010) provide evidence of empirical findings supporting the effects of neurofeedback interventions in decreasing ADHD symptoms in all subtypes.

Neurofeedback has been found to be equally effective as interventions using medication (Rossiter & La Vaque, 1995; Monastra et al., 2005; Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Greco & Orlandi, 2004; Le´vesque, Beauregard, & Mensour, 2006), with long-term improvements estimated to last from 6 months (Leins et al., 2007) up to 2 years (Gani, Birbaumer, & Strehl, 2009).

It is important to note that in the present study, neurofeedback training proved efficient not only in decreasing symptoms of both ADHD subtypes, operationalized according to DSM-IV (American Psychiatry Association, 2000) criteria, but also demonstrated its neuropsychological rehabilitative utility, marked by massive decreases in cognitive deficits of participants. The exception to these findings was the result obtained with the IVA - Balance subscale. To the extent that this measure assesses visual or auditory cognitive dominant preferences for learning, it has been found to be sensitive to learning disorders (Standford &Turner, 1995). Since, for the purposes of the present study, it was desired that children conforming the experimental groups, be a free as possible from co-morbid disorders, the screening process in the present study involved excluding all children with learning disorders, and as such, it can be said that children participating in the present study did not have notorious learning disorders and thus, their performance on the Balance subscale fell within normal ranges, and neurofeedback training was irrelevant to the participant ADHD children’s performance on this measure.

Another important finding of the present study refers to the equal effectiveness of neurofeedback training, in terms of neuropsychological rehabilitation, for children from both attention deficiency (IA) and combined (C) ADHD subtypes. Neurofeedback training was differentially effective only in relation to the IVA Readiness subscale, having a significantly more enhancing effect upon children diagnosed with IA subtype, in comparison to those diagnosed with ADHD-C subtype. For interpretation of the undifferentiated results obtained regarding post-training performance of participant children from IA and C subtypes, neuroimaging data from structural and functional brain imaging studies indicates that the neural substrates underlying both subtypes could have been affected by NF training. For instance, on the one hand, the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) have been identified as two areas functionally responsible for ADHD attention deficits, including focusing, selective attention, vigilance, attention stability (deficits fundamentally associated with IA subtype), and, on the other hand, these same areas are equally involved in cognitive inhibition, response control, physical relaxation, motor response, motor regulation (deficits fundamentally associated with C subtype (Lubar et al., 1995). Moreover, given the assumption that neurofeedback training protocols administered in the present study directly affect brain-activation activity in these areas, it is expected that neurofeedback intervention in the present study should have affected most cognitive deficits associated to these cortical areas. To deepen our interpretation of findings, a description of brain dynamics seems appropriate at this point. Within a dynamic framework, it is assumed that the brain functions according to a complex neural network, conformed by a high number of nerve cells, which are related to each other in a systemic fashion, such that changes initiated in one area, will have an effect on other brain areas. For instance, the ACC sends signals to the Septum, PFC, and parietal cortex, and in this way communication with other brain areas is established (Lubar et al., 1995). Based on this information, it can be said that neurofeedback training affects brain areas involved in all variations of attention deficit and hyperactivity disorder, over and above ADHD subtypes.

Regarding the selective enhancement of performance among IA subtype children on the IVA readiness measure, it can be said that IA children, more so than children in the C subtype, are expected to be more pronouncedly deficient in resisting the inability to continue to pay attention to a task. In the present study, although both groups initially performed at the same level, it seems that neurofeedback training had a differentially rehabilitative enhancing impact on IA subtype children. In the past, the differential effects of neurofeedback training have been documented. For instance, neurofeedback therapy has been shown to be more effective in decreasing symptoms associated with attention deficiency, more so than symptoms related to hyperactivity and impulsivity (Butinik, 2005; Carmody, Radvansik, Wadhwani, Sabo & Vergara, 2001; Monastra, Monastra, & George, 2002).

Some limitations in this study have to be recognized. One main limitation of the present study was the use of DSM-IV-R criteria for subtype selection, which has been questioned due to the ambiguity and overlapping of symptoms. New theoretical and methodological developments in the study of ADHD have challenged the validity of subtype categories in attempting to conceptualize ADHD. Basically, researchers have begun to question whether ADHD subtypes are basically different in nature, and challenge the adequacy of the categorical approach, in comparison to the dimensional approach, in explaining observed differences in the disparate groups of affected individuals that are included within this disorder. Fundamentally, new hypotheses should center on the question of whether phenotypic differences observed in the disorder’s symptoms, are differences in degree of severity and represent quantitative differences in hyperactivity, impulsivity and inattention along a single continuum, or these differences reflect separate categories or subtypes which are qualitatively different from each other (Lubke et al., 2007). In addition, it has been said that DSM-IV-R criteria fail to properly discriminate IA and C subtypes as they truly are (Hinshow, 2001; Lahey, 2001). Future research is warranted to include more adequate criteria, beyond that offered by DSM-IV-R, in classifying children according to ADHD subtypes. It is possible that when using different criteria, neurofeedback training may yield different results. Also, more recently, researchers (Chhabildas, Pennington, & Willcut, 2001; Ogrim, Kropotov, & Hestad, 2012; Thompson & Thompson, 2009) are attempting to break new ground in search of better methods for classification of ADHD subtypes, which seriously questions the appropriateness of using DSM-IV-R criteria. In this approach, ADHD individuals are classified based on different neuropsychological patterns of brain wave activity revealed in quantitative electroencephalograms (QEEG). It remains to be seen whether this new approach offers advantages over present methods in terms of clinical utility for diagnosis and treatment of ADHD children. However, it must be mentioned that this new approach will offer a clear advantage to neurofeedback training in terms of guiding the type of protocols to be used in different interventions based on different wave activity patterns of ADHD patients. Therefore, it is recommended that future research evaluate the neuropsychological profiles of subtypes of ADHD based on DSM-IV-R criteria. Likewise, using different measures to evaluate treatment outcome will be appropriate. For example, the Cambridge Neuropsychological Test Automated Battery (CANTAB), has been used in preterm children, children with typical development, and children with neuro-developmental disorders such as ADHD and autism, is a computerized battery of EF which specifically includes measures of frontal lobe function (Luciana, Lindeke, Georgieff, Mills, & Nelson, 1999; Curtis, Lindeke, Georgieff, & Nelson, 2002).

Another limitation concerns the recordings of baseline in pre- and post-treatment. Our subjects were ADHD boys 8–12 years old that did not take any medication across 40 session's neurofeedback. As such, recording the baseline in the first 5–6 sessions of neurofeedback was not possible due to the hyperactivity and impulsivity of participant children. As a result, a comparison of pre- and post-treatment baseline is not possible in the present study. However, comparison of QEEG data before and after treatment is an alternative for this purpose. In this study we obtained pre-treatment QEEG information only for diagnostic purposes (the comparison of QEEG patterns in two subtypes will constitute a separate research). Such comparative examinations of pre- and post-neurofeedback in two subtypes is suggested for future research studies.

In conclusion, in spite of these limitations, the present findings supported the effectiveness of neurofeedback training in enhancing the neurocognitive rehabilitation of ADHD children, regardless of subtype classification.

Acknowledgment. The authors would like to appreciate the collaboration of Atieh Neuropsychological Clinic for facilitating patients and their parents as well as its research facilities, without which performing this research would not have been possible.

References

Abedi, A., Jamali, S., Faramarzi, S., Aghayi, E., & Behruz, M. (2012). A comprehensive meta-analysis of the common interventions in ADHD. *Contemporary Psychology, 7*(1), 17–34.

Arnsten, A. F. T., & Dudley, A. G. (2005). Methylphenidate improves prefrontal cortical cognitive function through α2 adrenoceptor and dopamine D1 receptor actions: Relevance to therapeutic effects in attention deficit hyperactivity disorder. *Behavioral and Brain Functions*, *1*, 2.

Arns, M., deRidder, S., Strehl, U., Breteler, M., & Coenon, A. (2009). Efficacy of neurofeedback in ADHD: The effects on inattention, impulsivity and hyperactivity: A meta analysis. *EEG and Clinical Neuroscience, 40*, 180–189. http://dx.doi.org/10.1177/155005940904000311

Babayi, L. (2001). The examination of effect of methylphenidate and three cyclic drugs in treatment of ADHD. (Doctoral dissertation), Kermanshah Medical Science University, Kermanshah, Iran.

Bakhshayesh, A. R. (2007). The efficacy of neurofeedback compared to EMG biofeedback in the treatment of ADHD children (Doctoral dissertation), Universität Potsdam.

Barabasz, A., & Barabasz, M. (1996). Attention deficit hyperactivity disorder: Neurological basis and treatment alternatives. *Journal of Neurotherapy, 1*, 23–45. http://dx.doi.org/10.1300/J184v01n01_01

Barkley, R. A. (1997). Behavioural inhibition, sustained attention and executive function: Constructing a unify theory of ADHD. *Psychological Bulletin. 121*, 65–94.

Barkley, R. A. (2003). Attention-deficit/hyperactivity disorder. In E. J. Mash & R. A. Barkley (Eds.), *Child psychopathology* (2nd ed., pp. 75–143). New York, NY: Guilford Press.

Barkley, R. A. (2005). ADHD and the Nature for Self-Control. New York, NY: Guilford press.

Barkley, R. A. (2006). Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment. (3rd Ed.). New York, NY: Guilford Press.

Barkley, R. A., & Cunningham, C. E. (1979). Do stimulant drugs improve the academic performance of hyperkinetic children? *Clinical Pediatrics, 17*(1), 85–92.

Barkley, R. A., McMurray, M. B., Edelbrock, C. S., & Robbins, K. (1990). Side effects of methylphenidate in children with attention deficit hyperactivity disorder: A systematic, placebo-controlled evaluation. *Pediatrics, 86*(2), 184–192.

Barkley, R. A. (2012). Barkley Deficits in Executive Functioning Scale—Children and Adolescents (BDEFS-CA). New York, NY: Guilford Press.

Banaschewski, T., & Brandeis, D. (2007). Annotation: What electrical brain activity tells us about brain function that other techniques cannot tell us—A child psychiatric perspective? *Journal of Child Psychology and Psychiatry, 48*(5), 415–435.

Booth, J. R. Burman, D. D., Meyer, J. R., Lei, Z. Trommer, B. L., Davenport, N. D., … Mesulam, M. M. (2005). Larger deficits in brain networks for response inhibition than for visual selective attention in attention deficit hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry*, *46*(1), 94–111. http://dx.doi.org/10.1111/j.1469-7610.2004.00337.x

Brown. T. E. (2006). The inattentive type of ADHD as a distinct disorder: What remains to be done. *Clinical Psychology: Science and Practice, 8*(4), 489–493.

Bidwell, L. C., McClernon, F. J., & Kollins, S. H. (2011). Cognitive enhancers for the treatment of ADHD. *Pharmacology, Biochemistry and Behaviour, 99*, 262–274. http://dx.doi.org/10.1016/j.pbb.2011.05.002

Burns, G. L., Boe, B., Walsh, J. A., Sommers-Flannagan, R., & Teegarden, L. A. (2001). A confirmatory factor analysis on the DSM-IV ADHD and ADD symptoms: What is the best model for the organization of these symptoms? *Journal of Abnormal Child Psychology, 29*, 339–349.

Bussing, R., Fernandez, M., Harwood, M., Wei Hou, Garvan, C. W., Eyberg, S. M., Swanson, J. M. (2008). Parent and teacher SNAP-IV ratings of attention deficit hyperactivity disorder symptoms: Psychometric properties and normative ratings from a school district sample. *Assessment, 15*(3), 317–28. http://dx.doi.org/10.1177/1073191107313888

Butinik, S. M. (2005). Neurofeedback in adolescents and adults with attention deficit hyperactivity. *Journal of Clinical Psychology, 61*, 621–625. http://dx.doi.org/10.1002/jclp.20124

Butcher, A. T. (2000). Symptom dimensions and neurocognitive functioning in adult ADHD (Doctoral dissertation), Virginia Polytechnic Institute and State University, U.S.A.

Casey, B. J., Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D, Schubert, A. B., … Rapoport, J. L. (1997). Implication of right frontostriatal circuitry in response inhibition and attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 36,* 374 –383.

Camobel, N. G. (2003). The central auditory processing and continued performance of children with attention deficit hyperactivity disorder (ADHD) in the medicated and non-medicated state (Doctoral dissertation), University of Pretoria, South Africa.

Carmody, D. P., Radvansik, D. C., Wadhwani, S., Sabo, M. J., & Vergara, L. (2001). EEG biofeedback training and attention-deficit/hyperactivity disorder in an elementary school setting. *Journal of Neurotherapy, 4*(3), 5–27. http://dx.doi.org/10.1300/J184v04n03_02

Chemark, G. D., Hall. J. W., & Musiek. F. E. (1999). Differential diagnosis and management of central auditory processing disorder and attention deficit disorder. *Journal of the American Academy of Audiology, 10,* 289–303.

Chhabildas, N., Pennington, B. F., & Willcutt, E. G. (2001). A comparison of the neurological profiles of the DSM-IV subtypes. *Journal of Abnormal Child Psychology, 29,* 520–540.

Conners, C. K. (2004). Conners' Continuous Performance Test-Version II (CPT-II). Windows Technical Guide and Software Manual, New York, MHS.

Curtis, W. J., Lindeke, L. L., Georgieff, M. K., & Nelson, C. A. (2002). Neurobehavioral functioning in neonatal intensive care unit graduates in late childhood and early adolescence. *Brain: A Journal of Neurology, 125*(7), 1646–59. http://dx.doi.org/10.1093/brain/awf159

Diamond, A. (2005). Attention disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurologically and behaviourally distinct disorder from attention deficit/ hyperactivity disorder (with hyperactivity). *Development and Psychopathology, 17*, 807–825.

Drechsler, R., Straub, M., Doehnert, M., Heinrich, H., Steinhausen, H., & Brandeis, D. (2007). Controlled evaluation of a neurofeedback training of slow cortical potentials in children with ADHD. *Behavioral and Brain Functions, 3,* 35.

Esmaieli, T., Bahriniyan, A., & Hahemiyan, P. (2004). The examination of effect the behavior therapy with and without methylphenidate in ADHD children. *Journal of Research in Medical Science, 29,* 135–140.

Faraone, S. V., & Buitelaar, J. (2009). Comparing the efficacy of stimulants for ADHD in children and adolescents using meta-analysis. *European Child and Adolescent Psychiatry, 19,* 353–364. http://dx.doi.org/10.1007/s00787-009-0054-3

Fischer, M., Barkley, R. A., Smallish, L., & Fletcher, K. (2005). Executive functioning in hyperactive children as young adults: Attention, inhibition, response perseveration, and the impact of co-morbidity. *Developmental Neuropsychology, 27*(1), 107–133. http://dx.doi.org/10.1207/s15326942dn2701_5

Fox, D. G., Tharp, D. F., & Fox, L. C. (2005). Neurofeedback: An alternative and efficious treatment for attention deficit hyperactivity disorder. *Applied Psychophysiology and Biofeedback, 30,* 365– 373.

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.

Fuster, J. M. (2008). The prefrontal cortex (4th ed.). London, U.K.: Elsevier.

Gani, C., Birbaumer, N., & Strehl, U. (2009). Long term effect after feedback of slow cortical potentials and theta- beta- amplitudes in children with attention deficit hyperactivity disorder. *International Journal of Bioelectromagnetics, 10*, 209–232.

Gevensleben, H., Holl, B., Akbrecht., B., Vogel, C., Schlamp, D., & Kratz, O. (2009). Is neurofeedback an efficacious treatment for ADHD? A randomised controlled clinical trial. *Journal of Child Psychology and Psychiatry, 50*, 780–789. http://dx.doi.org/10.1111/j.1469-7610.2008.02033.x

Goldman, R. D. (2010). ADHD stimulants and their effect on height in children. *Canadian Family Physician, 56*(2), 145–146.

Halperin, J. M., & Healy, M. H. (2011). The influences of environmental enrichment, cognitive enhancement, and physical exercise on brain development: Can we alter the developmental trajectory of ADHD? *Neuroscience and Biobehavioral Review, 35(3),* 621–634. http://dx.doi.org/10.1016/j.biopsych.2003.11.013

Holtmann, M., Grassmann, D., Cionek-Szpak, E., Hager, V., Panzer, N., Beyer, A., Poustka, F. & Stadler, C. (in press). Specific effects of neurofeedback on impulsivity in ADHD. *Kindheit und Entwicklung, 18,* 95–104.

Heinrich, H., Gevensleben, H., Freisleder, F. J., Moll, G. H., & Rothenberger, A. (2004).Training of slow cortical potentials in attention-deficit/hyperactivity disorder: Evidence for positive behavioral and neurophysiological effects. *Biological Psychiatry,* 55, 772–775. http://dx.doi.org/10.1016/j.biopsych.2003.11.013

Hinshaw, S. P. (2001). Is the inattentive subtype of ADHD a separate disorder? *Clinical Psychology, Science and Practice, 8*, 498–501.

Imani, R., (2009). Comparing the effect of two drugs (Ritalin) in treatment of children and adolescent with ADHD (Doctoral dissertation), Tehran University, Iran.

Kaplan, H. I., Sadock, B. J., & Grebb, J. A. (Eds.). (2003). Synopsis of psychiatry (9th ed.). Baltimore, MD: Williams & Wilkins.

Kaiser, D. A., & Othmer, S. (2000). Effects of neurofeedback on variables of attention in a large multi-center trial. *Journal of Neurotherapy, 4*(1), 5–15. http://dx.doi.org/10.1300/J184v04n01_02

Karatekin, C. (2006). Improving antisaccade performance in adolescents with attention-deficit/hyperactivity disorder (ADHD). *Experimental Brain Research, 17* (2), 324–341. http://dx.doi.org/10.1007/s00221-006-0467-x

Karahmadi, M. (2007). Comparing the effect of Iranian methylphenidate with foreign version of this drug in the treatment of ADHD (Doctoral dissertation), Medical Science University, Isfahan, Iran.

Klingberg, T. (2009). The overflowing brain: Information overload and the limits of working. New York, NY: Oxford University Press.

Lahey, B. B. (2001). Should the combined and predominantly inattentive type of ADHD be considered distinct and unrelated disorder? Not now, at least. *Clinical Psychology, Science and Practice, 8*, 494–497. http://dx.doi.org/10.1093/clipsy.8.4.494

Leins, U., Goth, G., Hinterberger, T., Klinger, C., Rumpf, N., & Strehl, U. (2007). Neurofeedback for children with ADHD: A comparison of SCP and theta/beta protocols. *Applied Psychophysiology and Biofeedback, 32*, 73–88. http://dx.doi.org/10.1007/s10484-007-9031-0

Levesque, J., Beauregard, M., & Mensour, B. (2006). Effect of neurofeedback training on the neural substrates of selective attention in children with attention-deficit/hyperactivity disorder: A functional magnetic resonance imaging study. *Neuroscience Letters, 394(3),* 216–221. http://dx.doi.org/10.1016/j.neulet.2005.10.100

Linden, M., Habib, T., & Radojevic, V. (1996). A controlled study of the effects of EEG biofeedback on cognitive and behaviour of children with attention deficit disorder and learning disabilities. *Biofeedback and Self-Regulation, 21*, 35–49.

Liu, Y. C., Liu, S. K., Shang, C. Y., Lin, C. H., Tu, C. L., & Gau, S. S. F. (2006). Norm of the Chinese version of the Swanson, Nolan, and Pelham, version IV scale for ADHD. *Taiwanese Journal of Psychiatry, 20*, 290–304.

Lofthouse, N. A., Hersch, S., Hurt, E., & DeBeus, R. (2012). A review of neurofeedback treatment for pediatric ADHD. *Journal of Attention Disorders, 16*, 351–72. http://dx.doi.org/10.1177/1087054711427530

Loo, S. K., & Barkley, R. A. (2005). Clinical utility of EEG in attention deficit hyperactivity disorder. *Applied Neuropsychology, 12* (2), 64–76. http://dx.doi.org/10.1207/s15324826an1202_2

Lubar, J. F. (1991). Discourse on the development of EEG diagnostics and biofeedback for attention deficit hyperactivity disorders. *Applied Psychophysiology and Biofeedback, 16*, 201–225.

Lubar, J. F. (2003). Neurofeedback for the management of attention-deficit/hyperactivity disorders. In M. S. Schwartz & F. Andrasik (Eds.), *Biofeedback: A practitioners guide* (3rd ed.). New York, NY: Guilford Press.

Lubar J. F., & Shouse M. N. (1967). EEG and behavioral changes in a hyperkinetic child concurrent with training of the sensorimotor rhythm (SMR): A preliminary report. *Biofeedback Self-Regulation, 1*(3) 293–306.

Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & Timmermann, D. L. (1995). Quantitative EEG and auditory event-related potentials in the evaluation of attention-deficit/hyperactivity disorder: Effects of methylphenidate and implications for neurofeedback training. *Journal of Psycho-Educational Assessment*, *ADHD Special*, 143–160.

Luciana, M., Lindeke, L., Georgieff, M., Mills, M., & Nelson, C. A. (1999). Neurobehavioral evidence for working-memory deficits in school-aged children with histories of prematurity. *Developmental Medication and Child Neurology, 41*(8), 521–33.

Mashhadi, A. (2009). Study of executive functions and effect of treatment (medication, executive function training and combination of two methods) in rehabilitation of executive function and decrease clinical symptoms in ADHD children (Doctoral dissertation), Tarbiat Modares University, Tehran, Iran.

Makris, N., Biederman, J., Valera, E. M., Bush, G., Kaiser, J., Kennedy, D. N., … Seidman, L. J. (2007). Cortical thinning of the attention and executive function networks in adults with attention-deficit/hyperactivity disorder. *Cerebral Cortex, 17*, 1364–1375. http://dx.doi.org/10.1093/cercor/bhl047

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 Psychology and Biofeedback, 27*, 231–249. http://dx.doi.org/10.1007/s10484-005-4305-x

Millstein, R. B., Wilens, T. E., Biederman, J., & Spencer, T. J. (1998). Presenting ADHD symptoms and subtypes in clinically referred adults with ADHD. *Journal of Attention Disorder, 2,* 159–166. http://dx.doi.org/10.1177/108705479700200302

Milich, R., Ballentine, A. C., & Lynam, D. R. (2001). ADHD/combined type and ADHD/predominantly inattentive type are distinct and unrelated disorders. *Clinical Psychology: Science and Practice, 8,* 463–468. http://dx.doi.org/10.1093/clipsy.8.4.463

Molina, B. S., Hinshaw, S. P., Swanson, J. M., Arnold, L. E. (2009). The MTA at 8 years: Prospective follow-up of children treated for combined type ADHD in a multisite study. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*, 484–500. http://dx.doi.org/10.1097/CHI.0b013e31819c23d0

Monastra, V. J., Monastra, D. M., & George, S. (2002). Effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of attention deficit/hyperactivity disorder. *Applied Psychophysiology and Biofeedback*, *27*(4), 231–49.

Nigg, J. T. (2006). What causes ADHD? Understanding what goes wrong and why? New York, NY: Guilford Press.

Nigg, J., Willcutt, E., Doyle, A., & Sonuga-Brake, E. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychological impaired subtypes? *Biological Psychiatry, 57,* 1224–1230. http://dx.doi.org/10.1016/j.biopsych.2004.08.025

Patoine, B. (2009). ADHD studies target circuitry stimulants' effects. *The DANA Foundation, 17*.

Pillow, D. R., Pelham, W. E., Hoza, B., Molina, B. S. G., & Stulz, C. H. (1998). Confirmatory factor analysis examining attention deficit hyperactivity disorder symptoms and other childhood disruptive behaviours. *Journal of Abnormal Child Psychology, 26*, 293–309.

Riccio, C. A., Reynolds, C. R., Lowe, P., & Moore, J. J., (2002). The continuous performance test: A window on the neural substrates for attention? *Archives of Clinical Neuropsychology, 17,* 235–272. http://dx.doi.org/10.1093/arclin/17.3.235

Rossiter, T. R. (2004). The effectiveness of neurofeedback and stimulant drugs in treating AD/HD: Part II. Replication. *Applied Psychophysiology & Biofeedback, 29*(4), 233–243. http://dx.doi.org/10.1007/s10484-004-0383-4

Rossiter, T. R., & La Vaque, T. J. (1995). A comparison of EEG biofeedback and psycho stimulants in treating attention deficit hyperactivity disorders. *Journal of Neurotherapy, 1,* 48–59. http://dx.doi.org/10.1300/J184v01n01_07

Seckler, P., Burns, W., Montgomery, D., & Sandford, J. A. (1995). *A Reliability Study of IVA: Integrated Visual and Auditory Continuous Performance Test.* Presented at the Child and Adolescent Developmental Disorders (CHADD) Annual Convention, Washington D.C., U.S.A.

Sherlin, L., Arns, M., Lubar, J., & Sokhadz, E. (2010). A position paper on neurofeedback for treatment of ADHD. *Journal of Neurotherapy, 14,* 66–78. http://dx.doi.org/10.1080/10874201003773880

Shaw, P., Eckstrand. K., Sharp. W., Blumenthal. J., Lerch. J. P., Greenstein, D., ... Rapoport, J. L. (2007). Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation. *Proceedings of the National Academy of Sciences of the United States of America, 104,* 19649–19654. http://dx.doi.org/10.1073/pnas.0707741104

Shaw, P., Gogtay, N., & Rapoport, J. (2010). Childhood psychiatric disorders as anomalies in neurodevelopmental trajectories. *Human Brain Mapping, 31,* 917–925. http://dx.doi.org/10.1002/hbm.21028

Sandford, J. A., & Turner, A. (1995). *Manual for the Integrated Visual and Auditory (IVA) Continuous Performance Test*. Richmond, Virginia: Brain Training.

Sonuga-Barke, E. J, Daley, D., Thompson, M., Laver-Bradbury, C., & Weeks, A. (2001). Parent-based therapies for pre-school attention-deficit/hyperactivity disorder: A randomized controlled trial with a community sample. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*, 402–408. http://dx.doi.org/10.1097/00004583-200104000-00008

Sonuga-Barke, E. J. S., Sergeant, J. A., Nigg, J., & Wilcutt, E. (2008). Executive dysfunction and delay aversion in attention deficit hyperactivity disorder: nosologic and diagnosis implication. *Child and Adolescent Psychiatric Clinics of North America, 17*, 376–384. http://dx.doi.org/10.1016/j.chc.2007.11.008

Sergeant, J. A., Oosterlaan, J., & Van der Meere, J. J. (1999). Information processing and energetic factors in attention deficit/hyperactivity disorder. In H. C. Quay & A. Hogan (Eds.), *Handbook of disruptive behavior disorders* (pp. 75–104). New York, NY: Plenum Press.

Shirazi, A. (2005). Primary study of the effect of Floxitin on ADHD. *Journal of Cognition and Behavior, 1,* 15–23.

Strehl, U., Leins, U., Goth, G., Klinger, C., Hinterberger, T., & Birbaumer, N. (2008). Self-regulation of slow cortical potentials: A new treatment for children with attention-deficit/hyperactivity disorder. *Pediatrics, 118,* 1530–1540. http://dx.doi.org/10.1542/peds.2005-2478

Swanson, J. M., Nolan, W., & Pelham, W. E. (1993). *The SNAP-IV Rating Scale.* Retrieved February 28, 2014from http://www.adhd.net

Swanson, J. M., Kraemer, H. C., Hinshaw, S. P., Arnold, L. E., Conners, C. K., Abikoff, H. B., … Wu, M. (2001). Clinical relevance of the primary findings of the MTA: Success rates based on severity of ADHD and ODD symptoms at the end of treatment. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*(2)*,* 168–79. http://dx.doi.org/10.1097/00004583-200102000-00011

Ogrim, G., Kropotov, J., & Hestad, K. (2012). The QEEG theta/beta ratio in ADHD and normal controls: Sensitivity, specificity, and behavioural correlates. *Psychiatry Research, 198*(3), 482–488. http://dx.doi.org/10.1016/j.psychres.2011.12.041

Pastor, P. N., & Reuben, C. A. (2008). Diagnosed attention deficit hyperactivity disorder and learning disability: United States. *Vital Health Statistics 10*, 1–14.

Thompson, M., & Thompson, L. (2009). Neurofeedback for ADHD. In T. Budzynski, H. Budzynski, J. Evans, & A. Abarbanel (Eds.), Introduction to quantitative EEG and neurofeedback: Advanced theory and applications (2nd ed., pp. 337–364). New York, NY: Academic Press, Elsevier.

Van Mourik, R., Oosterlaan, J., & Sergeant, J. A. (2005). The Stroop revisited: A meta-analysis of interference control in AD/HD. *Journal of Child Psychology and Psychiatry, 46*, 150–165. http://dx.doi.org/10.1111/j.1469-7610.2004.00345.x

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Farone, S. V., & Penningtone, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analysis review. *Biological Psychiatry, 57*(11), 1336–1346. http://dx.doi.org/10.1016/j.biopsych.2005.02.006

Williams, J. M. (2010). Does neurofeedback help reduce attention-deficit hyperactivity disorder? *Journal of Neurotherapy, 14*(4), 261–279. http://dx.doi.org/10.1080/10874208.2010.523331

White, H. A., Shah, T. (2006). Uninhibited imaginations: Creativity in adults with attention-deficit/hyperactivity disorder. *Personality and Individual Differences, 40*, 1121–1131. http://dx.doi.org/10.1016/j.paid.2005.11.007

Yaghubi, H. (2007). Comparing the effect of neurofeedback, Ritalin and combined treatment in decrease of symptoms in ADHD children. (PhD Dissertation), Rehabilitation Science University, Tehran, Iran.

Young. S., & Amarasinghe, J. M. (2010). Practitioner review: Non-pharmacological treatments for ADHD: A lifespan approach. *Journal of Child Psychology and Psychiatry, 51(2)*, 116–133. http://dx.doi.org/10.1111/j.1469-7610.2009.02191.x

Yang, R. (2010). Does medication benefit the long-term psychiatric outcomes of children with ADHD? *The British Journal of Psychiatry, 197*(5), 414–414. http://dx.doi.org/10.1192/bjp.197.5.414

Xiong, Z., Shi, S., & Xu, H. (2005). A controlled study of the effectiveness of EEG biofeedback training on children with attention deficit hyperactivity disorder. *Journal of Huazhong University of Science and Technology, 25*(3), 368–370.