ПРИЛОЗИ. Одд. за мед. науки, XLI 2, 2020 МАНУ
CONTRIBUTIONS. Sec. of Med. Sci., XLI 2, 2020 MASA

ISSN 1857-9345
UDC: 616.831-073.97:004.946-053.2

NEUROFEEDBACK – A METHOD WHICH TRAINS THE BRAIN TO OBTAIN CHANGES IN BEHAVIOUR

Nada Pop-Jordanova and Jordan Pop-Jordanov

Macedonian Academy of Sciences and Arts, Skopje, R.N. Macedonia

Corresponding author: Nada Pop-Jordanova, Bul Krste Misirkov br.2, P.O.Box 428, 1000 Skopje, North Macedonia, e-mail: popjordanova.nadica@gmail.com

ABSTRACT

EEG can determine changes in brain activity that might be useful in diagnosing different brain disorders as well as some mental states. Many advantages of this record have been the reason for resurrect the EEG in current clinical practice and research. More sophisticated form, the Q-EEG comprises a procedure that processes the recorded EEG activity from a multi-electrode recording using a computer, where data is processed with various algorithms, such as the Fourier or Wavelet analysis. Q-EEG data are important as a marker for many psychophysiological disorders.

Neurofeedback (NF) is a form of behavioural training aimed at developing skills for self-regulation of brain activity. It is a treatment method for altering brain functioning by the use of signals provided to a patient that reflect the moment-to-moment changes in the patient's electroencephalogram.

This article summarizes some of our large experience with neurofeedback training in different groups of disorders in children and adolescents. Positive outcome is promising for more expansive use of this non-pharmacological, cost-benefit methodology in paediatric and general population.

Keywords: neurofeedback, children, disorders, learning control

INTRODUCTION

What happens in the brain when we think, make decision, how we remember, perceive, when we feel something etc.? These questions arise especially when some neuropsychiatric disorder is disturbing behaviour and everyday life. In this context, to evaluate brain functioning was of priority interest in medical professionals, especially in neuropsychiatric field.

The electric phenomena of the brain were known much earlier by other clinicians; Hans Berger (1873-1942) is known to be the first in the recording of this activity through electroencephalogram, an invention described as "surprising, remarkable and momentous developments in the history of clinical neurology" (Haas, 2003).

An EEG can determine changes in the brain activity that might be useful in diagnosing brain disorders, especially epilepsy or another seizure manifestation. An EEG might also be helpful for diagnosing brain tumour, brain damage from head injury, brain dysfunction that can have a variety of causes (encephalopathy), inflammation of the brain (encephalitis), stroke, sleep disorders etc. Additionally, it was shown that mental states are also reflected in the electroencephalogram. For this reason, EEG and studies of event related potentials ERPs) are used extensively in neuroscience, cognitive science, cognitive psychology, neurolinguistics and psychophysiological research, but also in the study of many human functions. In a meanwhile, other more sophisticated methods for assessing the brain functioning were invented, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), magnetoencephalography (MEG), nuclear magnetic resonance spectroscopy (NMR or MRS), electrocorticography (ECoG), single-photon emission computed tomography (SPECT), near-infrared spectroscopy (NIRS) and event-related optical signal (EROS). All these techniques allowed better understanding of morphology and function of the brain.

Despite the relatively poor spatial sensitivity of EEG, it possesses multiple advantages over some of mentioned techniques: low costs of hardware, mobility of the recording system, sensors which may be placed in more places that in other methods, very high temporal resolution (sampling is commonly between 250 and 2000 Hz). It is also tolerant for subject movement, as well as a very silent procedure, it does not involve exposure to high-intensity magnetic fields or radioligands, and it is extremely uninvasive. All these advantages allow very large use of EEG in everyday practice, as well as for different kind of research.

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste, usually after preparing the scalp area by light abrasion to reduce impedance due to dead skin cells. Many systems typically use electrodes, each attached to an individual wire. Some systems use caps or nets into which electrodes are embedded. Electrode locations and names are specified by the International 10–20 system (Fig. 1).

Quantitative Electroencephalography (QEEG) represents an advanced method of EEG recording. QEEG is a procedure that processes the recorded EEG activity from a multi-electrode recording using a computer. These multi-channel EEG data are processed with various algorithms, such as the “Fourier” or “Wavelet” analysis. The digital data are statistically analysed, sometimes comparing values with “normative” database reference values. The processed EEG is commonly converted into colour maps of brain functioning called “Brain maps”.

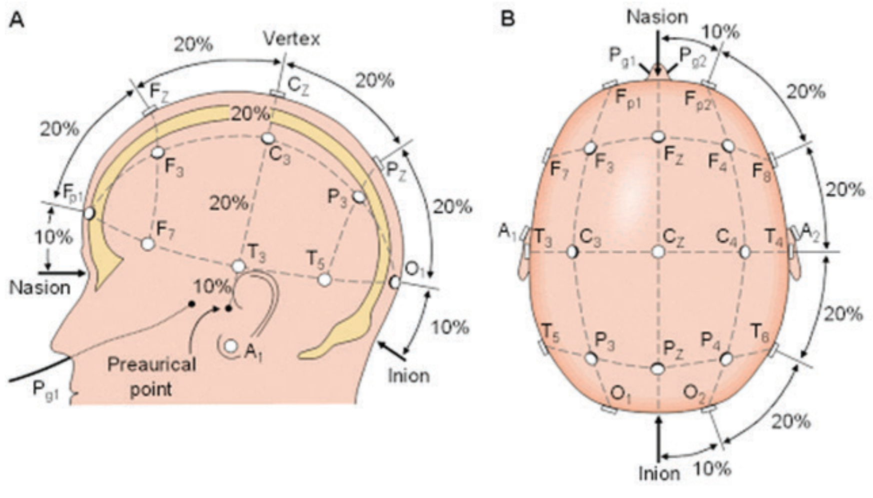

Fig. 1. *Placement of electrodes in 10/20 international system*

Neurofeedback (NF) is a treatment method for altering brain functioning by the use of signals provided to a patient that reflect the moment-to-moment changes in the patient’s electroencephalogram. It was shown that an effective intervention into any system is to intrude feedback of the signal to be changed into the system. This allows the system to self-regulate. The models of how this works are explained differently, starting from systems theory, to anatomical/structural models, learning theory, even non-linear dynamics or “chaos theory”. In practice, it is the basis of neurofeedback as methodology used today for treatment of many mental problems.

Consequently, NF is a form of behavioural training aimed at developing skills for self-regulation of brain activity. The method typically uses advanced statistical analysis of quantitative data from the EEG to provide feedback to the patient in real time. This approach allows the operant conditioning of the patient’s EEG, which can have the effect of therapeutically altering cognition, emotions, and behaviour (Schwartz, 2008).

The methodology named as biofeedback generally can be peripheral or central. The peripheral biofeedback uses electrodes placed on skin, on muscles, over blood vessels, heart etc. The aim is measuring the activity of the mentioned organs and following obtained results to provide self-regulation of autonomic nervous system. For our results of electrodermal activity used in peripheral biofeedback see article (Pop-Jordanova, Pop-Jordanov, 2020).

In NF training (i.e. central biofeedback), self-regulation of specific aspects of electrical brain activity is acquired by means of immediate feedback and positive reinforcement. In frequency training, activity in different EEG frequency bands has to be decreased or increased. NF studies revealed paradigm-specific effects on attention and memory processes and performance improvements in real-life conditions, in healthy subjects as well as in patients. In many studies it was shown that children with attention deficit hyperactivity disorder (ADHD) improved behavioural and cognitive variables after frequency training. There is growing evidence for NF as a valuable treatment module in different neuropsychiatric disorders (depression, OCD, PTSD even in autism and schizophrenia) as well as for better achievement in school and sport (Kropotov, 2009).

EEG biofeedback and QEEG are gradually emerging into mainstream psychiatry and medicine as promising diagnostic and treatment approaches. In our clinical research both methods are used intensively.

The aim of this article is to present our own experience with neurofeedback treatment in selected psychophysiological disorders in children and adolescents.

METHOD AND PARTICIPANTS

For using NF method, patients must be firstly evaluated with QEEG. The electrophysiological assessment in our research was performed with system Mitsar 19-channel QEEG 201 (Mitsar Ltd). Quantitative EEG (QEEG), as mentioned before, is a collection of quantitative methods designed to process EEG signals. The QEEG includes spectral and wavelet analyses of the EEG signals. The recording is made up of two conditions, eyes closed and eyes open, each lasting 5 min. In the following, data were recorded, while subjects were performing a visual continuous performance task (VCPT) from Psytask program designed by the Human Brain Institute in Saint Petersburg, Russia. This program comprises the Go/No Go task, which performance is associated with a group of psychological operations named as executive, such as detection and recognition of the stimulus, refreshing the working memory, initiation, and/or inhibition of the behavior and monitoring of the action results. The duration of the tasks was approximately 22 min. Separate channels for recording a signal from the button were used for monitoring the accuracy of the test performance and measuring the response trial. Electrodes were placed according to the International 10–20 system using an electrode cap with tin electrodes (Electrocap International Inc.). The input signals referenced to the linked ears were filtered between 0.5 and 50 Hz and digitized at a sampling rate of 250 Hz. The impedance was kept below 5 kΩ for all electrodes. The quantitative data were obtained using WinEEG software.

NF training was made using Biograph ProComp. Thought Technology, LTD., Canada. Additionally, for obtain better achievement in healthy subjects, we used Peak Achievement Trainer, NeuroTek, LLC 2003, USA.

Statistical evaluation was done using Statistica-10 software.

We will present the more characteristic samples of disorders we treated with neurofeedback.

RESULTS

In our practice, we used neurofeedback as a non-pharmacological, adjuvant treatment in different psychophysiological disorders. In this article we selected patients with anorexia mentalis, post-traumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD), attention deficit hyperactivity disorder (ADHD) and traumatic brain injuries. In addition, a group of healthy students were trained for better school achievement with Peak Performance Trainer as well as a group of musicians for better performance. Different personalized protocol for training were used depending on results obtained with QEEG.

A group of anorectic girls (N= 28, mean age 14.25 ± 2. 4 years), additionally to the general paediatric care, were treated with neurofeedback because of very high anxiety scores. QEEG showed overactivated brain with predominant beta waves especially in frontal, posterior and lateral left regions (Table 1).

We used protocol for diminishing beta waves and to obtain mainly alpha activity with electrode placement in Cz. Figure 2 shows differences in beta values in the first and last session measured in μV.

Table 1. *Summary post hoc Bonferoni p values for beta spectral power in anorectic and control*

		Frontal Beta	Central Beta	Posterior Beta	Lateral Left Beta	Midline Beta	Lateral Right Beta
Group effect	Normal vs. Anorectics	0.019454					
Condition effects	EC vs. EO			0.000667			
	EC vs. VCPT				0.046602		
	EC vs. ACPT			0.008745			
	EO vs. VCPT						
	EO vs. ACPT						
	VCPT vs. ACPT						

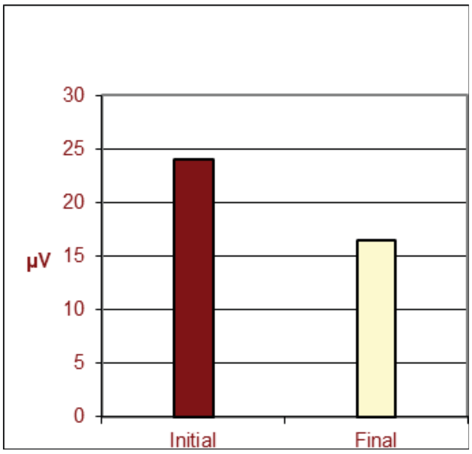

Fig. 2. *Changes in beta activity in anorectic girls*

It is clear that high beta activity after training was significantly diminished, resulting with diminished anxiety. 20 sessions of neurofeedback training were required. This multidimensional treating of anorexia showed good outcome (Pop-Jordanova, 2000; Pop-Jordanova and Pop-Jordanov, 2002; Pop-Jordanova, 2003).

A group of children with PTSD (N=10, mean age 12.2 ± 2.56) were treated with both modalities, electrodermal and neurofeedback. Peripheral biofeedback aimed to stabilise autonomic nervous system (sympathetic hyperactivity) while neurofeedback aimed to increase sensorimotor rhythm (SMR waves). SMR is an oscillatory idle rhythm of synchronized electric brain activity. The frequency of the SMR is in the range of 13 to 15 Hz, which belong to higher alpha or low beta frequencies. Either the meaning of SMR is not fully understood, phenomenologically a person is producing a stronger SMR amplitude when the corresponding sensorimotor areas are idle, e.g. during states of immobility. In practice, SMR training is a common protocol used to improve attention and focus. The SMR frequency band is associated with an alert, attentive state coupled with calm or silent motor activities. SMR training improves focus and attention by decreasing drowsy, mind-wandering theta waves and anxious or racing high beta waves, while increasing the calm, focused SMR waves. SMR training also improves motoric precision and balance and the ability to relax. Principles in SMR training are: to inhibit theta and high beta, and to reward SMR. Location of electrodes are on Cz or C4. In children manifesting PTSD this neurofeedback protocol is very useful. Figure 3 shows changes in SMR after only 10 sessions (Pop-Jordanova, Zorcec, 2004).

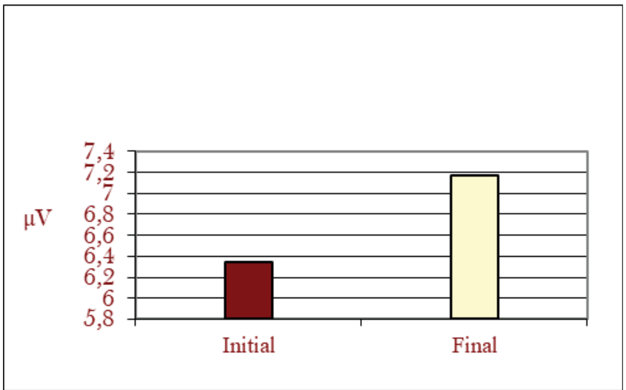

Fig. 3. *SMR waves pre and after treatment in PTSD children*

The sample of obsessive-compulsive disorder (OCD) comprised 20 children (both genders), between 7 and 14 years of age (M=10.33±1.83), all diagnosed using DSM-IV. Obsessive Compulsive Disorder is characterized by obsessive, repetitive behaviours and compulsions, and the inability for the person to control these impulses. The most frequently used neurofeedback is frequency/power neurofeedback. This technique typically includes the use of one or two surface electrodes, sometimes called "surface neurofeedback". It is used to change the amplitude or speed of specific brain waves in particular brain locations. Typical QEEG obtained in our patients is shown in Figure 4. It can be seen low/negative alpha band and significant high beta band especially in frontal regions. These spectra characteristics confirm high anxiety. Neurofeedback training comprised SMR training in C4. After 15 sessions of SMR training significant clinical improvement was obtained.

Logically, the majority of neurofeedback training was used for a large group of children manifesting attention deficit hyperactivity disorder (ADHD). As known, this complex disorder has three main clinical presentations: inattentive, hyperactive and mixed. More important are QEEG characteristics of these children showing four subtypes: I subtype, where abnormal increase of delta-theta frequency range, centrally or centrally frontally, is dominant; II subtype, where abnormal increase of frontal midline theta rhythm is present; III subtype with an abnormal increase of beta activity frontally; and IV subtype characterized with an excess of alpha activities at posterior, central, or frontal lobes (Kropotov, 2009). It is important to verify the subtype of ADHD for treatment plan-

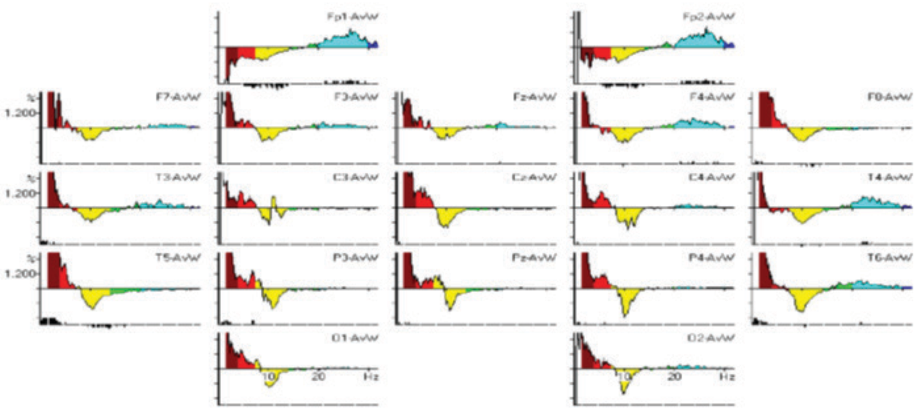

Fig. 4. *QEEG spectra in OCD patient*

ning. Our experience with more than 100 ADHD children (mean age 10.5 ± 2.35 years) confirmed that 45% belong to the last subtype (alpha excess), 30% belong to the first subtype (increase theta activity in frontocentral region), and 25% belong to third subtype (beta overactivated frontal cortex) (Pop-Jordanova, 2005; 2012).

Figure 5 shows a typical QEEG map for the first type of ADHD where theta activity is dominant.

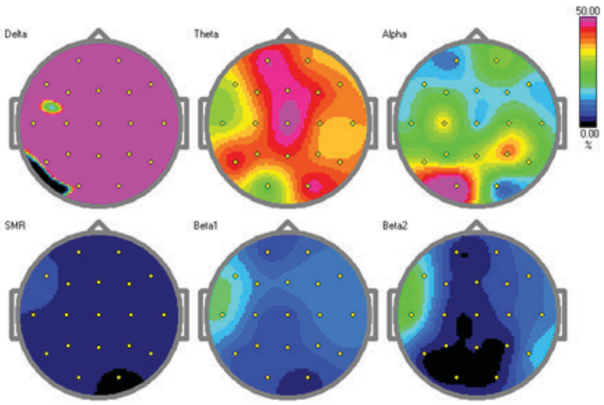

Fig. 5. *Brain maps for ADHD child showing predominance of theta waves*

Each subtype of ADHD children needs individually tailored protocol for neurofeedback training. The below presented child needed theta/beta training that comprise stimulation of beta and diminution of theta waves. In general, ADHD children need about 40 sessions for learning this kind of brain functioning. Table 2 shows changes in brain waves before and after 40 session of neurofeedback training.

The efficacy of NF training is confirmed with the improvement of the results on WISC-R test (intelligence scores) shown on Table 3.

A group of 30 healthy students aged 16-18 years, both genders, are trained for better school achievement using Peak Achievement Trainer, NeuroTek, LLC 2003, USA. Electrode positioning comprised active electrode on the forehead, two reference electrodes on the earlobes. Subject which is trained is being suggested to concentrate on the line presented on the screen (Fig. 6). The more concentrated one is, the lower the line is. The periods of concentration are also accompanied by a sound signal. Every subject went through 5 sessions each lasting 15 minutes.

Peak Achievement Trainer helps people to improve the ability to concentrate and stay focused, while reducing stress and anxiety to

Table 2. *Changes of brain waves after NF training*

Parameter	Before NF	After NF	t-test	Significance
Beta waves	4.86 ± 1.6	8.0 ± 1.38	5.23	P< 0.01
Theta waves	20.95 ± 1.38	15.29 ± 1.38	8.47	P < 0.01
Theta/beta	4.7 ± 1.38	2.0 ± 1.6	4.5	P < 0.01

Table 3. *Results for WISC-R*

	Global IQ (mean ± SD)	Verbal IQ (mean ± SD)	Manipulative IQ (mean ± SD)
Before NF	80 ± 18.3	90 ± 15.5	73 ± 18.9
After NF	85 ± 15.2	100 ± 12.3	80 ± 7.2

t = 6.97 p < 0.001

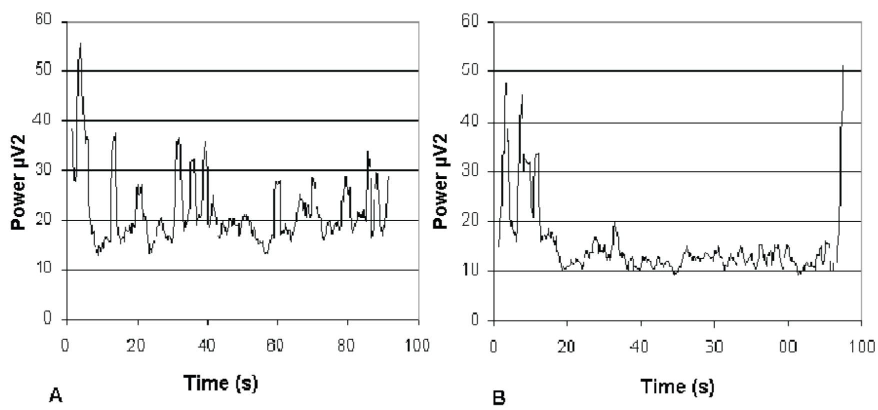

Fig. 6. *Changes of the concentration line during the PAT session*

achieve peak performance in a wide variety of different areas, including better job performance, improved academic achievement and behavior.

Results obtained with PAT (first and last session duration in seconds) as well as the percent of time in concentration are presented on Figures 6 and 7.

The efficacy of PAT training is confirmed with psychometric tests Trial Making Test Form A (TMT- A) where t-test = 8.302 and form B (TMT-B), where t- test = 5.137 and Verbal Span Assessment (WMS-R) Numbering - forward (t-test 3.521) and backward (t-test= 2.323) for all obtained results statistical significance was $p< 0.05$ (Pop-Jordanova, Cakalaroska, 2008).

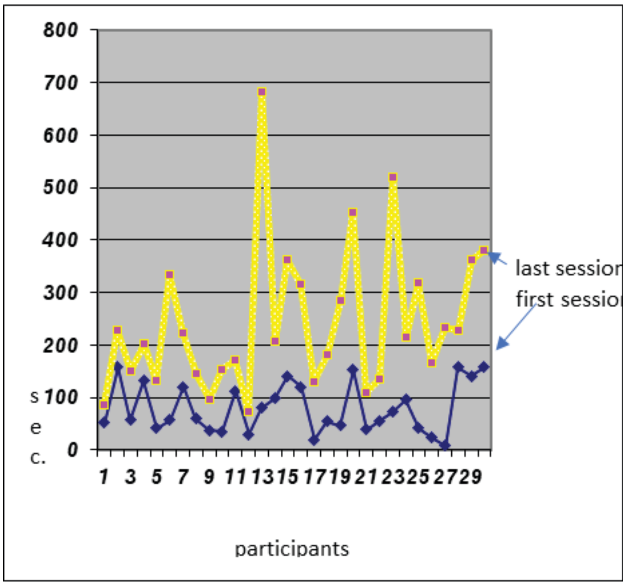

Fig. 7. *Changes of the concentration time during the first and last session*

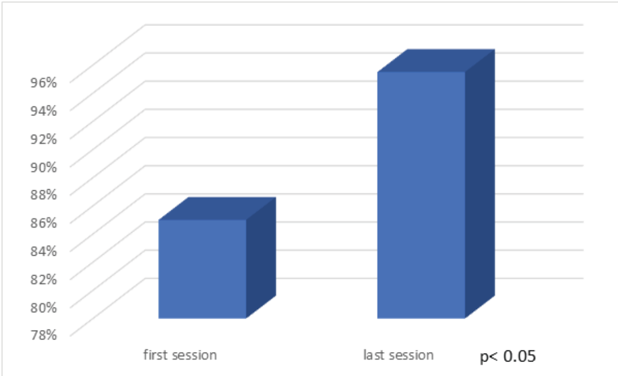

Fig. 8. *Percent (%) time of concentration*

More interesting was the biofeedback training for better performance in musicians. The evaluated group comprised 27 musical students, mean age 19.01± 2.98 years. It is well documented that musical performance skills rely on cognitive processes of awareness and optimal muscle activation without increasing the tension of muscles which do not participate in the execution. Additionally, it was shown that skilled musicians use much fewer motor areas of the brain than non-musicians.

The aim of our study was to investigate the impact of alpha-EEG/EMG biofeedback on electrophysiological and psychometric parameters in musicians. The following psychometric test were used: Spielberger State and Trait Anxiety Inventory and Rheinberg Self-actualization Inventory.

The training comprised EEG/EMG biofeedback, twice per week during two months. Figure 9 shows placement of electrodes and record for EEG and EMG during the assessment and training sessions (Pop-Jordanova, 2006; Markovska-Simoska, 2008).

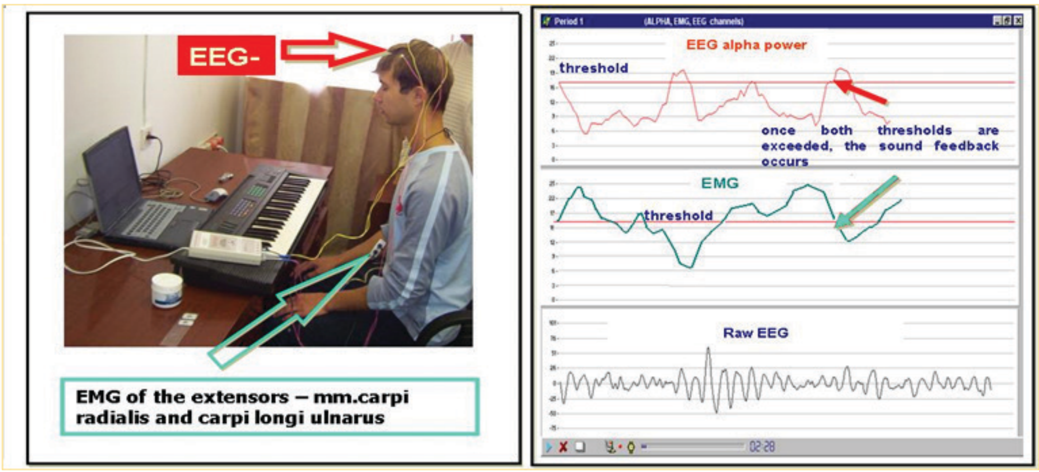

Fig. 9. *Placement of electrodes and record of EEG and EMG*

Figure10 schematically shows successful and unsuccessful periods of training session.

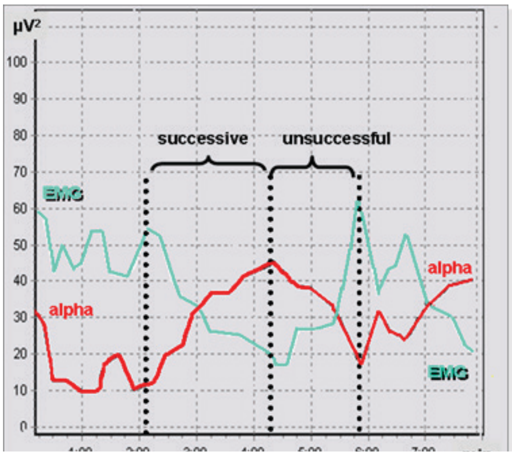

Fig. 10. *Periods of success and non-success during training session*

Alpha-EEG/ EMG BFB is efficient in increasing voluntary self-control in musicians during musical performance. The aim of the training was to increase alpha activity in the brain and to decrease muscular tension. The psychometric test confirmed improvement of the scores for anxiety, self-satisfaction, as well as technique, creativity, musicality and sound quality (p< 0.05).

Finally, in this article we will present results of neurofeedback in patients with traumatic brain injuries. Traumatic brain injury (TBI) is a serious and growing problem, and long-term consequences become more widely acknowledged recently. A group of six patients with traumatic brain injury have been accepted for neurofeedback training. All of them have been injured by car accident. Mild motor impairment was apparent in all patients; however, cognitive difficulties were the main problem. Some specifics of TBI patients are presented on Table 4. Preliminary Q-EEG assessment showed generally predominance of slow brain waves in frontal-parietal regions (Figure 11). This finding indicated the type of applied training protocols. We organized 20 sessions of neurofeedback, two times a week, each of 40-minute duration. Subjective assessment concerning mood, quality of sleep, ever day's activity and cognitive abilities, as well as the changes of Q-EEG findings promised good outcome. All patients except one continued normal education as well as normal life. It was the first application of neurofeedback for TBI treatment in our region (Zorcec et al., 2011).

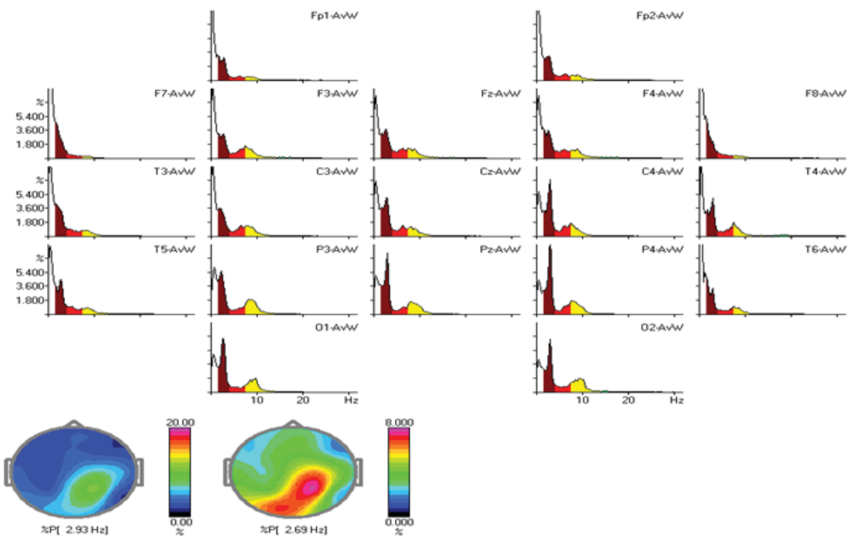

Fig. 11. *Spectra with brain map showing significant slowing in centroparietal region for patient I*

Table 4. *Some specifics of patients with TBI*

	I	K	M	V	B	G	mean
Age	18	15	19	15	55	15	22,83
Period since brain injury (years)	5	5	3	2	5	5	4.16
Length of coma (days)	95	2	15	25	3	3	23.83
Estimated pre-morbid IQ	120	135	120	100	110	110	115.83
Post-morbid IQ	75	140	80	75	82	85	89,5

It is important to stress that regardless of the site of injury, real-time digital EEG assessment always involves recording sensorimotor cortex (sites T4, C4, T3, C3 and Cz). Sensorimotor cortex controls all sensory and motor functions and mediates behaviour based on incoming sensory input and past experience. In general, higher amplitudes of slow waves in some region indicate the site of impact, while beta amplitude can be increased in an effort to compensate. So, the goal of neurofeedback is mainly to reduce the theta activity. Beta amplitude automatically increases, and there it is no need for special training of beta activity.

Individual protocols for neurofeedback training are adapted concerning Q-EEG findings. Generally, all patients were trained for SMR rhythm (high alpha) for 20 sessions. The position of the active electrodes for training was in Fz and Cz. The goal was to inhibit theta (4-7 Hz), rewarded sensory motor rhythm (high alpha 10-14 Hz), and inhibit muscle activity/tension. In addition to neurofeedback, some modalities for peripheral biofeedback (namely, skin conductance or pulse balance) have been used for obtaining control of the autonomous nervous system. Table 5 shows statistically significant change in absolute power following neurofeedback.

Table 5. *Statistically significant change (p-values) in absolute power following neurofeedback*

location	*delta*	*theta*	*Alpha*	*beta*
Fz	0.056*	0.001*	0.788	0.423
Cz	0.131	0.023*	0.196	0.004*

* significant change

DISCUSSION

As mentioned before, the QEEG includes many sophisticated methods for analysis of brain electrical activity with the goal of clarifying the differential diagnosis. QEEG data help the clinician to determine the optimum treatment for a given patient, including EEG biofeedback or psychopharmacological therapies.

The use of electroencephalography (EEG) in biofeedback to treat psychiatric disorders dates to the mid-1960s (Budzynski, Evans & Abarbanel, 1999). Commonly used protocols initially entailed the modification of averaged EEG activity with the goal of increasing activity or coherence in the alpha frequency band (between 8 and 12 Hz), or increasing activity in a portion of beta frequency band (between 15 and 20 Hz) while inhibiting activity in the theta frequency band (between 4 and 8 Hz). Psychologists and psychiatrists use QEEG and EEG biofeedback singly or in combination with more conventional methods in the diagnosis and treatment of numerous psychiatric and neurological disorders, including ADHD, PTSD, depression, substance abuse and alcoholism, traumatic brain injury and post-stroke rehabilitation. In this context, today there is significant scientifically based studies for the benefit of NF training in different disorders, somatic and mental.

We introduced QEEG and biofeedback methodology in 1996, at the University Paediatric Clinic and we used them for diagnostics and treatment of more than 1000 patients.

Significant advances in EEG biofeedback include a report by Ibric (2002) showing a reduction in the symptoms of Parkinson's disease; research reports showing reduction in the severity of depressed mood using an alpha asymmetry EEG biofeedback protocol (Rosenfeld, 2000; Baehr, Rosenfeld, & Baehr, 2001); a report by Hammond (2003) of positive outcomes with EEG biofeedback training for obsessive compulsive disorder; and promising early reports on the treatment of eating disorders (Smith, 2014) and trigeminal neuralgia (Sime, 2002).

Our obtained results, as showed before, with neurofeedback in children and adolescent with OCD and anorexia mentalis are also very positive.

However, neurofeedback treatment stays as more valuable treatment in different forms of ADHD. Used protocols are different depending on QEEG record. Mainly used NF protocols comprise theta/beta training, beta enhancement, alpha enhancement etc.

In this way, the apparent quieting effect of SMR training on the excitability of the sensorimotor system inspired Lubar and co-workers to apply a protocol of SMR enhancement to the treatment of attention deficit hyperactivity disorder (Lubar and Shouse, 2006). Studies with ADHD children, though important, had not established a direct association between the ability to learn to enhance the desired frequency band in the EEG and the improvement in behaviour and cognition. In our practice, depending of the subtype QEEG, we applied theta/beta training together with peripheral biofeedback for majority of ADHD children.

As mentioned in other studies, NF training is useful in healthy people for better achievement (Gruzelier, 2005; 2006; 2013; 2014). In the study of Egner and Gruzelier (2006), conservatoire students were trained on an attention-targeting SMR(C4)/beta1(C3) neurofeedback protocol involving ten 15-min sessions of both SMR and beta training. Our experience for musicians corresponds to their research. Additionally, we used simultaneous muscle training with placement of the electrode to the hand.

Traumatic Brain Injuries is currently a serious and growing problem, and long-term consequences become more widely acknowledged recently. In a research of Bounias et al (2001; 2002) as well as in Rima et al (2002) positive outcome with neurofeedback training was obtained in patients with traumatic brain injuries. Our results in a small group of TBI patients confirm positive outcome.

CONCLUSION

It is hypothesized that operant conditioning methodology, such as NF, produces its behavioural and electrophysiological effects by gaining access to and control over regulatory mechanisms that increase or decrease synchronous or dyssynchronous activity in brain networks. Our presented results confirm the validity, effectiveness and cost-benefit of this methodology in large paediatric population.

REFERENCES

1. Haas LF (2003): Hans Berger (1873–1941), Richard Caton (1842–1926), and electroencephalography. J Neurol Neurosurg Psychiatry, 74(1): 9.
2. Schwartz MS, Andrasik F. (2008): Biofeedback. A Practioner Guide (3th edition), NY, Guilford Press.
3. Pop-Jordanova N. Pop-Jordanov J. (2020): Electrodermal activity is valuable for stress assessment, Prilozi, in press.
4. Kropotov J. (2009): Quantitative EEG, event-related potentials and neurotherapy. Elsevier, Amsterdam.
5. Pop-Jordanova N. (2000): Psyhological characteristics and biofeedback mitigation in preadolescents with eating disorders, Pediatrics International; 42 (1): 76–81.
6. Pop-Jordanova N. (2003): Chapter III: Eating Disorders in the Preadolescent Period: Psychological Characteristics and Biofeedback Mitigation, Focus on Eating Disorder Research, ed. P. I. Swain, Nova Biomedical Books, New York, 2003: [45]–56.
7. Pop-Jordanova N., Pop-Jordanov J. (2002): Psychophysiological comorbidity and computerized biofeedback, The International Journal of Artificial Organs; 25 (2): 429–433.
8. Pop-Jordanova N. (2005): Chapter IV: Biofeedback modalities for children and adolescents, New Research on Biofeedback, ed. H. L. Puckhaber, Nova Biomedical Books, New York : [117]–131.
9. Pop-Jordanova N., Zorčec T. (2004): Child Trauma, Attachment and Biofeedback Mitigation, Прилози. МАНУ (Одд. биол. мед. науки) / Contributions. MASA (Sec. Biol. Med. Sci.), 2004; 25 (1–2): [103]
10. Pop-Jordanova N., Zorcec T., Markovska-Simoska S. Neurofeedback(2005): Treatment of Children with Attention Deficit Hyperactivity Disorder, Прилози. МАНУ (Одд. биол. мед. науки) / Contributions. MASA (Sec. Biol. Med. Sci.); 26 (1): [71]–80.
11. Pop-Jordanova N. (2012): Chapter 13: QEEG Characteristics and Biofeedback Modalities in Children with ADHD, Current Directions in ADHD and its Treatment, ed. J.M. Norvilitis, InTech, Rijeka, Croatia: [249]–268.
12. Pop-Jordanova N., Cakalaroska I. (2008): Comparison of Biofeedback Modalities for Better Achievement in High School Students, Macedonian Journal of Medical Science, 2008; 1 (2): 25–30.
13. Pop-Jordanova N., Bazanova O., Georgiev D., Kondratenko A., Kondratenko O., Markovska-Simoska S., Mernaya J. (2006): Simultaneous EEG and EMG Biofeedback for Peak Performance in Musicians, Proceedings of Workshops and Scientific Programme: [Inaugural Meeting of the SAN & EU COST B27, 14th – 19th September 2006; Swansea, UK], Swansea University: 23.
14. Markovska-Simoska S., Pop-Jordanova N., Georgiev D. (2008): Simultaneous EEG and EMG biofeedback for peak performance in musician, Прилози. МАНУ (Одд. биол. мед. науки) / Contributions. MASA (Sec. Biol. Med. Sci.); 29 (1): [239]–252.
15. Zorcec T, Demerdzieva A, Pop-Jordanova N. (2011): QEEG, Brain rate, Executive Functions, and Neurofeedback trainingg in patients with Traumatic Brain Injuries, Acta Informatica Medica, 19 (1): 23–28.

16. Budzynski T, Budzynski H, Evans J, Abarbanel A., (1999): Introduction to Quantitative EEG and Neurofeedback: Advanced Theory and Applications, Elsevier Inc.
17. Ibric S. (2002): Neurofeedback training enhanced by light and/or electromagnetic slosed-loop EEG induces analgesia in patients with neuropathic pain syndromes, Pain, Suppl., 439–440 (S1338)
18. Rosenfeld, P. (2000): An EEG Biofeedback Protocol for Affective Disorders. Clinical EEG and Neuroscience, 31(1): 7–12.
19. Baehr E, Rosenfeld P, & Baehr R, (2001): Clinical use of an alpha asymmetry neurofeedback protocol in the treatment of mood disorders, J of Neurotherapy 4 (4): 11–18.
20. Hammond, D. C. (2003): QEEG-guided neurofeedback in the treatment of obsessive-compulsive disorder. Journal of Neurotherapy, 7 (2): 25–52.
21. Hammond, D. C., & Kirk, L. (2008): First, do no harm: Adverse effects and the need for practice standards in neurofeedback. Journal of Neurotherapy, 12(1): 79–88.
22. Smith, ML, Collura TF, Tarrant J. (2014): Neurofeedback. Taylor and Francis publ.
23. Sime, A. (2004): Case study of trigeminal neuralgia using neurofeedback and peripheral biofeedback. Journal of Neurotherapy, 8(1): 59–71.
24. Lubar J., Shouse M. (2006): SMR training in Event-Related Dynamics of Brain Oscillations, by Crista Neuper and Wolfgan Klimesch, (264 pp).
25. Gruzelier, J., & Egner, T. (2005). Critical validation studies of neurofeedback. Child & Adolescent Psychiatric Clinics of North America, 14, 83–104.
26. Gruzelier, J., Egner, T., & Vernon, D. (2006). Validating the efficacy of neurofeedback for optimising performance. Progress in Brain Research, 159, 421–431.
27. Gruzelier J. (2014): EEG-neurofeedback for Optimising Performance. I: A Review of Cognitive and Affective Outcome in Healthy Participants. Neurosci Biobehav Rev; 44: 124–41.
28. Gruzelier JH, Holmes P, Hirst L, Bulpin K, Rahman S, van Run C, Leach J. (2014): Replication of elite music performance enhancement following alpha/theta neurofeedback and application to novice performance and improvisation with SMR benefits. Biol Psychol.; 95: 96–107.
29. Gruzelier JH, Hirst L, Holmes P, Leach J. (2014) Immediate effects of Alpha/theta and Sensory-Motor Rhythm feedback on music performance. Int J Psychophysiol.; 93(1): 96–104.
30. Egner T, Gruzelier JH.(2001): Learned Self-Regulation of EEG Frequency Components Affects Attention and Event-Related Brain Potentials in Humans. Neuroreport; 12(18): 4155–9.
31. Bounias, M., Laibow, R. E., Bonaly, A., & Stubblebine, A. N. (2001): EEGneurofeedback treatment of patients with brain injury: Part 1: Typological classification of clinical syndromes. Journal of Neurotherapy, 5(4): 23–44.
32. Bounias, M., Laibow, R. E., Stubblebine, A. N., Sandground, H., Bonaly, (2002): A. EEG-neurofeedback treatment of patients with brain injury: Part 4: Duration of treatments as a function of both the initial load of clinical symptoms and the rate of rehabilitation. Journal of Neurotherapy, 6(1): 23–38.
33. Rima EL., Albert NS, Henry S.(2002): EEG-NeuroBioFeedback treatment of patients with brain injury , Journal of Neurotherapy, 1: 5–21.

Резиме

НЕВРОФИДБЕК-МЕТОДА ШТО ГО ТРЕНИРА МОЗОКОТ ДА ПРОИЗВЕДЕ ПРОМЕНА ВО ОДНЕСУВАЊЕТО

Нада Поп-Јорданова и Јордан Поп-Јорданов

Македонска академија на науките и уметностите, Скопје, РС Македонијаа

ЕЕГ-то ја детерминира промената на мозочната активност, што може да биде полезно во дијагнозата на разни мозочни растројства и некои ментални состојби. Многуте предности на ова снимање биле причина за воскресување на ЕЕГ-то во современата клиничка практика и во истражувањата. Пософистицираната форма, квантитативно ЕЕГ, подразбира процедура во која се процесираат забележаните ЕЕГ-активности добиени преку мултимодално снимање со користење компјутер, каде што податоците се обработуваат преку разни алгоритми, како што се Фуриевата или Вејвлетовата анализа. Q-EEG-податоците се важни како маркер за многу психофизиолошки растројства.

Неврофидбек (НФ) претставува форма на тренинг на однесувањето, која има цел да развие вештини на саморегулација на мозочната активност.

Овој труд сумира некои од нашите опсежни искуства со неврофидбек-тренингот кај разни групи растројства кај деца и адолесценти. Позитивниот исход ветува поекспанзивна примена на оваа нефарнмаколошка, евтина методологија во педијатријата, но и кај општата популација.

Клучни зборови: неурофидбек, деца, растројства, контрола на учење