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NEUROFEEDBACK TREATMENT OF CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

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Abstract: ***Background****:* Biofeedback is a modern computer-related technique used for assessment and therapy of many psychophysiological disorders, especially stress-related ones. After a short overview of the basic concepts of biofeedback, in this study the application of EEG biofeedback (neurofeedback) in the assessment of and therapy for attention deficit hyperactivity disorders (ADHD) is presented and discussed.

Methods*:* The study comprised 12 children diagnosed as ADHD, selected according to ICD–10, and assessed by WISC–R, Q–EEG, neurofeedback and Conner's questionnaire for parents and teachers. The mean age was 9.5 years (7 to 13), both sexes. Each of them participated in a five-month programme of neurofeedback training, performed two times weekly with Biograph/ProComp 2.0 protocols.

Results*:* Post-treatment results showed an improved EEG pattern expressed in increased 16–20 Hz (beta) activity and decreased 4–8 Hz (theta) activity. In parallel, higher scores on WISC–R, better school notes and improved social adaptability and self-esteem were obtained.

Conclusions*:* EEG biofeedback operant conditioning is a good choice for treatment of ADHD children. The method is non-invasive and has high cost-benefit. Optimal results are obtained in children of higher age. Cooperation with family members and teachers is crucial.

Key words: attention deficit hyperactivity disorder, brain waves, neurofeedback, operant conditioning.

Introduction

Biofeedback is a self-control method, based on electronic measuring and feeding back of information about one's own inner activity. Bearing in mind that this approach is not well known in broader medical circles, we quote here an expanded definition, developed recently by M.S. Shwartz:

″As a process, biofeedback is a group of therapeutic procedures that uses electronic or electromechanical instruments to accurately measure, process and feed back to persons and their therapists information with educational and reinforcing properties about their neuromuscular and autonomic activity, both normal and abnormal in the form of analogue or binary, auditory and/or visual feedback signal. Best achieved with a competent biofeedback professional, the objective are to help persons develop greater awareness of, confidence in, and an increase in voluntary control over their physiological processes that are otherwise outside awareness and/or under less voluntary control, by first controlling the external signal and then with internal psychophysiological cognitions and/or by engaging in and applying behaviour to prevent symptom onset, stop it, or reduce it soon after onset.″ [1]

Biofeedback may be divided into peripheral (based on electromyography-EMG, electrodermal response-EDR, etc.) and central (based on electroencephalography- EEG, i.e. neurofeedback). Once a clinician has determined that a patient is a good candidate for biofeedback, a protocol can be developed as a part of the treatment plan. The protocol includes biofeedback modality (EDR, EMG, temperature training, peripheral blood flow or EEG) and individualized specifics of treatment. The practice of skills includes regular individual sessions and homework .

Peripheral biofeedback has been used for psychophysiological like disorders such as neuromuscular problems, cardiac arrhythmia, hypertension, vascular migraine, fecal incontinence and enuresis, bruxism, Raynaud's disease, etc. It is an especially good tool for stress diminishing.

In recent years, we obtained encouraging results with the application of EDR biofeedback in paediatric patients with different psychosomatic problems [2, 3, 4]. Treatment generally consisted of training patients in strategies for lowering arousal and maintaining a healthful Sy/PaSy tone.

Neurofeedback (NFB) is an operant conditioning procedure whereby an individual modifies the amplitude, frequency, or coherency of the electrophysiological dynamics of his/her own brain. It involves teaching skills through the rewarding experience of inducing changes in a perceivable signal (light or sound). Although NBF might be the treatment of choice in many diseases, the clinician must have the capacity to recognize the conditions, signs and symptoms, which should be medically treated with NFB, solely or complementarily.

In this context, a detailed pretreatment interview, including neuro-mental status, family history, psychosocial history, medication, risk factors, etc., should be taken into account. During the assessment it is very important to use tests that measure cognitive ability, neuropsychological tests, EEG and quantitative electroencephalograpy – Q–EEG [5, 6, 7, 8, 9].

In this paper, some of our experience with neurofeedback in ADD/-ADHD children will be presented. As it is known, ADHD and ADD are disorders that affects about 10% of child population. According to the DMS–IV there are three main clinical forms of this disorder: inattentive, hyperactive/impulsive and combined. The overlapping of both ADD/ADHD and 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 ADHD mostly overlaps with conduct disorder. Some children with ADD/ADHD have movement disorders or tics and occasionally they may have seizure disorders. Some new studies [10] showed a strong genetic component in this constellation of problems, related to defects in chromosome 11.

Applying SPECT and PET scan to cortical surface blood flow and cortical activity five subtypes of ADHD were identified [9]:

– frontal lobe deactivation (presented as ADD, which responds to therapy with Ritalin);

– temporal lobe dysfunction (very like temporal epilepsy, responds to therapy with anticonvulsant);

– homogenous cortical suppression (responds to combination antidepressives + Ritalin);

– increased activity in the anterior medial aspects of the frontal lobes – girus rectus (responds to alpha adrenergic blockers like clonidine);

– hypofrontality at rest, but normal frontal activity in intellectual stress (responds to Ritalin).

NFB is indicated in 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 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 NBF training.

Although biofeedback techniques, both peripheral and neurofeedback, are extensively used in the USA, Canada and several European countries [1], our team is the first, and to our knowledge still the only one, applying these techniques in the South-Est European region.

Method and sampling

The aim of our study was to evaluate the effect of neurofeedback treatment on patients diagnosed as attention deficit hyperactivity disorder (ADHD). Mean age of the patients was 9 years (SD±1.5), 11 boys and one girl. Clinical features comprised selective attention, distractibility only in the girl, and impulsivity/hyperactivity in all the boys (ICD–10). Connor's rating scales for parents and teachers, and Wechsler intelligence scales-revised (WISC–R) were used as psychometric instruments. The final selection of patients was based on the Q–EEG findings. We used 16 channel Q–EEG ″Dantec″ – Concerto (1889). Then we set up a training procedure with protocols based on those abnormalities, applying neurofeedback for both assessment and therapy.

The goal of the NFB treatment was to train the individual to normalize the abnormal EEG frequencies and, at the same time, to develop as much awareness as possible of what that normalized EEG state is like, i.e. to learn feeling it.Namely, the theta/beta ration in children with ADHD is often above 3. The aim of NFB training is to obtain a ratio lower than 2.5 [ref. 11, p. 166].

We used the Biograph/Procomp neurofeedback software with EEG recording in CZ. Assessment procedure of 30-minute duration, and training was performed twice a week (50 minutes per session). The final effect was analysed after 40 sessions.

EEG recordings were obtained from electrodes situated: active at the Cz, reference electrode on the right or left ear and ground on the opposite ear, using the 10–20 International System. Omni Prep was used to prepare the skin and ten20 conductive paste was used to connect the electrodes to the skin. The subject's EEG was sampled at a rate of 256 samples/sec.

The following physiological responses were monitored during each session:

a) Theta brain activity defined as 4–8 Hz

b) Beta brain activity defined as 16–20 Hz

c) SMR brain activity defined as a 12–15 Hz

d) EMG activity (muscle artifact) defined as 40–60 Hz

Biofeedback was performed to suppress (decrease) the theta (4–8 Hz) and enhance (increase) the beta (16–20 Hz) bands on the EEG. Threshold levels were determined for each subject from the baseline amplitude measures of theta and beta activity.

Audio (tones, bleeps) and visual (graphs, game movement, or points) feedback was attained by the subjects when three conditions were met simultaneously: the beta amplitude was above its threshold, the theta amplitude was below its threshold and also the EMG (muscle artifact) was below its threshold. Thus, the EEG brainwaves were shaped to obtain a theta/beta ration below 2.5.

Patients were re-evaluated (after completion of 40 sessions) using parent and teacher behaviour rating scales and WISC–R.

Results

The fact that practically all the children were boys corresponds to the findings in the literature about the prevalence of the disorder [1, 5]. All children from the sample were tested for intellectual capacities with WISC–R before treatment. We obtained scores for WISC–R in the normal range: global IQ = 80 ± 18.3; verbal IQ = 90 ± 15.5; manipulative IQ = 73 ± 18.9.

Connor's scales checked by mothers confirmed attention deficit, impulsivity, social inadaptability and hyperactivity of children (mean scores 87 ± 2.3; from max. 144).

EEG assessment in all the children showed dominant theta activity (4–8 Hz) and a deficit of beta activity (16–20 Hz) in CZ.

Q-EEG confirmed excessive EEG slowing in the superior frontal cortex and in the midline central cortex (interpretation by Dr. Sc. Gordana Kiteva).

Average school marks before treatment were for mathematics – 3 (range 1–5), language – 4.5, nature and society 3; they increased after treatment by 10–25 percent.

Figure 1 shows average amplitudes of theta brain waves obtained at the beginning and after the end of neurofeedback treatment for each of total 12 children.

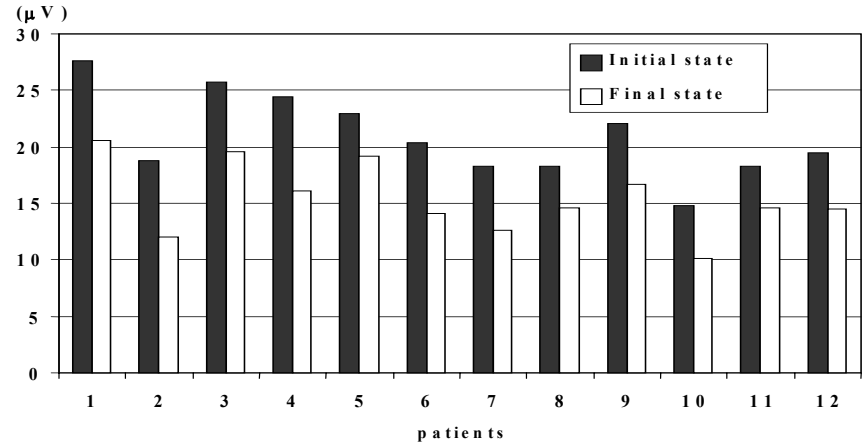

Figure 1 – *Average amplitudes of theta brain waves at the beginning and after the end of neurofeedback treatment*

Слика 1 – *Средни амплитуди на тета брановите на почетокот и по неурофидбек тренингот*

Figure 2 shows average amplitudes of beta brain waves obtained before and after training. Statistics showed no significant changes for theta waves (t = 0.47, $p > 0.05$). For beta waves, the training showed significant improvement (t = 3.30, $p < 0.01$).

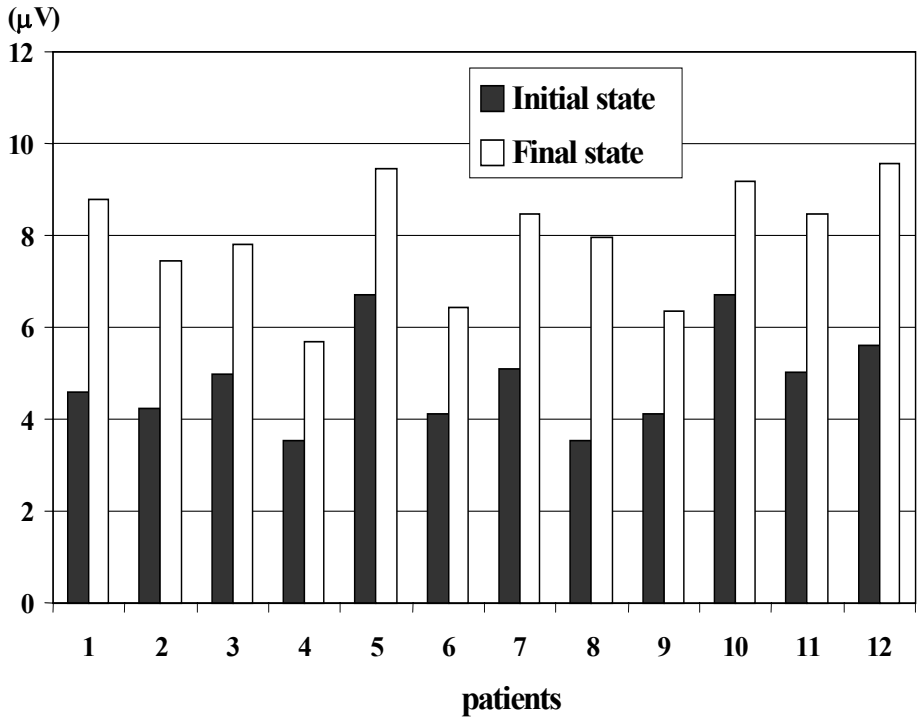

Figure 2 – *Average amplitudes of beta brain waves obtained before and after training*

Слика 2 – *Средни амплитуди на бета брановите пред и по тренингот*

The above results for theta and beta amplitudes are in good agreement with the recent publications on ADHD children of a similar age (10–13 years) showing the change of average EEG amplitude values near CZ between 17 μV and 50 μV in the case of theta, and between 4.5 μV and 7.5 μV in the case of beta [9 pp. 117, 118, 129].

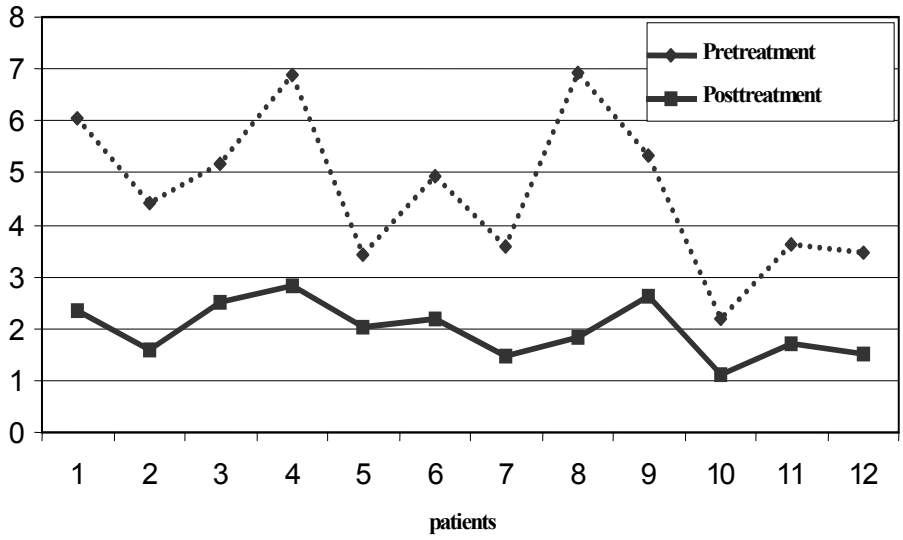

Figure 3 – *Changes in theta/beta ratios of average amplitudes*

Слика 3 – Промена во односот на средните амплитуди тета/бета

The results obtained from WISC–R before and after treatment are shown in Table 1.

Table 1 – Табела 1

Results obtained for WISC-R

Добиени резултати со WISC-R

	Global IQ (mean ± SD)	**Verbal IQ** (mean ± SD)	**Manipulative IQ** (mean ± SD)
Pre-treatment	80 ± 18.3	90 ± 15.5	73 ± 18.9
Post-treatment	85 ± 15.2	100 ± 12.3	80 ± 7.2

$t = 6.97,\ p < 0.001$

It is clear that verbal and manipulative intelligence scors are higher after NFB training and it correspond with better school marks for 10–25 percent. Our results are similar to the findings of other authors [12, 13].

Discussion

We followed two treatment protocols. First training to increase the EEG rhythm called the sensorimotor rhythm (SMR) on a location over the motor strip and, at the same time, training to inhibit (decrease) slow activity in the range from 4–8 Hz over the same area. That approach is primarily used for the hyperactive component of ADHD. Then, training with focusing of attention is performed, aiming at increasing higher frequency beta activity in the range between 16 and 20 Hz. At the same time training for decreasing the slow activity continued. [7, 12, 13].

The changes in the EEG pattern of all the children obtained as a result of the training are obvious. Interview and follow-up Conner's scale showed better school performance, lower hyperactivity, better social relationships and improved self-esteem after neurofeedback treatment.

Why does neurofeedback show itself to be so effective in ADHD?

ADHD could be defined as a dysfunction of the executive (control) system of the brain. Direct evidence for such definition is obtained from MRI, fMRI, PET and lesion studies. It is supposed that the executive dysfunction of ADHD is reflected in the impairment of the executive system of the brain, which in turn is expressed in an abnormal EEG pattern in ADHD patients. This means that ADD/ADHD is reflected in the way the child processes information and in turn affects how the individual perceives the world and therefore responds to it.

For the present, ADD/ADHD is not a curable disease; it can be only managed, because it is a lifelong neurologically based disorder. However, as many researchers have confirmed, human subjects have the ability to voluntarily produce the ″normal″ EEG pattern and to maintain it for long periods of time. Using NFB we can effect a longer-term change in this disorder than psychotherapy or pharmacotherapy. The stimulant medications are powerful for many hyperactive children (60–70% improvement), but the stopping of medication returns the behaviour. As is known, medication temporarily improves the distribution of neurotransmitters (dopamine and norepinephrine) in the brain [9, 11, 14].

The use of NBF eliminates medication and the learned behaviour endures for a long term (over 10 years). On the other hand, NFB does not have any side- effects. The children are learning to internalise control and change themselves accordingly.

Conclusion

EEG biofeedback operant conditioning is a good choice for treatment of ADHD children. Optimal results are obtained in children of higher age. This method has high cost-benefit and, being noninvasive, it is very comfortable in application. Cooperation with family members and teachers is crucial.

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Резиме

НЕУРОФИДБЕК ТЕРАПИЈАТА КАЈ ДЕЦА СО ДЕФИЦИТ НА ВНИМАНИЕТО И ХИПЕРАКТИВНОСТ

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Биофидбек претставува модерна компјутерски поддржана техника што се користи за проценка и терапија на разни психофизиолошки растројства, особено оние кои се стресно индуцирани. По кусиот приказ на базичните концепти на биофидбекот, во оваа студија е прикажана апликацијата на неурофидбек (ЕЕГ биофидбек) во проценка и терапија на деца со дефицит на вниманието и хиперактивност (АДХД).

Студијата опфаќа 12 деца дијагностицирани како АДХД, селектирани според МКБ-10, проценети со WISC–R, Q–EEG, неурофидбек и Coner's прашалник за родители и наставници. Средната возраст на децата е 9.5 години (7 до 13), и се од двата пола. Секое од нив учествуваше во петмесечен програм на неурофидбек тренинг, изведуван двапати неделно со Biograph/-ProComp 2.0 протокол.

Резултатите после третманот покажуваат подобрени ЕЕГ параметри искажани преку зголемена 16–20 Hz (бета) активност и намалена 4–8 Hz (тета) активност. Паралелно со тоа, постигнати се повисоки скорови на WISC–R тестот за интелигенција, подобри школски резултати како и подобрена адаптибилност и само-почитување.

Во заклучок би кажале дека ЕЕГ биофидбек оперантно условување претставува добар избор за терапија на децата со АДХД. Методата е неинвазивна и со висок cost-benefit. Многу битно за постигнување успех е добрата соработка со членовите на семејството и наставниците.

Клучни зборови: дефицит на вниманието со хиперактивност, мозочни бранови, неурофидбек, оперантно условување.