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Is Neurofeedback training an efficacious treatment for ADHD? Results from a systematic review

¿Es efectivo el entrenamiento en Neurofeedback para el tratamiento del TDAH? Resultados a partir de una revisión sistemática

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Abstract
Based on a systematic review of empirical articles published between 2001 and 2011, this study aims to establish the viability of using Neurofeedback training as a technique to reduce the symptoms of attention deficit hyperactivity disorder in children and teenager. 88 articles were identified and based on the defined inclusion criteria, and 11 articles were selected. Evaluation of efficacy was based on the criteria defined by the Association of Applied Psychophysiology and Biofeedback (Association for Applied Psychophysiology and Biofeedback - AAPB -). The results point to a level of efficacy located between level two (potential effectiveness) and level three (probable effectiveness), therefore, it is necessary to conduct a research with a higher level of control of variables and larger samples. Related clinical uses and methodological aspects are discussed for future studies.

Keywords: Neurofeedback, Attention Deficit Disorder with Hyperactivity, ADHD, Neuropsychology, Efficiency Levels.

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Resumen
El objetivo del presente trabajo es establecer, a partir de la revisión sistemática de artículos empíricos publicados entre 2001 y 2011, la viabilidad del uso del Neurofeedback como técnica de entrenamiento para disminuir los síntomas del Trastorno por déficit de atención-hiperactividad en población infantil y adolescente. Se identificaron 88 artículos y con base en los criterios de inclusión definidos previamente, se seleccionó un total de 11 artículos. La evaluación de eficacia se hizo con base en los criterios definidos por la Asociación de Psicofisiología Aplicada y Biofeedback (*Association for Applied Psychophysiology and Biofeedback* -AAPB-). Los resultados apuntan a un nivel de eficacia situado entre nivel dos (posible eficacia) y nivel tres (eficacia probable), por lo que se hace necesario la realización de investigaciones con un mayor nivel de control de variables y en muestras más amplias. Se discuten aspectos relacionados con su uso clínico y metodológico para futuros estudios.

Palabras claves: Neurofeedback, Trastorno por Déficit de Atención-Hiperactividad, TDAH, Neuropsicología, Niveles de Eficacia.

Introduction

The disorder attention deficit hyperactivity disorder (ADHD) is a behavioral disturbance with neurobiological basis, characterized by having difficulties with attention, impulsivity and hyperactivity, affecting globally between 4.1 and 5% of children and teenagers (American Psychological Association APA, 2000; Polanczyk, Lima, Horta, Bierderman & Rhode, 2007; Word Health Organization WHO, 2011). Reported prevalence rates in Colombia ranges from 3.1 % (Torres, Berbesi, Bareño & Montoya, 2010) to 15.86 % in school-age children (Cornejo et al., 2005). Figures show negatively an impact not only in the proper development but also, at the school, family and social performance (Trujillo - Orrego, Ibanez & Pineda, 2012) of this population as well as in adolescent groups.

From the neuropsychological point of view, the most studied disorders of ADHD have been related to executive-level failures, both in tests and scales measuring the effect of executive functions in daily life of patients (Shimoni Engel-Yeger & Tirosh, 2012). However, Willcutt, Doyle, Nigg, Faraone, and Pennington (2008), from a meta-analysis of 83 studies concluded that the heterogeneity of the disorder cannot generalize these executive failures in all ADHD diagnosed patients, for this reason, there have been a number of efforts to conceptualize ADHD from the formulation of different cognitive profiles associated with it.

In this line, Sonuga-Barke, Bitsakou and Thompson (2010) conducted a study to establish empirically the plausibility of an explanatory pattern from two means: one stratal fronto dorsal, which would produce a deregulation in inhibitory processes, and other in which the ventral frontostriatal circuit affect the ability to identify signs of greater latency, what would mean, difficulties to postpone greater rewards in favor of immediate rewards. The results confirm the possibility of these two models and identify a third component associated to failures in the temporal processing, probably related to alterations in the basal ganglia.

Therefore, in the development of new non-pharmacological treatments, neurofeedback (NF) has emerged as an intervention technique that is being investigated as an alternative to the attention of various neuro-psychiatric disorders. Although a great part of the published studies have focused on establishing its efficacy in the treatment of ADHD, many of these studies have used methodologies that make it difficult to extrapolate their results to clinical practice. For that reason, the importance of addressing the conceptual and methodological aspects of the use of NF in the treatment of ADHD, in order to establish possible research areas for clinical use.

As well the NF as the biofeedback, consist in a series of procedures that allow, from the acquired information and a physiological variable of interest, to modify voluntarily values on the participant (Olivares, Méndez & Bermejo, 1998). Also, it is understood as a self-regulation technique in which patients develop a voluntary control what was once thought as involuntary (Frank, Khorshid, Kiffer, Moravec & Mckee, 2010). For this purpose, The NF is supported in equipment designed in order the patient may detect the changes produced in the selected physiological responses and through operant or classical conditioning processes, he can learn to modify the values of the signal (See Figure 1); in the specific case of NF, physiological signal is used as brain waves. From this perspective, it is considered more like training than a therapy, insofar the patients play an active role and practice until developing the control skill (Frank, et al., 2010).

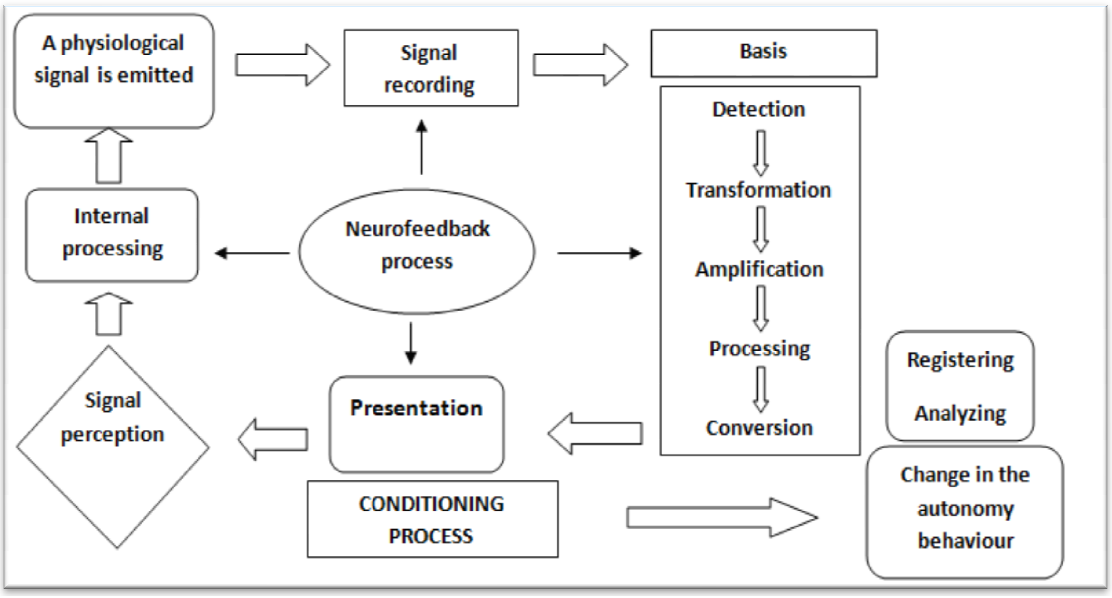

Figure 1. Model operation NF

The participant produces a physiological signal and consequently the equipment is in charge of registering, transforming, and enlarging it in a pattern that can be presented to the participant with the aim of receiving direct information of the changes produced in the physiological signal, and thus learning how to modify it through classical conditioning and/or operant processes. (Graphic based on Carrobles & Godoy, 1987).

Among the main objectives to be achieved with the use of NF are: controlling a system of physiological responses through training, keeping controlled these responses in the absence of the feedback and generalizing and maintaining the achieved self-control (Conde & Menéndez, 2002).

The NF or Biofeedback encephalographic has as a purpose that the patient, by means of operant conditioning, learns to control the brain's electrical activity, which is an unconscious physiological function, increasing the frequency of desired brainwave and deleting the unwanted one (Friel, 2007). The NF has been studied in depth, for treatments in epilepsy, anxiety , depression, and learning disorders (Fernández et al., 2007), Asperger (Thompson, Thompson & Reid, 2010) and, there are particularly, a variety of studies related to ADHD (Masterpasqua & Healey, 2003; Heinrich, Gevensleben & Strehl, 2007; Legarda, McMahon, Othmer & Othmer, 2011; Gruzelier & Egner, 2005; Thompson & Thompson, 2005).

The mentioned studies are based on findings of the electroencephalogram (EEG) in children with ADHD, which have identified a higher proportion of waves Theta / Beta, a high level of Theta waves and low level of Betha waves (Loo & Barkley, 2005; Othemer & Kaiser, 2000; Butnik, 2005), This is apparently related to the behavior of motor restlessness and lack of concentration. In addition, the EEG in children with ADHD has shown a positive correlation with the levels of cerebral perfusion associated with hypoperfusion in the frontal lobe that is related to an alteration in the rate of Theta waves (Gunkelman & Johnstone, 2005).

These results have supported the development of NF as a technique that would change the typical EEG patterns of ADHD and also improve its symptoms. While medication has been one of the most evident effective treatment, along the cognitive behavioral therapy, it has been suggested that about 20% of children do not respond adequately or have side effects that hinder their use (Diaz, 2006), that is the reason, this technique has become especially important in recent years (Baydala & Wikman, 2001, Meisel et al, 2011;. Rossiter, 2004), without presenting relevant side effects so far (Gevenselebel, et al. 2009; Henrich et al 2007; Bakhtadaze, Janelidze, & Khachapuridze, 2011).

Preliminary findings indicate that train individuals on controlling their own electrocortical activity, may have beneficial effects on reducing symptoms of ADHD (Masterpasqua & Healey, 2003; Butnik, 2005). To this purpose, it has been developed a variety of protocols, such as the Theta / Betha, which is based on increasing Betha waves while Theta waves are been decreasing. This protocol has yielded positive effects on the concentration and hyperactivity symptoms reduction (Harvard Mental Health Letter, 2010). Another protocol is based on training slow cortical potentials [Slow Cortical Potential Training] (SCP), in order to regulate the phasic cortical activity rather than the tonic.

One aspect of particular interest is the effectiveness in brainwaves modification after 20 training sessions in over 30% of patients with ADHD and the prevalence of its effects, which is estimated from one to ten years, having as a consequence the decreasing of impulsivity and hyperactivity

symptoms (Fox, Tharp & Fox, 2005). In addition, several studies report a significant improvement in the levels of attention in the IQ, and the scores on the conduct scales carried out by parents and teachers (Gevensleben, Holl, Albrecht, Vogel, et al, 2009.; Gevensleben, Holl, Albrecht, Schlamp, Kratz, Studer, Wangler, et al, 2009;. Leins et al, 2007; Strehl, et al, 2005).

Although, some of these studies have been controversial due to the lack of scientific rigurosity, and limitations such as lack of control groups, small sample sizes and non-probability sampling (Harvard Mental Health Letter, 2010, Heinrich et al 2007,. Drechsler et al. 2007).

In order to obtain greater effectiveness, it is proposed to join the NF to a multimodal therapy that combines some of the following aspects: psychoeducation, medication, behavioral intervention, parent training and / or academic support, among others (Campbell, 2004; Hoekstra, 2010; Lansbergen, Dongen-Boomsma, & Buitelaar Slaats-Willemse, 2011). School and parents support have proved to be crucial in the treatment, so most studies have attempted to involve them (Pop-Jordanova, Markovska-Simoska & Zorcec, 2005, Roman, 2010).

This study aims to track and analyze the implemented advances in NF technique as an alternative treatment to ADHD, and classify the findings according the efficacy levels proposed by the Association for Applied Psychophysiology and Biofeedback, [Association for Applied Psychophysiology and Biofeedback] (AAPB) and the Society for Neuronal Regulation in 2001.

Method

The present work is a systematic revision, where articles related to NF and ADHD in children and adolescents from the database PubMed, Ebsco database (Psychology and Behavioral Sciences) and PsyARTICLES were taken as a unit of analysis, during a temporary margin of 11 years, between 2000 and 2011.

Firstly, the search was conducted using the terms: Neurofeedback and Attention Deficit Hyperactivity Disorder (ADHD), and a total of 88 items were found. 44 articles related to children and adolescent diagnosed with ADHD were taken, and consequently they were intervened with NF as the main technique. Finally, articles of theoretical type were discarded, having a final selection of 11 items. Thus, the inclusion criteria were:

- Empirical articles which sample made up by children and / or adolescents.
- Items selected with a sample who presented as a primary disorder ADHD, intervened with NF technique.

The information is organized into the following categories for the analysis: title, authors, country and year, sample protocol used, design, control group, results and conclusion. Finally, it was assigned to the evidence found a level of effectiveness in accordance with the established parameters by the AAPB and the Society for Neuronal Regulation, which identify five levels (Moss & Gunkelman, 2002), in order to classify the carried out studies on the issue that might lead to future research (Yucha & Gilbert, 2004). See Table 1.

Table 1. Efficacy ratings for Neurofeedback studies, according to AAPB and the Society for Neuronal Regulation

Level	Type of efficacy	Description
Level 1	No empirical support	It only has anecdotal reports and case studies
Level 2	Posible efficacy	At least one study with enough statistical power with well-defined outcome measures, but without a random assignment to a condition of internal control for the study
Level 3	Probable effficacy	Multiple observational studies, clinical trials, controlled studies on the waiting list and responses in the inter-and intra-subject studies demonstrating efficacy
Level 4	Efficacy	a. Compared to an untreated control group, alternative treatment group or placebo control group using random assignment, the treatment to be investigated is significantly superior to the control condition or the investigated treatment is equivalent to a previously established treatment of efficacy. b. Studies are conducted in a population treated for a specific problem and the inclusion criteria are drafed in a reliable way, and defined operationally. c. The study uses specific, clear and valid outcome measures. d. Data are subject to a proper analysis result. e. The diagnosis and treatment variables, as well as procedures, are defined in a clear way that allows replication of the study by independent investigators. f. The superiority or equivalence of the investigated subject has been shown at least in two independent research areas.
Level 5	Effecive and specific	The investigated treatment showed to be statistically superior to medication or treatment, in at least two independent fields of research.

Results

Regarding knowledge production between 2000 and 2011 about the NF and ADHD in children and adolescents, a reduced volume of articles was recorded in the databases. Lack of studies in Latin America is evident and most of the articles from this region are review articles.

Eight of the research articles are studies carried out in Germany (Gevensleben, Holl,

Albretch, Vogel, et al., 2009; Leins et al., 2007; Gevensleben et al., 2010; Gevensleben, Holl, Albretch, Schlamp, et al., 2009; Strehl et al., 2005; Wangler, et al., 2011; Bakhshayesh, Hansch, Wyschkon, Rezai & Esser, 2011; Fuchs, Birbaumer, Lutzenberger, Gruzelier & Kaiser, 2003), it corresponds to a 73% of the total analyzed volume that fulfills with the inclusion criteria. The other 27% was divided among Switzerland (Drechsler et al., 2007), Macedonia (Pop-Jordanova et al., 2005) and the Netherlands (Lansbergen et al., 2011) with an article each one.

The studies of Gevensleben et al. (2010); Wangler et al. (2011) y Gevensleben, Holl, Albretch, Schlamp, Kratz, Studer, Wangler, et al. (2009), took final samples from a group of 102 children from Gevensleben, Holl, Albretch, Vogel, et al. (2009) work. Sharing the demography characteristics of this sample, in a way that children and adolescents with comorbid emotional disorders, tics or dyslexia were excluded. On the other hand, Leins et al. (2007) did not exclude participants with psychiatric or neurologic disorders different from Lansbergen, et al. (2011) who did excluded from their study any type of comorbid disorder. On the contrary, Drechsler et al. (2007), had samples without any comorbid disorder or any known neurological damage. While Strehl et al. (2005), similarly than Bakhshayesh et al. (2011), involved participants in this etereo group, with no additional neurological disorders. Finally, the studies of Fuchs et al. (2003) and Pop-Jordanova et al. (2005) did not specify if the comorbid neurological or psychiatric disorders are part of the inclusion criteria.

Secondly, the IQ was part of the initial evaluation, and in several studies those participants who presented a IQ higher than 80 were considered as inclusion criteria (Bakhshayesh et al., 2011; Drechsler et al., 2007; Fuchs et al., 2003; Lansbergen et al., 2011; Leins et al., 2007; Strehl et al., 2005).

Similarly, there were some differences with regard to the inclusion or not of children and adolescents with medication or alternative treatment. In the studies of Gevensleben, Holl, Albrecht, Vogel, et al. (2009); Gevensleben, et al. (2010); Wangler et al. (2011) and Gevensleben, Holl, Albrecht, Schlamp, Kratz, Studer, Wangler, et al. (2009), participants should not be under medication or attending psychotherapy for at least six weeks prior to the study. Meanwhile, in the study of Fuchs et al. (2003) the sample should not be linked to any treatment before or during the study. In contrast, the studies of Lansbergen et al. (2011), Drechsler et al. (2007) and Bakhshayesh et al. (2011) did not exclude children and adolescents who were under medication at the time of the study, provided the dose was controlled without any variation along the study. The mentioned above, is based on the concept that the NF should be part of a multimodal therapy. Finally, Pop-Jordanova et al. (2005) did not specify this criterion.

Protocols of NF used

The protocols of NF used in the studies were Training Theta / Beta and training called Slow Cortical Potential Training (SCP), being used in 73% of the studies analyzed. Some studies have only worked with SCP (Drechsler et al, 2007; Strehl et al, 2005) and a study with the Theta / Beta training (Bakhshayesh et al, 2011) . However, some studies have used both protocols either using them in separate blocks to a single group (Wangler et al, 2011; Gevensleben et al, 2010; Gevensleben,

Holl, Albrecht, Schlamp et al, 2009; Gevensleben, Holl, Albrecht, Vogel, et al., 2009) or selecting one for each experimental group (Leins et al., 2007). Another protocol widely used is the Rhythm Sensory Motor, which was practiced in 27% [Sensorimotor Rhythm (SMR)] (Fuchs et al, 2003; Lansbergen et al, 2011; Pop-Jordanova et al., 2005). On the other hand, Lansbergen et al. (2011) propose another training way on NF, in which NF individual protocols were used, based on visual inspection and comparison who researchers conducted between the initial EEG of children evaluated and the quantitative electroencephalogram (QEEG) of the NeuroGuide database that contains records of 625 healthy children with electrophysiological heterogeneity.

Control group

All studies, except those by Leins, et al. (2007), Pop-Jordanova et al. (2005) and Strehl et al. (2005), used this methodological strategy, in order to compare the effectiveness of NF with other interventions. These interventions included training on attention skills, electromyography biofeedback training or cognitive behavioral therapy, among others.

Reported main findings

In relation to NF training, regardless of the protocol used, it was found that ADHD symptoms were reduced in all studies, especially in those related to inattention (Bakhshayesh et al., 2011) and self-regulation (Drechsler et al., 2007; Leins et al, 2007). Considering the baselines of psychometric tests and neuropsychological, an improvement in reaction time on the tests was found, as well as in parent and teachers' ratings, and in some cases IQ increasing was presented (Pop-Jordanova et al. 2005; Gevensleben, Holl, Albrecht, Vogel, et al, 2009;. Gevensleben, Holl, Albrecht, Schlamp, et al, 2009; Leins et al, 2007; Strehl et al., 2005).

Referring to Theta / Betha training, a positive impact can be observed, so through this the Theta / Beta tax was reduced (Bakhshayesh et al., 2011) or the presence of theta waves are decreased and Betha waves are increased (Gevensleben, Holl, Albrecht, Vogel, et al, 2009; Gevensleben, Holl, Albrecht, Schlamp, et al, 2009,.. Leins et al, 2007), which was associated with significant reductions in reported symptoms of ADHD.

With respect to the training results with SCP, positive results were found in several studies. An increase in the central midline of the alpha activity was correlated with an improvement in the level of ADHD (Gevensleben, et al., 2010), as well as an increase in the specific CNV (Contingent Negative Variation) to the SCP was associated with a reduction of ADHD symptoms (Wangler et al., 2011) and a learning response in the negative regulation of SCP (Strehl et al., 2005). However, Drechsler et al. (2007) found that less than a half of the participants who received SCP training were able to differentiate their cortical activation in transfer trials Drechsler et al. (2007), so that the effects could not be fully attributed to the electrophysiology training.

Additionally, training with SMR protocol, succeeded in reducing ADHD symptoms in all studies in which it was used (Pop-Jordanova et al, 2005; Lansbergen et al, 2011; Fuchs et al, 2003.). See Table 2.

Table 2. Training protocols in NF, study design and main conclusions reported in the selected papers.

Study	Authors	Country and year	Sample	Neuro-feedback Protocol	Design	Control group	Results	Conclusions
Neuro-feedback in children with ADHD: Specific event-related potential findings of a randomized controlled trial	Wangler et al.	Ger-many 2011	102 children with ADHD aged 8 to 12 years.	36 Theta/Be-tha training sessions and SCP	ERP pre, during and post-training With control group and random group assignment	28 children with ADHD Protocol 36 AST sessions	In both groups, there were an improvement in the test performance and a decrease in the p300 component, possibly due to the adaptation to the attention test. After the NF training, there was an increase in the CNV specific for SCP. A greater pre-training in CNV was associated with a decreased in the ADHD symptoms in the SCP training.	The effects of CNV reflect on the underlying neural circuits to the sources of assigned resources in the cognitive preparation, related to a successful NF training in children with ADHD. A neuropsychologi-cal assessment is suggested to optimize and individualize NF training.
Neuro-feedback in ADHD: a single-blind randomized controlled trial	Bakhshay esh, Hansch, Wysch-kon Rezai, & Esser.	Ger-many 2011	35 children with ADHD, aged 6 to 14 years.	30 Theta/Be-tha training sessions	Psycophy-siological, neuropsyco logical and psychome-tric measure-ment pre and post-training. With control group and random group assignment	17 children with ADHD. Protocol Elecromy ography biofeed-back training.	The Theta/Betha rate and the EMG levels were reduced in the groups. The parents reported important reductions in primary symptoms of ADHD and the inattention improvements were greater in the NF group, in which an improvement was also noticed in the reaction time at the neuropsychologi-cal assessment.	It is important to discuss if the therapeutic alliance may result by itself in changes in cerebral activity The behavior contingencies, self-efficacy, relaxation, the structured learning environment, routines, among others factors, should be taken into account.
Neuro-feedback training in children with ADHD: 6-month follow-up of a randomized controlled trial	Gevensle ben, Holl, Albretch, Schlamp, et al.	Ger-many 2010	61 children with ADHD, aged 8 to 12 years	The children comple-ted 36 sessions of Theta/Be-tha training and SCP in a previous phase of the study.	Follow-up study	23 children with ADHD with previous training on AST.	50% of the sample responds to the follow-up, versus a 30.4% in the control group.	Improvement in behavior related with NF training was remained for six months and being higher than the control group. The NF may be considered effective in the ADHD treatment.

Distinct EEG effects related to neuro-feedback training in children with ADHD: A randomized controlled trial	Gevensleben, Holl, Albretch, Schlamp, Kratz, Studer, Wangler, et al.	Germany 2009	102 children (72 at the end) aged 8 to 12 years, with ADHD	36 sessions of Theta/Betha training and SCP	EEG pre, during and post-training.	26 children with ADHD Protocol 36 AST sessions.	A reduction in Theta activity in the EEG was evident in the NF trained group. Also, an increased in the alfa activity central midline, which was correlated with an improvement in the ADHD scale.	Theta and Betha differential patterns in EEG, show the neural mechanisms that could cause improvements in behavior on children with ADHD.
Is Neuro-feedback an efficacious treatment for ADHD? A randomized controlled clinical trial	Gevensleben, Holl, Albretch, Vogel, et al.	Germany 2009	102 children (94 at the end) with ADHD,aged 8 to 12 years	36 sessions of Theta/Betha training and SCP	Psychometric measurement pre and post-training. With control group and random group assignment	35 children with ADHD. Protocol 36 AST sessions.	51% of the experimental groups responds to the treatment (Theta waves decrease) compared with a 2% in the control group. According to parents and teachers, there was an improvement in behavior.	Combination of protocols in NF training has an effective effect in children with ADHD, however more studies are needed.
Neuro-feedback for Children with ADHD: A Comparison of SCP and Theta/Beta Protocols	Leins et al.	Germany 2007	38 children with ADHD aged 8 to 13 years.	30 sessions of Theta/Betha training, or 30 sessions of SCP training.	Psychometric measurement pre, post-training and follow-up. Random group assignment	Absent	Intentional regulation of cortical activity in both groups, improving attention and IQ. Parents and teachers also reported important improvements in behavior and cognitive level. Clinical effects were maintained during six months posterior to the treatment and the groups did not differ from each other.	NF training has a positive and lasting effect. Limitations: Lack of control group, sample size, control of nonspecific effects.
Self-regulation of Slow Cortical Potentials: A New Treatment for Children With Attention-Deficit/Hyperactivity Disorder	Strehl et al.	Germany 2005	23 children with ADHD between 8 and 13 years old.	30 SCP sessions.	Psychometric and neurologic evaluation pre and post-treatment.	Absent	The children learned how to regulate the negative SCP. An improvement in attention, behavior and IQ score was observed. Changes remained the six months after.	Evidence supports a SCP efficacy level 2. Future research should control medication, nonspecific effects and subtypes, in order to know if SCP is an alternative treatment to ADHD. Limitation: Sample size

Neuro-feedback Treatment for Attention-Deficit/Hy-peractivity Disorder in Children: A Compari-son with Methyl-phenidate	Fuchs, Birbau-mer, Lutzen-berger, Gruzelier & Kaiser.	Ger-many 2003	34 children aged 8 to 12 with ADHD	36 sessions of Neurocy-bernetics EEG Biofeedb ack System C4 and SMR were used in hyperacti ve children and C3 en beta1 was used in predomin antly inattenti-ve children.	Neuropsyco logical and psychome-tric measure-ment pre and post-treatment, or training. Intentional assignment to groups according to choice of parents. Control group missing due to ethical considerati ons.	12 children with ADHD Protocol Treatmen t with methylph enidate (10 to 60 mg daily).	Both treatments reduced the ADHD symptons. There were improvements in d2 and TOVA. No significant differences in Conners or Weschler results were found between groups.	A greater sample size is necessary to determine equivalence between groups, because both led to significant improvement in many variables, although the equivalence test was not significant for all dependent variables. Changes in electroencephalog raphic bands were not monitored after NF training.
Neurofeed-back treatment of children with Attention Deficit Hyperactivi ty Disorder	Pop-Jordano-va, Markovs-ka-Simoska & Zorcec.	Mace donia 2005	12 children aged 7 to 13 years with ADHD	40 Biograph/ ProComp 2.0 sessions and EEG ratings SMR	Neuropsyco logical measureme nt pre and post-treatment.	Absent	Increase in Betha waves activity and decrease in Theta waves. Improvement in school grades, social adaptation and self-esteem was observed. ADHD symptoms were reduced.	NF is a good choice to ADHD treatment. Cooperation of parents and teachers is essential.
Controlled evaluation of a neurofeed-back training of slow cortical potentials in children with Attention Deficit/Hy-peractivity Disorder (ADHD)	Drechsler , Straub, Doehnert , Heinrich, Steinhau sen, & Brandeis.	Swit-zer-land, 2007	30 children with ADHD aged 9 to 13 years.	SCP training	Scales and neuropsy-cholofical assessment pre and post-training.	13 children with ADHD. Protocol Group cognitive-behaviora l therapy	Both groups showed improvement in the neuropsychologica l assessment. Less than half of the NF participants were able to differentiate their cortical activity on transference trials, so the effects cannot be completely attributed to the electrophysiologic al training.	Improvement in behavior may be related to NF, especially at a regulated level, but the found advantage in parents and teacher's scale in the NF groups cannot be explained by electrophysiologic al mechanisms in the entire group, however, it can be influenced by mediated variables such as parental support.

ADHD and EEG-neurofeed-back: a double-blind randomized placebo-controlled feasibility study	Lansber-gen, Dongen-Booms-ma, Buitelaar & Slaats-Willemse.	Ne-ther-lands 2011	14 children with ADHD betwee n 8 and 15 years old.	30 Theta supre-ssion SMR sessions. Individual NF protocols .	Clinical neuropsych ological, pre and post.train-ing. Control group and random group assignment .	6 children with ADHD. Protocol Placebo feedback	Changes were similar in both groups, with a significantly decreasing in ADHD symptoms.	Improvements after NF could be attributed to nonspecific effects such as time spent, given attention, therapeutic interaction or expectations, rather than the ability to have self-control cerebral activity The sample size was limited. It is possible to conduct a rigorous study controlled by placebo feedback.

* Considered Absent group because there were two groups, each one with a different protocol Neurofeedback: untrained or alternative treatment

In table 3 are included the main criteria considered by AAPB and the Neuronal Regulation Society, to defined the efficacy levels in studies with NF.

Table 3. Efficacy levels evaluation in the selected studies, based in the criteria of the AAPB and the Neuronal Regulation Society

Study	The sample is specific to a particular clinical condition	Specific, clear and valid measure-ment, with exclusion and inclusion criteria	A control group is included in the design.	Random participant assignment	Results compared with established efficacy treatments	Intra and inter individual s statistical analysis.	The informatio n given by the paper allows to replicate the study	Efficacy levels
Neurofeedback in children with ADHD: Specific event-related potential findings of a randomized controlled trial	Yes	Appropriate	Yes	Yes	Partially	Yes	Yes	III
Neurofeedback in ADHD: a single-blind randomized controlled trial	Yes	Yes	Yes	Yes	No	Yes	Yes	III
Neurofeedback training in children with ADHD: 6-month follow-up of a randomised controlled trial	Yes	Yes	Yes	Yes	Appropriate	Yes	Yes	IV

Is Neurofeedback an efficacious treatment for ADHD? A randomized controlled clinical trial	Yes	Yes	Yes	Yes	Appropriate	Yes	Yes	IV
Distinct EEG effects related to neurofeedback training in children with ADHD: A randomized controlled trial	Yes	Yes	Yes	Yes	Appropriate	Yes	Yes	IV
Neurofeedback for Children with ADHD: A Comparison of SCP and Theta/Beta Protocols	Yes	Yes	No	Yes *	No	Yes	Partially	II
Self-regulation of Slow Cortical Potentials: A New Treatment for Children With Attention Deficit/Hyperactivity Disorder	Yes	Yes	No	No	No	Yes	Partially	II
Neurofeedback Treatment for Attention-Deficit/Hyperactivity Disorder in Children: A Comparison between Methylphenidate	Yes	Yes	Yes	No	Yes	Yes	Yes	III
Neurofeedback treatment of children with Attention Deficit Hyperactivity Disorder, and a	Yes	Yes	No	No	No	Yes	Yes	II
controlled evaluation of a neurofeedback training of slow cortical potentials in children with Attention Deficit/Hyperactivity Disorder (ADHD)	Yes	Yes	Yes	Partially	Yes	Yes	Yes	III
ADHD and EEG-neurofeedback: a double-blind randomized placebo-controlled feasibility study	Yes	Yes	Yes	Yes	No**	Yes	Yes	IV

* Participants were randomly assigned to two different experimental conditions with no control group
**In this study the control group used a placebo neurofeedback protocol

Discussion and Conclusions

According to the review of the factors that determine the efficacy level of the NF as an alternative for the ADHD treatment, it is determined that the selected studies present efficacy levels between II and IV (see Table 3), which suggests that the NF would be an effective technique for controlling some of the symptoms of ADHD.

In the same table it can be seen that there are three studies classified in level IV, which suggests that it is a really effective technique. However, according to the proposed classification by the AAPB and the Society for Neuronal Regulation, in order to consider the highest level of efficacy, it is necessary that such studies are conducted by independent groups, but this is not the case, so the three classified studies as level IV, were performed in the same research center. Additionally, there are several factors that deserve to be into consideration.

Furthermore, other mediating variables such as parental and school support have proved to be decisive (Pop-Jordanova et al., 2005). The sample size and the timing and type of measurement are still a limitation in many studies. Hence, the importance of having a baseline of register of EEG and a post NF, in order to know and control fluctuations waves (Vernon, 2005; Dempster & Vernon, 2009).

Based on levels of efficacy, three studies of this type of classification were found. Monastra et al., (2005) assigned to the EEG biofeedback a level of "probable efficacy" as a treatment for ADHD and explained, that in spite of 75% of patients from published studies reported significant clinical improvement, further studies would be necessary with random and controlled groups to provide a better estimate percentage of real patients.

Arns, M. de Ridder, S. Strehl, U. Breteler, M. & Coenen, A. (2009) exposed in a meta-analysis, that the ADHD treatment using the NF technique, improves behavior in open trials with medium sizes of compared samples with active or passive controlled groups. It was concluded that treatment with NF can be ranked in level 5 of efficacy: Effective and specific.

However, a study based on the random presentation of electroencephalographic changes published in 2013, in which a placebo training protocol was used, indicates that there were not statistically significant differences obtained with the group under training with NF (Vollebregt Dongen-Boomsma, Buitelaar Slaats-Willemse, 2013).

Secondly, it is important to differentiate between effectiveness and efficacy. Rossiter (2004) explains that effectiveness studies place a greater emphasis to external validity, while efficacy studies are focused on the internal validity.

In this line, Pine (2009) argues that until the effects are not replicated convincingly, and there are no more results to compare the efficacy of different trials, the NF should not be recommended as an alternate treatment for ADHD. Although, the carried out researches presented some findings in favor the use of NF techniques in ADHD treatment, it cannot be recommended yet, as a unique treatment option. In spite of the multiple factors involved in the disorder and heterogeneity of neuropsychological patterns reported, it is suggested their use as a suitable complement, when it is focused on effective parenting patterns oriented in developing skills that allow dealing with children and adolescents and

providing support at the school. Interventions that promote the recognition of the impairment and provide strategies of environmental type are generally favorable and could be an ideal complement to the work with the NF techniques. Its use does not appear to be incompatible with the pharmacological support, though it is not established yet, whether the combination of these two strategies could be better than the particular use of the drug.

Finally, in order to do for further studies, it is important to consider the control level of the variables and select broader samples, as well as to provide a proper diagnosis and establish groups of participants according to neuropsychological performance patterns. In that way, some patients might obtain greater benefit from the use of NF, due to the circuits that could have been affected rather than the technique itself.

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