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The Effect of Psycho-Educational Therapy on Electroencephalographic Biofeedback Scores in Attention Deficit Hyperactivity Disorder

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1. Introduction

Attention deficit/Hyperactivity (ADHD) disorder, a neuropsychiatric disorder characterized by inattention, hyperactivity and impulsivity, has been precisely described by the American Psychiatric Association (APA, DSM-IV, 2000). According to the diagnostic criteria these main symptoms must appear before the age of 7 years, be present for at least 6 months, be evident in at least two settings, and the impairment must contribute to social, academic, or occupational dysfunction. An increasing number of patients, mostly children, are diagnosed with ADHD. Recent studies focusing on the epidemiology of the disorder, reported variable prevalence of ADHD in childhood that reached in some studies the percentage of 14% (Barbaresi et al, 2004; Froehlich et al, 2007; Pliszka, 2007; Merinkagas et al, 2010; CDC, 2010). It is estimated that 30-70% of children with ADHD continue to experience ADHD symptoms into adulthood (Vollmer, 1998; Wender, 1997; Mannuzza et al, 1991; Elia et al, 1999).

The therapeutic approach of ADHD includes several treatment modalities (pharmacotherapy, behavioral, psychological and educational interventions). The choice of treatment depends mainly on the patient's characteristics such as age at diagnosis, the presence of co-morbid conditions and the therapeutic goals. Behavioral interventions alone have not been effective in ameliorating the core symptoms of ADHD to a significant extent (The Multimodal Treatment study of Children with ADHD [MTA], 1999; Brown et al, 2005). Their main contribution is the improvement of the behavioral problems that frequently accompany ADHD (Kolko et al, 1999; Pelham et al, 1998). Pharmacotherapy is one of the most efficacious treatment approaches both in children and adolescents. Stimulants have been for many years the first-line treatment for ADHD with a response rate of approximately 70% or more when patients are strictly complying with the treatment (MTA, 1999; Miller et al, 1998; Schachter et al, 2001). Atomoxetine seems to be about equally effective to stimulants, even though in a recent meta-analysis it was reported that stimulants (especially the long-lasting ones) demonstrated greater efficacy than atomoxetine during the short duration of treatment evaluation (≥ 2 weeks) (Wang et al, 2007; Faraone & Glatt, 2010). In most of the patients it is beneficial to combine medications with psychological and educational interventions especially when there is a suboptimal response to pharmacotherapy, a co-morbid disorder and stressors in the family. A systematic review of 11 randomized controlled trials, including 428 children 5-18 years old, demonstrated that combination therapy with methylphenidate and behavioral/psychological treatments significantly improved ADHD behaviors, symptoms, and measures of academic achievement compared to behavior/psychological treatments alone (Lord & Paisley, 2000). Guidelines on the management of ADHD in children include all aforementioned options, alone or in combination (American Academy of Pediatrics, 2001; Golgman et al, 1998; Dulcan, 1997).

The next important issue on ADHD management is the duration of the positive effects of these interventions. For example, the long term efficacy of medications has not been demonstrated. The Multimodal Treatment Study of Children with the combined type of ADHD (MTA study), which compared pharmacotherapy- short acting methylphenidate - versus behavioral therapy or their combination or the standard care provided by community providers, reported in 2004 that treatment with stimulants for 24 months had a reduced effect, as compared to the effectiveness at 14-months published by the same group (MTA, 2004). At 3 years of follow-up of the same patients, the advantage of medications in comparison to all other treatment options disappeared although in all treatment groups an improvement on ADHD symptoms was observed compared to baseline (Jensen et al, 2007). The possible explanations of the loss of the pharmacotherapy advantage over all other treatments were an age-related decline in ADHD symptoms, changes in the intensity of medical management, and alternating periods of treatment/no-treatment after the 14 month study period. In 2002, Monastra et al demonstrated that patients treated with short acting stimulants (Ritalin) lost the benefits derived from the drugs one year after cessation of the drug (Monastra et al, 2002). Similar results had also been presented on the long term effectiveness of atomoxetine, 9 months after drug discontinuation (Michelson et al, 2004). All these observations along with the fact that 25–40% of children with ADHD do not respond to medications and other conservative treatments makes the research on alternative therapeutic approaches an interesting field (MTA, 1999; Pelham et al, 1998; Miller et al, 1998; Swanson et al, 1993; Barkley, 1998).

Neurofeedback, a form of biofeedback linked to brain activity, was first described as an option for ADHD treatment in the mid-1970's, by Lubar and Shouse (Lubar & Shouse, 1976). The hypothesis behind the use of this method is that it may enable the user to modify brainwave activity in order to improve attention, reduce impulsivity and control hyperactive behavior. This modification is based on self-regulation of neuronal oscillations recorded by EEG. The goal is to enhance some types of EEG activity or reduce some others in one or more frequency bands by visual or auditory feedback; for example in ADHD, the aim is to enhance beta activity and to inhibit theta activity. There are two major categories of neurofeedback training protocols: one that uses frequency bands of the brain activity and a second which involves training of slow cortical potentials (SCPs), with the first being far more studied than the latter (Vernon et al, 2004). Concerning the first training strategy, three parameters are usually used in children with ADHD: theta frequency (4-8 Hz), beta frequency (15-20 Hz) and sensorimotor rhythm (SMR) (12-15 Hz). The target of the patient under training is to decrease the power of theta activity and/or to increase power of beta activity and SMR activity, in order to improve attention skills. Research protocols usually combine two or even more parameters. SCPs were first described by Heinrich et al in 2004 (Heinrich et al, 2004). They are event-related shifts of cortical activity lasting from several hundred milliseconds to several seconds (Birbaumer et al, 1990). The training of the SCPs involves an effort to increase positivity or negativity over sensorimotor cortex, in order to enable the subject to control cortical regulation and to allocate resources efficiently, functions that are supposed to be impaired in ADHD (Sergeant, 2000; 2005).

Several studies have demonstrated that neurofeedback has a favorable effect on ADHD symptomatology and cognitive function, as compared to both placebo and psychostimulants, regardless of the protocol used (Monastra et al, 2002; Arns et al, 2009; Gevensleben et al, 2009a, Drechsler et al, 2007; Heinrich et al, 2007; Levesque et al, 2006; Rossiter, 2004; Fuchs et al, 2003). Furthermore, in 2010, Gevensleben H et al published a 6 months follow-up study providing evidence for long-term benefits of neurofeedback training in children with ADHD (Gevensleben et al, 2010).

In spite of these promising results considerable controversy continues to surround neurofeedback as a therapeutic option for ADHD patients. The skepticism towards this type of training is based mostly on methodological shortcomings of the published research. Small sample size, non-randomized group assignment, and control conditions that do not control for confounding factors since they lack a double-blind setup are the major design problems, that are not easy to overcome (Heinrich et al, 2007). It is questionable whether behavioral improvements after neurofeedback training can be related to the improved cortical regulation or rather to non-specific treatment effects such as invested time and attention, therapist- patient interaction, expectancies, changes in the parental attitude, enhanced awareness of the problem or maturation-related factors. Since systematic reinforcement and a positive relationship to a therapist are integral parts of the neurofeedback training and of any other behavioral intervention especially with children, selective effects of the neurofeedback are difficult to isolate (Drechsler et al, 2007). The best way to resolve this is the correct choice of a control group. However, the implementation of a control condition for neurofeedback training is also difficult. For research purposes, the best control condition would be a placebo neurofeedback condition in which provided feedback is similar to neurofeedback, but not related to the child's own brain activity. The main advantage of this type of control condition would be that it could allow participating children, parents and trainers to be blinded for group allocation; thus confounding factors would be minimized. However, implementing a placebo control condition in a randomized controlled trial may lead to ethical concerns, mostly because this design also involves withholding evidence-based treatment (LaVaque & Rossiter, 2001; Strehl et al, 2006). Moreover, it has been argued that placebo neurofeedback training may not be feasible since positive or negative therapeutic effects will be perceived by the patient or the therapist (Kotchoubey et al, 2001). Additionally, in a placebo-controlled study it is important to monitor adverse events during the training period in order to test the safety of the placebo condition, that could potentially represent a problem in this type of setting (Birbaumer et al, 1992). For these reasons, the use of a placebo-control study design is rather limited. To our knowledge, only one double-blind placebo-controlled trial has already been published (Lansbergen et al 2011). Other types of control groups that have been utilized are a waiting list control group (Heinrich et al, 2004; Levesque et al, 2006), children undergoing group therapy (Drechsler et al, 2007), and a group undergoing computerized attention training (Gevensleben et al, 2009a). Group therapy and computerized attention training may effectively control for unspecific effects such as invested time and treatment expectancies. Waiting list, on the other hand, may introduce bias because of maturational changes, multiple testing or changed parental attitudes (Drechsler et al, 2007). Finally, it has also been argued that neurofeedback training protocols may have a selection bias by design. Given the financial investment and time commitment required for the completion of neurofeedback training program, the majority of children who receive such a treatment are most likely from "stable, upper socioeconomic households, who may have simply improved over time because of their advantaged position" (Baydala & Wikman, 2001).

Nevertheless, the evidence provided by the most recent and better designed studies is considered to be substantial if not yet conclusive and the use of neurofeedback training for ADHD had gained empirical support. In addition to the accumulating evidence on the effectiveness of neurofeedback in patients with ADHD, it is now suggested that this treatment may be integrated in a multimodal therapeutic approach (Gevensleben et al, 2009a; MTA, 1999). The combination of neurofeedback with standard therapies such as pharmacotherapy, and/or social skills training and parental interventions could result in additional improvements not only to the primary symptoms of the disorder but to other related areas such as learning, behavior and emotional stability. The aim of this study was to explore the interactions between neurofeedback and a program of psychological and educational interventions prescribed for the management of ADHD. Our hypothesis was that the combination of these treatments may induce larger improvements of the examined electrophysiological parameters studied than neurofeedback alone, suggesting a synergistic effect of these two treatment modalities on brain training.

2. Methods

2.1 Patients

Children consecutively evaluated in the outpatient Child Neurology clinic with an ADHD diagnosis according to DMS IV criteria were considered as candidates for this study. Only children that scored within the normal IQ range (IQ>80), according to WISC III, were included in the study. The presence of co-morbidities other than learning disorders was an exclusion criterion. After an initial evaluation by the clinical psychologist, the teacher of special education, the speech therapist and the occupational therapist, 30 children who fulfilled our inclusion and exclusion criteria were recruited for this study. All of them had learning difficulties in reading and writing.

2.2 Interventions

Two kinds of therapeutic interventions were proposed with the intention to be combined: a psycho-educational program (2 hours/week) and a biofeedback training protocol (2 hours/week). The combined program was not accepted by several families due mostly to financial reasons (the biofeedback was covered by most insurance agencies), or due to time restrictions. As a result we ended up with two groups: the first group included 15 children who attended the biofeedback program only (NF group) whereas in the second group (n=15) children were treated with both biofeedback and psycho-educational treatment (NF+PSE group).

2.2.1 Neurofeedback

The biofeedback protocol that was used was the **Sensorimotor rhythm (SMR) enhancement/theta suppression**. This is based on the concept that improved attention and behavioral control is achieved when the child learns to reduce the production of theta and increase the production of the 12–15 Hz sensorimotor rhythm generated over the electrodes C3 or C4 that are positioned over the motor cortex. EEG recordings were obtained from one active site (C3 or C4), referenced to linked earlobes. Theta/Beta ratio was measured before the training initiation, after the 20th session and after the 40th session. In each of these instances, the ratio was obtained in three conditions: Eyes closed, eyes opened and during an attentional task (eyes fixed task). Mean values were calculated over these three conditions.

The neurofeedback training program was designed to last for 40 sessions. Each neurofeedback session lasted for about 45 minutes. Each child worked individually under the supervision of a psychologist (certified neurofeedback trainer). Children were seated facing a computer screen. Once the electrodes were synchronized with the trainer's computer, the children were directed to start playing a computer game. In all the neurofeedback games, the children were asked to move a target, by using their gaze and by remaining concentrated on the target. For as long as the children remained with their gaze perfectly concentrated on the target, they gained points and completed the game by fulfilling the defined goal. Visual (animated figures) feedback was provided based on the patient's success in controlling a) the amplitude in microvolts of theta or sensorimotor rhythm (SMR) or b) the percentage of time that theta rhythm was below pre-treatment threshold or SMR was above pre-treatment threshold. Patients were informed via auditory (tone) and visual feedback when they produced 0.5 seconds of desired EEG activity. By the end of each game, the children got a sum of points, depending on their performance. The goal for each child was to achieve a score that is closer to what is considered appropriate for his/hers age level. Throughout a session the children played as many as 6 games. In between the games, they received immediate feedback on their performance so that they could then proceed to adjustments of the attention level. After a break of 1 to 2 minutes, they proceeded to the next one. This process was repeated throughout the whole session. At the end of each session, children and parents were informed on the total score.

2.2.2 Psycho-educational

This was based on the cognitive-behavioral approach for children with ADHD and was scheduled for 2 hours/week right after the neurofeedback session. The intervention program addressed both reading and writing difficulties and at the same time the specialized therapist provided support to the children who due to their learning difficulties struggled at school. Furthermore, both patients and parents received practical counselling with regard to time organisation and scheduled activities management.

2.3 Statistical analysis

Mean Theta/Beta ratio scores at the first session and after the 20th and the 40th (last) session, were tested for normality using Shapiro-Wilk distributional test. Normal data were expressed as mean values ± standard variation (SD), whereas non normal data as median values (25th -75th percentile). The comparison of mean neurofeedback scores between the two treatment options was assessed with t-test when normally distributed or with Mann-Whitney U Test when non-normal. Categorical variables were compared with Chi square test or Fisher's exact test according to number of observations per cell. P-values for the tests applied in two different occasions (after the 20th and after the 40th session) were corrected with Bonferroni Correction for multiple comparison test, in order to reduce Type I error. Finally, mixed effects model was applied to test the longitudinal evolution of mean Theta/Beta ratio, taking into account the therapy group in which each patient is assigned. In these models, patient and number of sessions were treated as random variables.

3. Results

The patients (N=30, 15 boys and 15 girls) had a mean age of 7 years 7 months (± 1 year 2 months). The two groups (NF and NF+PSE group) consisted of 15 patients each and they were similar in terms of age and sex. All patients followed their treatment consistently and there were no dropouts.

At baseline (first neurofeedback session), mean Theta/Beta ratios were not significantly different between the two therapy branches (3.13 ± 0.02 for the NF+PSE group versus 3.10 ± 0.2 for the NF group, p-value=0.265). Two out of the patients of the NF group managed to obtain the target ratio (< 3) already during their first neurofeedback training session.

	Theta/Beta ratio at First session	Theta/Beta ratio after 20th session	Theta/Beta ratio after 40th session
NF group	3.10 ± 0.08	3.03 ± 0.10	2.95 ± 0.13
NF+PSE group	3.13 ± 0.06	3.05 ± 0.06	2.94 ± 0.06

Table 1. Mean Theta/Beta values for children the two treatment groups at discrete observation times

Table 1 displays mean Theta/Beta ratios for children in both treatment groups. All patients presented a decrease in Theta/Beta ratio values during their treatment. According to the mixed effects model applied, this observed decrease was significant as treatment evolved (p-value <0.001). However, the size effect of time elapsed was quite small with the ratio after the 20th session being as much as 0.078 units lower than its initial value, and after the 40th session being as much as 0.172 units lower than its initial value. Similarly, age of patients was a significant predictor of mean Theta/Beta values obtained (p-value <0.001). More specifically, children 8 or more years old had slightly lower mean values than those younger than 8 years, adjusted for treatment group and time of observation (coefficient = -0.082, 95% CI = between -0.127 and -0.038).

On the other hand, mean values of Theta/Beta ratios were not significantly different between the two treatment groups, at a precise time point (after the 20th or after the 40th neurofeedback session – p-value=0.841). These results are graphically demonstrated in Fig 1. However, when we compared the percentages of patients who succeeded to obtain the target ratio between the therapy groups, we were able to display that significantly more patients of the NF+PSE group reached the target, as compared to the NF group only after the 40th session (14 versus 6 patients respectively, p-value=0.006). The difference after the 20th session was not significant (4 patients of the NF+PSE group versus 4 patients of the NF group, p-value=0.841) (Fig 2). In this analysis, we omitted the two patients of the NF group who had a successful first session, although their inclusion does not really affect the results.

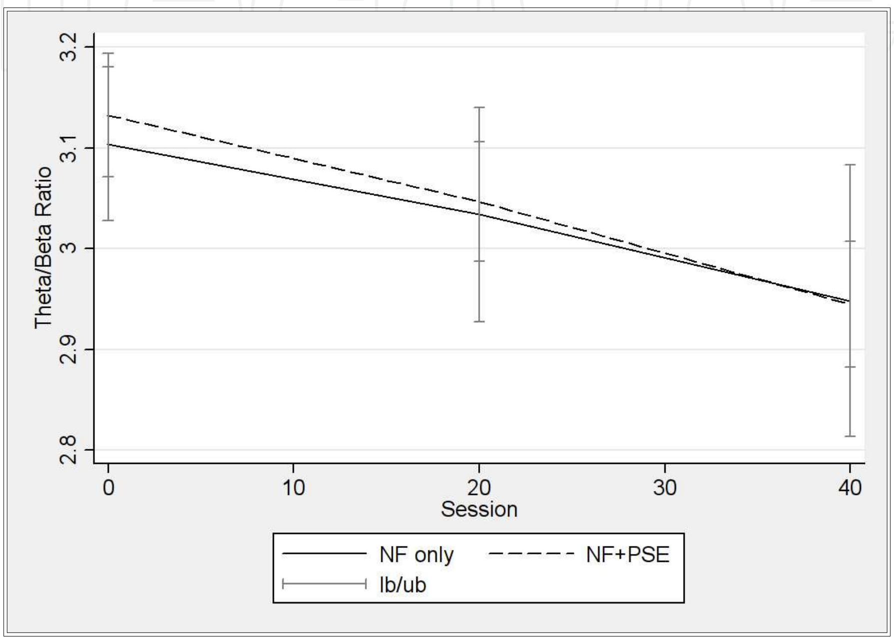

Fig. 1. Longitudinal evolution of mean Theta/Beta ratio for patients of the two treatment groups

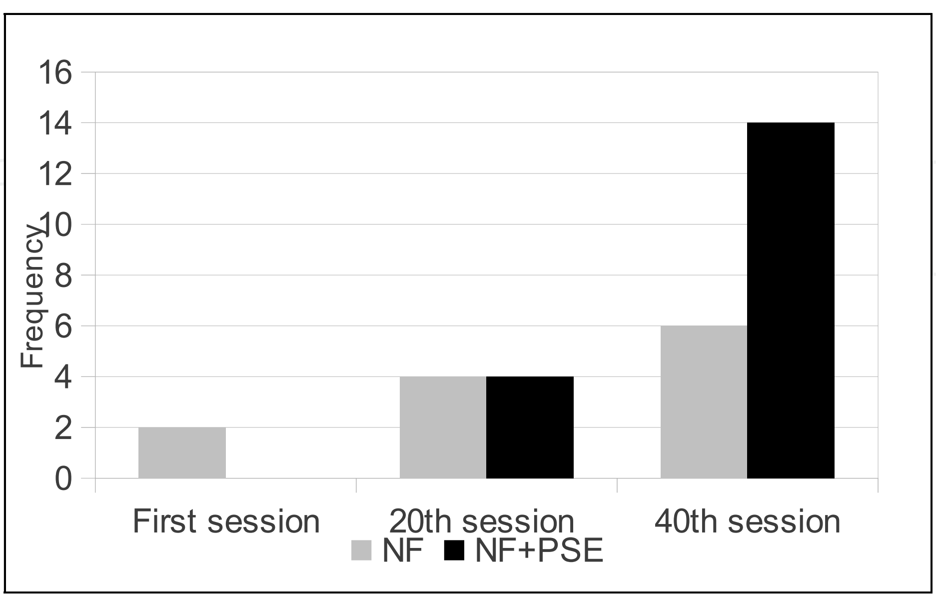

Fig. 2. Frequency of children who had achieved the goal of Theta/Beta <3 at the first, after the 20th and after the 40th session

4. Discussion

The main result in this study was that the addition of psycho-educational treatment to EEG biofeedback resulted in normalization of Theta/Beta ratio and thus in reducing the slowing of the frontal brain activity. To our knowledge, this is the first study to report changes on neurofeedback studied parameters in relation to the psycho-educational intervention.

Up to the present time, only a few studies have assessed the effects of pharmacotherapy, mostly psychostimulants, on EEG patterns in children with ADHD. It has been demonstrated that the use of psychostimulants produce a decrease in Theta/Beta ratio in children with ADHD, to the point of reaching normal values and this was more prominent in the right hemisphere (Clarke et al, 2001a; Clarke et al, 2007; Dixit et al, 2002; Kerdar et al, 2007, Hermens et al, 2005). In their study in 2005, Song DH et al demonstrated that the treatment with methylphenidate induced an increase in Theta/Beta ratio in the right frontal and parieto-occipital region in 20 boys with ADHD, during continuous performance test (CPT) and not in resting states (Song et al, 2005).

When used as part of multimodal treatment in ADHD the psycho-educational intervention aims to maximize the likelihood of the child's academic success by developing areas of strength, by adapting to special needs and by remediating knowledge and skill deficits (William & Smucher, 2001). There is great variability concerning the form of psycho-educational intervention in bibliography. It may include informative sessions on ADHD, behavioral strategies (parental training, child self-control instruction training, school-based techniques, family counseling) and/or educational packages in combination with behavioral techniques (Montoya et al, 2011).

In the present study, we were able to demonstrate that the psycho-educational program which was added to the treatment of ADHD children could enhance the effect of the neurofeedback protocol used. We have shown that the percentage of patients who reached EEG activity normalization was higher in the NF+PSE compared to the NF group. However, when we compared the longitudinal evolution of Theta/Beta ratio between the treatment groups, the psycho-educational program did not have an effect. Taking into account the fact that all children learned to reduce brain slowing but not all of them achieved normal Theta/Beta ratios during the 40 sessions programmed, it can be postulated that the implementation of a psycho-educational program may accelerate the neurofeedback training process. Whether the effect of the psycho-educational program is modified by other unspecified factors needs to be further studied .

One factor that has been demonstrated to be an important moderating factor of behavior at home, especially in children treated with neurofeedback, was parental support. In the study of Monastra et al, when "systematic" approaches towards parent mediated reinforcement strategies were used with patients treated with both neurofeedback and standard therapies, improved behavioral ratings were demonstrated not only at school environment but also at home, even when medication was discontinued (Monastra et al, 2002). On the contrary, when electrophysiological parameters were examined, as in the study of Drechsler et al, there was no evidence of a direct influence of parent directed approaches on successful cortical control, as 50% of the children who performed well in neurofeedback training and 66% of those who performed bad, belonged to the high parental support group (Drechsler et al, 2007). In the current study, we did not examine parental support as a factor that could affect the results of the prescribed treatment.

Table 1 reports absolute values of Theta/Beta ratios on three different occasions: at first session, after the 20th session and after the 40th session. To our knowledge, only few neurofeedback studies focus on brain activity modification itself and EEG data are rarely available. Initial values for Theta/Beta ratio at first session were not similar to those reported by Monastra et al in 1999 for a group of ADHD children of the same age (Monastra et al, 1999). In this study, authors used a Theta/Beta value that was at least 1.5 SD higher than the value reported for normal age peers as a cutoff point for ADHD diagnosis. In the current study, mean Theta/Beta values at first session (practically before training) were lower as compared to those reported in the aforementioned study for children with ADHD but above the threshold for normal children 6-11 years old (which was set at the value of 3). On the other hand, the Theta/Beta ratios reported by Song et al in 20 patients with a mean age of 8.6 years (1.4 years) were lower than those presented in our study, in all brain regions that were examined (Song et al, 2005).

One explanation for this discordance in Theta/Beta values may be due to the positioning of electrodes. In some studies focusing on neurofeedback methodology, it was observed that when electrodes were fixed frontally, where more theta and less beta activity in patients with ADHD is found, then artifacts by eye movements may be a significant risk (Mann et al, 1992; Lubar et al, 1995; Chabot & Serfontein, 1996). For this reason it is suggested that electrodes are placed in a more central position at C3f (= halfway between C3 and F3) and C4f (= halfway between C4 and F4) (Monastra et al, 1999). In the current study electrodes were positioned at C3 or C4 positions (a bit posteriorly in relation to the positions described previously), whereas in the study of Song et al Theta/Beta ratios were recorded in all 30 regions defined by the International 10/20 system but not over C3-C4 or C3f-C4f (Song et al, 2005; Monastra et al, 1999). A second explanation may be the difference in the methodology used and more precisely in the calculation of the mean Theta/Beta ratio. In both the aforementioned studies and in the current study, the Theta/Beta ratio was measured in different conditions (performance tasks, resting states, eyes open/closed) and therefore the produced mean values are not expected to be similar.

Furthermore, in the present study we did not make a discrimination of the ADHD type. The composition of the study group in our study could also account for the observed differences in the Theta/Beta values from the study of Monastra et al (Monastra et al, 2002). According to some authors children with ADHD–Combined Type may exhibit more absolute and relative theta activity, and higher Theta/Alpha and Theta/Beta ratios when compared to those with ADHD–Inattentive type (Clarke et al, 1998; Clarke et al, 2001b; Clarke et al, 2003). Although these results were not reproduced by other authors, they may suggest that children with ADHD– Combined Type show the classic pattern of greater underarousal and maturational delay more so than the children with ADHD– Inattentive type. In contrast, the latter group of patients exhibited more relative alpha activity in the posterior regions than those with ADHD–Combined Type, which is consistent with reports of slower cognitive processing and increased rates of daydreaming among these kids (Monastra et al, 2001; Loo & Barkely, 2005).

As we have shown, Theta/Beta ratio decreased substantially, from the first to the 40th session. Similar results were reported previously (Monastra et al, 2002; Thompson L & Thompson M, 1998; Lubar et al, 1995; Loo & Barkley, 2005; Gevensleben et al, 2009b; Leins et al, 2007). In the first of these studies, patients who underwent neurofeedback training presented a significant reduction on their Theta/Beta ratio values from above 5.03 (pretreatment) to less than 3 (post-treatment) (Monastra et al, 2002). A decrease in Theta/Beta ratio was also observed in a randomized study published in 2009 by Gevensleben and colleagues (Gevensleben et al, 2009). In this study, the modification of EEG activity demonstrated in 72 children with ADHD was attributed to a marked decrease of theta activity in posterior midline position. The findings of Leins et al are also in accordance, although they used a different approach (Leins et al, 2007). They studied Theta/Beta ratios in activation and in deactivation tasks and in feedback and transfer conditions, in order to produce similar states with the SCP training program. They observed that Theta/Beta ratio changed significantly in deactivation tasks but not in activation tasks and only in feedback conditions. In activation tasks, a decrease in Theta/Beta ratio was observed already within the first sessions of the treatment but, in the end, it did not reach significance. It should be also noted that in the current study just as in the study published in 2002 by Monastra et al, Theta/Beta values by the end of neurofeedback training were similar to values produced by non-ADHD age peers. However, this finding was not reproduced in the study of Carmody et al, in which normalization of spontaneous EEG after frequency neurofeedback training was not found (Carmody et al, 2001).

Another important aspect of the current study is that all members of the study sample proved to be capable of altering their brain wave frequency. The percentage of patients who learn how to increase cortical activity varies across the studies published. In most of them, this percentage was quite high. As in the present study, Lubar et al reported, in a part of their research, that all patients managed to slow cortical activity (Lubar et al, 1995). In support of these data, the majority of patients in the study of Lansbergen et al learned to increase SMR and decrease theta activity (Lansbergen et al, 2011). Nevertheless, it has also been reported that some participants fail to obtain satisfactory training results during EEG feedback or transfer (Drechsler et al, 2007; Lubar et al, 1995; Strehl et al, 2006; Kropotov et al, 2005). This result was mostly observed in training SCPs protocols and it was attributed to the protocol itself since the SCP training, which is rather strategic in nature and prone to artifacts, may be more difficult for children with ADHD than a neurofeedback training based on frequency ratios (Drechsler et al, 2001).

Finally, it was shown that the effect of psycho-educational program on neurofeedback parameters is present only after 40 sessions. In most studies, it seems that a total of 40 sessions is needed in order to achieve improvements in ADHD symptoms and in daily functioning. In the study of Monastra et al, the EEG neurofeedback training was stopped when participants obtained Theta/Beta ratio in the normal range for age (within 1.0 SD of age peers) for at least 40 min and for 3 consecutive treatment sessions (Monastra et al, 2002). The average number of sessions needed to reach this goal was 43 (range: 34–50). However, fewer sessions may also be enough to produce the desirable effect. In the study of Gevensleben et al, the alteration of brain activity required only 18 sessions (Gevensleben et al, 2009b). Similar were the results of Leins et al who suggested that patients learn to alter EEG activity at a very early stage of the training but they don't show any improvement during the following sessions (Leins et al, 2007). When it comes to long-term benefits from neurofeedback, Fox et al suggested that for a long lasting change on EEG frequencies, many sessions, up to 60, may be required, even though it was demonstrated that 30% of patients treated with ADHD are capable of changing their brain waves frequency for a long time after as few as 20 sessions of neurofeedback training (Fox et al, 2005; Rossiter & LaVaque, 1995). Importantly, the desired improvement on behavioral rating scales and the Test of Variables of Attention (TOVA) was also achieved in 20 sessions (Rossiter & LaVaque, 1995).

The current study has several limitations. The main ones are the relatively small number of participants, the study design and the absence of follow-up data. Patients included in the research are not randomly assigned to the treatment groups and although they are similar for age and sex, they are not matched. Additionally, the procedure is not blinded, which in combination with the absence of randomization or matching, may allow confounding factors (such as parental expectation and style) to interfere with the results. Consequently, our results may not be easily generalized. Furthermore, although it was shown that the addition of a psycho-educational program does induce greater changes on Theta/Beta ratios towards normalization than neurofeedback alone, this effect is only apparent immediately after the completion of the training. We did not examine if that effect retained in the long term. If that proved to be true, it would greatly support the simultaneous use of neurofeedback with other behavioral interventions, based on a long standing, and hopefully permanent brain activity modification.

Another limitation of the current study is the lack of data concerning changes on patients' clinical characteristics. However, at this point of our investigation, the study was not designed to examine the correlation between changes presented in Theta/Beta ratios and behavioral alterations or if the addition of the psycho-educational program produced greater improvements on ADHD symptoms, in comparison with the presumed improvements due to neurofeedback training alone. In 1995, Lubar and coworkers found that all children who undertook the neurofeedback training showed improvements in behavior and attention, although not statistically significant. These improvements were present in both children who managed or did not manage to alter brain activity (Lubar et al, 1995). However, more recent research demonstrated that the extent of ADHD symptoms improvement along with the extent of neurophysiological parameters' improvement is positively correlated to the degree to which the patient is able to learn to alter his/her brain activity during training sessions. This correlation suggests that functional improvement is based on "the specific action of feedback-guided learning."(Hirshberg, 2007; Gruzelier & Egner, 2005).

5. Conclusion

To conclude, the decision to combine a psycho-educational intervention with neurofeedback in management of children with ADHD may be an advantageous option. The psycho-educational program seems to accelerate the ability of the child to alter brain activity and to reach the normal range of values of electrophysiological parameters. Further research should be focused on the clarification of variables involved in this bi-modal approach e.g. the exact type of the psycho-educational intervention applied, with detailed description of patient and parent derivatives and the best neurofeedback protocol for each ADHD subtype, with the goal to achieve the maximum effect not only on the brain activity but also on the ADHD symptoms. It would also be of importance to examine long term effects of the two treatments, on brain electrophysiolology and on clinical parameters such as ADHD symptoms, academic achievement and even quality of life.

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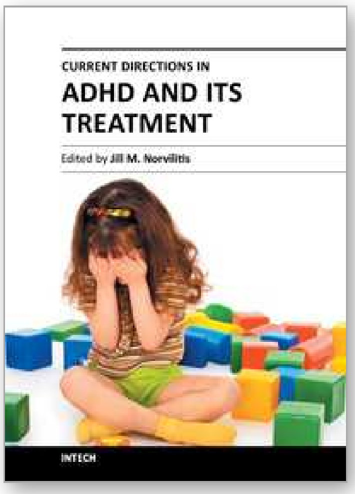

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The treatment of Attention Deficit Hyperactivity Disorder is a matter of ongoing research and debate, with considerable data supporting both psychopharmacological and behavioral approaches. Researchers continue to search for new interventions to be used in conjunction with or in place of the more traditional approaches. These interventions run the gamut from social skills training to cognitive behavioral interventions to meditation to neuropsychologically-based techniques. The goal of this volume is to explore the state-of-the-art in considerations in the treatment of ADHD around the world. This broad survey covers issues related to comorbidity that affect the treatment choices that are made, the effects of psychopharmacology, and non-medication treatments, with a special section devoted to the controversial new treatment, neurofeedback. There is something in this volume for everyone interested in the treatment of ADHD, from students examining the topic for the first time to researchers and practitioners looking for inspiration for new research questions or potential interventions.