International Journal of Medicine and Medical Sciences Vol.1(2) pp.017-022, February, 2009
Available online http://www.academicjournals.org/ijmms
2009 Academic Journals

Full Length Research paper

Biofeedback application for somatoform disorders and attention deficit hyperactivity disorder (ADHD) in children

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Accepted 22 January, 2009

Biofeedback is a modern computer-related technique used mainly for assessment and therapy of psychophysiological disorders. The influx of about 800 patients per year with stress related disorders is the cause of extensive clinical use of biofeedback in our Department. In this article some results obtained with electrodermal (EDR) and electroencephalography (EEG) biofeedback in the assessment and therapy of children with two most common disorders somatoform and Attention Deficit Hyperactivity Disorder in the period of fifteen years are presented and discussed. The two groups of patients comprised 243 children with somatoform problems (age 10.31 ± 2.75 years) and 50 children with Attention Deficit Hyperactivity Disorder (age 11.11 ± 4.51 years). Before application of individually adapted biofeedback modalities, interviews with parents and children, large scale of psychometric tests, as well as evaluations with Quantitative EEG (Mitzar, Russia) were performed. For EDR biofeedback relax plus and Inner Tunner Professional, Ultramind, UK, while for EEG biofeedback Biograph ProComp, Thought Technology LTD, Canada were applied. For somatoform problems 10 - 15 sessions of EDR biofeedback were sufficient, while for Attention Deficit Hyperactivity Disorder the number of needed sessions was 20 - 40, twice a week. Our experiences with these non-pharmacologic methods in the assessment and therapy of somatoform problems and Attention Deficit Hyperactivity Disorder are quite positive, providing that biofeedback is combined with psychological support and cognitive-behavioral psychotherapy. The results showed that the EDR biofeedback is more effective in the case of somatoform disorders, and the EEG biofeedback (neurofeedback) in the case of Attention Deficit Hyperactivity Disorder. Still, EDR biofeedback appeared to be more preferable method by young children than EEG biofeedback, either as a unique treatment or as a first step preceding the neurofeedback therapy.

Key words: Electrodermal biofeedback, EEG-biofeedback, somatofoam disorders, ADHD.

INTRODUCTION

The biopsycholosocial framework, that recognizes the importance of the mind-body interrelationship for the developing human being became relevant for the contemporary pediatric healthcare. Simultaneously, biofeedback has arise as a modern computer-related operant conditioning technique used for assessment and therapy of many psychophysiological disorders, especially the stress-related ones. Its objective is to increase the voluntary control over the physiological processes that are otherwise outside awareness, using the information about them in the form of an external signal.

Various biofeedback approaches are increasingly used Worldwide as non-pharmacological and cost-benefit effective research and therapeutic tools. A significant increase in research has documented the efficiency of biofeedback for children and adolescents that manifest behavioral, emotional and cognitive problems (Culbert et al., 1996; Scott, 1998; Pop-Jordanova, 1999; Schwartz, 1987). Unfortunately, biofeedback methods are not yet well known in pediatric settings.

Biofeedback modalities can be divided into peripheral (based on electromyography, electrodermal response, heart rate, temperature, blood volume pulse) or central (based on electroencephalography, that is, neuro-feed

back) .In this paper we will concentrate on two most characteristic modalities: electrodermal and electroencecephalographic.

Electrodermal response (EDR) is a complex (Schwartz, 1987) reaction with a number of control centers in the CNS. Three systems related to arousal, emotion and locomotion are responsible for the control of the electrodermal activity. (Boucsein, 1992) The reticular formation controls EDR related to states of arousal, the limbic structures (hypothalamus, cingulated gyres and hippocampus) are involved in EDR activity related to emotional responses and thermoregulation, while the motor cortex and parts of the basal ganglia are involved in locomotion. In particular, skin potential and skin conductance used as parameters in EDR biofeedback are related to both sympathetic and parasympathetic arousal. Treatment by EDR biofeedback is generally based on training patients in strategies for lowering arousal and maintaining (Mangina and Beuzeron-Mangina, 1996; Andreassi, 2000). Treatment by EDR biofeedback is generally based on training patients in strategies for lowering arousal and maintaining a healthful sympathetic/Parasympathetic tone. Consequently, EDR biofeedback modality is a first choice for introvert persons, where high inner arousal is a typical finding and biofeedback training is supposed to lower sympathetic arousal. Changes in electrodermal activity can be reliably detected with (Andreassi, 2000; Kropotov, 2009).

In one second of stimulus presentation, often following a single event. It is important to know that electrodermal conductance precede any other signals related to neuroimaging such Positron Emission Tomography (PET), Blood oxigen level-dependent functional magnetic resonance (BOLD), Single photon emission computed tomography (SPECT) etc which must be used in practice. In other words, the changes of electrodermal activity can be registered before the changes obtained by the other neuro-imaging techniques.

Neurofeedback (NF) that is EEG biofeedback refers to a specific operant-conditioning paradigm where an individual learns how to influence the electrical activity (frequency, amplitude or synchronization) of his brain. It involves teaching skills through the rewarding experience of inducing EEG changes reflected in a perceivable signal (light or sound). Neurofeedback has been shown to be particularly useful in reference to pathologies characterized by dysfunctional regulation of cortical arousal, such as epilepsy and attention deficit hyperactivity disorder (Sterman, 1977; Lubar et al., 1995; Lubar and Lubar, 1999; Lubar, 1991; Thompson and Thompson, 2003). We also used EEG biofeedback in a group of anorectic girls (Thompson and Thompson, 1998; Birbaumer and Roberts, 1999), PTSD (Pop-Jordanova, 2000), headaches (Pop-Jordanova, 2003), as well as for optimal school and music performance (Pop-Jordanova, 2004; Pop-Jordanova et al., 1998).

Our Department has an input of over 800 patients per year with different stress-related problems: psychosomatic disorders; behavioral problems; elimination disorders (enuresis nocturnal and encompresis); anxiety/phobic disorders; ticks; eating disorders (anorexia and bulimia, obesity); sleep disorders; Attention Deficit Hyperactivity Disorder A/ADD; PTSD (Posttraumatic Stress Disorder); speech problems (stuttering). Furthermore, 20% from all patients admitted at the Pediatric Clinic in Skopje are children who suffer from some comorbid chronic diseases as: cystic fibrosis; bronchial asthma; malignancies; diabetes mellitus; rheumatologic diseases; some kinds of immune deficit; epilepsy; brain injuries and kidney failure. In some of the mentioned conditions neurofeedback treatment is applied according to individual EEG indices (Pop-Jorda-nova and Cakalaroska, 2008; Markovska-Simoska et al., 2008; Pop-Jordanova et al., 2008). Besides, comparing the neurofeedback results at the begining and the end of the treatment, neurofeedback is actually used for dynamic evaluation of the progress-sion/regression of the treated illness. Recently, we started to use quantitative EEG, evoked potentials and event related potentials as a mean for assessment of children with psycho-physio-logical problems.

METHODS

In this prospective study two groups of children from both sexes were evaluated: first group with somatoform problems (N = 243, mean age 10.31 ± 2.75 years) and second group with ADHD (N = 50, mean age 11.11 ± 4.51 years). The diagnosis was made with criteria from ICD -10.

Psychophysiological assessment comprised clinical interview and standard checking, together with application of different psychometric instruments. For assessment of general cognitive abilities we used Wechsler Intelligence Scale-R (WISC) (Wechsler, 1994), Raven progressive matrices (Ravens Progressive Matrices, 1981), Rey complex figure (Test de copie d'une figure complexe de A. Rey, 1959) and Gestalt-Bender Test (Bender, 1946). For ADHD we used Conner's rating scales for parents and teachers (Goyette et al., 1978), while, for children we applied Amsterdam Neuro-psychological Test (ANT) (1994). Test of Variables of Attention (TOVA) (Greenberg and Crosby, 1992), PsyTask from MITSAR and Trail-test for measuring attention and concentration, as well as Verbal and Non-verbal tests for short-term memory (TMT, 1968). Additional psychometric instruments were used for evaluation of personality and emotions if needed. All tests were applied before and after the treatment.

The treatment strategy includes supportive psychotherapy, family therapy (if needed) and biofeedback modalities (EDR and EEG). Biofeedback training comprised 10 - 20 sessions in the case of EDR and 20-40 sessions in the case of EEG (one session per week with several games, total duration 60 min per session). The applied biofeedback equipment included Relax plus and Inner Tunner Professional, Ultramind, UK; Biograph ProComp, Thought Technology LTD, Canada; and Q-EEG, MITSAR Co. LTD, Russia.

RESULTS AND DISCUSSION

Somatoform problems

Somatoform disorders are the most frequent stress-

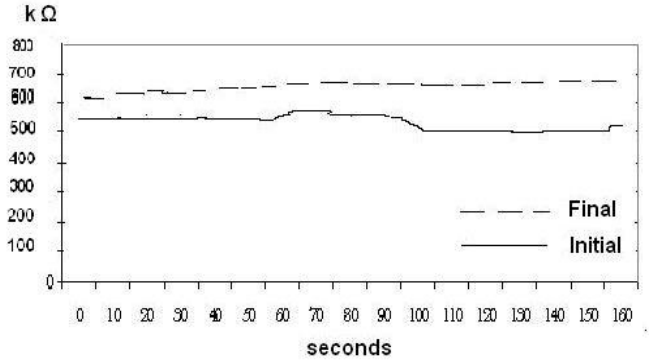

Figure 1. Changes of EDR for children with somatization (243 children, mean age 10.3 ± 2.75 years).

related manifestations in preadolescent children. These disorders comprise physical symptoms without any organic origin, usually related to emotional conflicts. In this study, results obtained for 243 children, mean age 10.31 ± 2.75 years (both sexes) are presented.

The main clinical manifestation was stomachache as a unique symptom (74%), followed by stenocardia/palpitation (16%) and nausea/vomiting without stomachache (10%). Children with different types of headache are analyzed separately. Interviews obtained from parents as well as the psychological assessment with General Anxiety Scale (GAS) and Child Behavior Checklist (CBCL) confirmed high anxiety in almost all children (92%) and in half of them behavioral problems (54%). The main provocation for somatization was related to school or family problems, including rivality with brother/sister. For all children in this group, electrodermal biofeedback was applied. The statistical analysis of the differences between initial and final electrodermal resistance showed satisfactory improvement with t-test amounting 10.05 ($p < 0.01$). The changes of electrode-mal resistance during first 3 min of initial and final sessions are shown on Figure 1. The obtained increase of resistance, indicating the stress diminishing, corresponds to the clinical symptom improvement confirmed by self-evaluation test results.

Self-evaluation was made by adapted Biondy questionnaire (Biondi and Portusci, 1994) where duration, intensity and frequency of symptoms were checked. In addition, the school absenteeism is also evaluated.

Attention deficit hyperactivity disorder

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most frequent diagnoses during childhood, varying between 2 and 10% depending on country or cultural area. In our county, the incidence of ADHD is about 2% (Pop-Jordanova et al., 2005). According Diagnostic and Statistic Manuel for Mental Diseases (DSM-IV) (ADHD) / Attention Deficit Disorder (ADD); Posttraumatic Stress Disorder (PTSD); Obsessive-Compulsive Disorder (OCD) there are three main clinical forms of this disorder: inattentive, hyperactive/impulsive and combined. The overlapping of all three forms with learning disabilities is very high (up to 70%), as well as with conduct problems. The ADD form mainly overlaps with anxiety disorders and learning disability, and HD mostly overlaps with conduct disorder. Some children with ADHD have movement disorders or tics and occasionally they may have seizure disorders. Strong genetic component related to defect in chromosome 11 is showed in some studies (Van Baal et al., 1998). Concerning the involvement of specific neurotransmitter systems in the pathophysiology of ADHD some authors suggests that the catecholaminergic dysregulations are centrally involved (Durston et al., 2005).

Modern of ADHD in our patients (N = 50, mean age 11.11 ± 4.51 years) was made by diagnostic criteria ICD - 10. We used Connors rating scales for parents and teachers' techniques like Positron Emission Tomography (PET) or functional Magnetic Resonance (fMRI) show structural differences on the frontal lobe of the neo-cortex or in the sub-cortical structures like basal ganglia and thalamus. Likewise, using q-EEG we can point out significant differences between ADHD children and so called "normal" children. Similarly, using q-EEG we can point out significant differences between ADHD and normal children. In this context, q-EEG is a very favorable diagnostic tool for ADHD (Linden et al., 1996; Monastra et al., 1999; Duffy et al., 1994).

In the last years many facts lead to accept the system of executive function as the most disturbed in ADHD children. Executive system is responsible for planning, steering and controlling cognitive functions. In ADHD children extrapolating features of executive functions are impaired together with the ability to predict consequences of their own actions (Kropotov, 2009).The diagnosis, as well as WICS-R for assessing the cognitive ability of patients. In addition, neurofeedback assessment (eyes open, 30 min recording) was made with Biograph/Procomp. Version 2.1 in Cz (10/20 international placement). The q-EEG for 25 patients is obtained by 21 standard MITSAR EEG recordings with the administration of standardized tests: eyes-open, eyes-closed, visual continuous performance, auditory continuous performance, reading test and math test. EEG data are analyzed for frequency content using the fast Fourier transformation. Statistical analysis compares subjects data with a normative database corrected for time-of-day variations. Data is also evaluated for percentage change across states and compared with a normative database for state modulation. Figure 2. The obtained topographic maps show covariance between all sites at relevant frequencies compared with a normative database to obtain functional cortical interactions. Our spectrogram analysis is based on Kropotov's five q-EEG subtypes of ADHD (Kropotov, 2009). The obtained q-EEG showed very slow alpha ex-

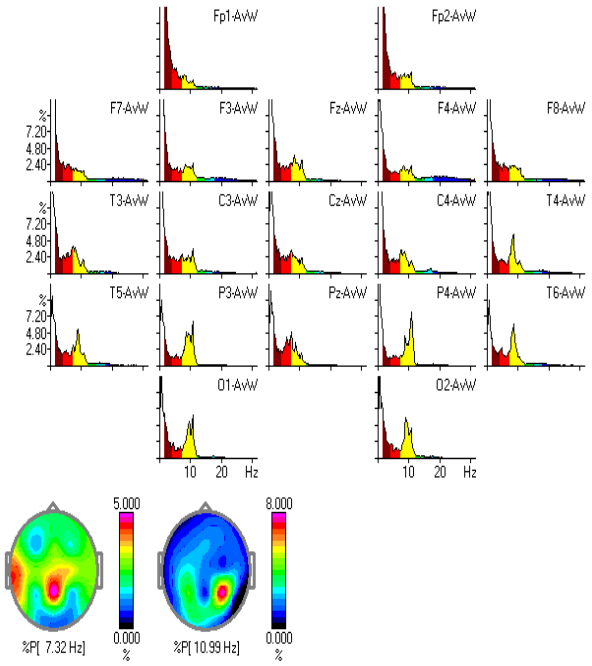

Figure 2. Q-EEG subtype 5 for an ADHD patient.

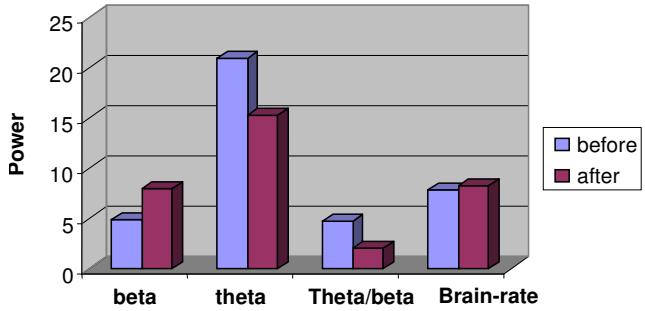

Figure 3. Changes of biofeedback parameters (before and after NF training).

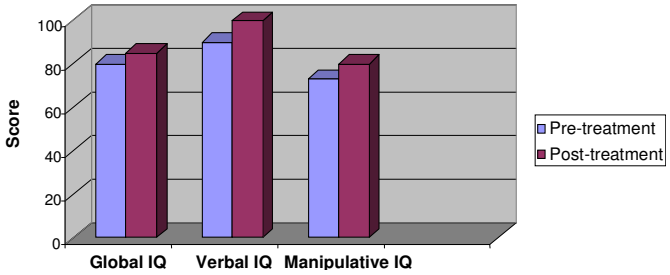

Figure 4. Changes of intelligence scores (before and after NF treatment).

cess (subtype 5) in 25% of children, and high theta/beta ratio in frontal-central cortex (subtype 2) in other 25% of children. The last 50% belong to the combined 1 and 2 subtypes. One characteristic picture of q-EEG type 5 is shown on Figure 2.

Neurofeedback treatment is indicated in ADHD patients who show excessive EEG slowing in the superior frontal cortex or the midline central cortex. The most relevant neurological EEG correlate at ADD/ADHD is usually assumed in the place where the highest ratio of theta/beta activity is seen. Placement of the electrode between Cz and Fz is the best for neurofeedback training. We followed consecutive two treatment protocols. (1) Training to increase the SMR EEG rhythm (11 - 13 Hz) and at the same time, to inhibit (decrease) slow activity in the theta range (4 - 8 Hz); this approach is primarily used for the hyperactive component of ADHD. (2) Training to focus attention aiming at increasing higher beta activity (16 - 20 Hz), while training for decreasing the slow activity continued. The training is performed with 40 sessions, 60 min duration per session, one per week (Duffy et al., 1994).

Figure 3 shows the decrease of theta and the increase of beta power, as well as the changes of theta/beta ratio as the most used neurofeedback training indicator. In addiion, changes in brain-rate as a spectrum shift indicator (Pop-Jordanova and Pop-Jordanov, 2005) are displayed.

All children from the sample were also tested for intellectual capacities with WISC-R before and after treatment. The findings are shown on Figure 4. It is clear from Figure 4 that verbal and manipulative intelligence scores are higher after neurofeedback training and it corresponds with the increase of school marks for 10 - 20 %. Connors rating scales for children checked by mothers and teachers before treatment confirmed attention deficit, impulsivity, social inadaptability and hyperactivity (mean score 87 ± 2.3). This figure was decreased after the treatment for about 30%.

Interviews and follow-up Connors rating scales showed better school performance, lower hyperactivity, better social relationships and improved self-esteem after the treatment. All these findings are in agreement with the changes in the EEG pattern shown in Figure 3. In our country stimulant medications for ADHD are not in use, therefore the success was only the result of neurotherapy combined with psychological support.

In the past, the world-wide prevalent approach for the treatment of ADHD involved the use of medications, primarily stimulants, supplemented by antidepressants, alpha-blockers or antipsychotic. Other non-medical therapies involved the extensive use of behavior therapy including rewards and punishments, the family system approach or cognitive-behavioral therapy.

Later on, neurofeedback appeared as a powerful adjunctive technique, which combined with the use of behavior modification techniques based mainly on reinforcement, showed very promising results. The need for

Table 1. Results obtained with EDR biofeedback.

Disorder	Number of patients	Mean age (years)	Changes of skin resistance (t-test)	Significance
Somatoform problems	243	10.31 ± 2.75	10.05	P < 0.01
ADHD	50	11.11 ± 4.51	5.07	p< 0.01

medication is diminished if we change cortical functioning using neurofeedback. The long-term effects of neurofeedback have already been documented (Kropotov, 2009; Sterman, 1977; Lubar et al., 1995; Lubar and Lubar, 1999; Lubar, 1991; Thompson and Thompson, 2003; Thompson and Thompson, 1998).

For comparison, the results obtained with EDR biofeedback in the two groups of disorders are summarized on Table 1. As can be seen, from Table 1, high statistical significance is obtained with t - test showing that EDR is less effective for ADHD. Still, in both cases, the improvements in EDR parameters have been accompanied by positive clinical outcomes. Similar results were obtained for chronic ill patients, using EDR biofeedback as additional therapy, especially for relaxation and coping with the illness.

The point is that biofeedback is not only a learning process, but has also symbolic meaning for children: something is changing in my body. To obtain best results, person who applies biofeedback must be friendly, efficient, and professional in appearance and behavior for inducing confidence, satisfaction and compliance of the patient. In addition, cognitive preparation of the patient is also important. It includes the explanation for the rationale for physiological self-regulation, therapy process and goals, exclusion of medications and symptom evaluation. In that way, the resistance, skepticism and pessimism at both sides (children and parents) could be override and the motivation increased. It must be mentioned that for all biofeedback applications, the motivation from both sides (children and parents) is of crucial importance.

Conclusion

In pediatric research and clinic, the holistic approach is particularly important, including physical, emotional and cognitive domains. In line with this philosophy, biofeedback can serve as a non-pharmacological and cost-benefit efficient component. Consequently, the efficiency of biofeedback is increased when used as a part of multicomponent treatment, combining it with behavioral training and the work with parents and teachers. Electrodermal biofeedback is shown to be very good choice for stress-related conditions in children, such as somatoform disorders. This can be explained by EDR involving amygdale-limbic system, related with emotions. More-over, our experience shows that children prefer EDR to other biofeedback modalities, especially since the animations included in EDR software appeared to be more amusing for children.

In the case of ADHD, neurofeedback that involve changes of EEG patterns is preferable modality. The use of quantitative EEG is highly important for accurate determination of subtypes and proper training protocols.

In general, the combination of EDR and NF biofeedback (targeting emotions and cognition, respectively) is confirmed to be the best choice for both disorders. This can be attributed to fundamental correlates of neurobiological systems underpinning emotion and cognition. Or, as one proverb says: "The days that make us happy, make us wise", and vice versa.

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