

ADAPTIVE NEUROSTIMULATION METHODS IN CORRECTING POSTTRAUMATIC STRESS DISORDER AND PROFESSIONAL BURNOUT SYNDROME

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Abstract. The study aimed to evaluate the effectiveness of previously developed methods of adaptive neurostimulation in correcting stress-induced states in specialists who demonstrate signs of post-traumatic stress disorder (PTSD) and professional burnout syndrome (PBS). **Materials and methods.** Each of the 17 stressed subjects participated in three examinations, alternated in random order. In the control experiment (control), simple listening to classical music was used. In two other examinations, musical or light-musical stimulation was used, automatically modulated by feedback signals from the rhythmic components of the subject's electroencephalogram (EEG). In the first case (musical feedback), the subjects were presented with music-like stimuli formed on the basis of the subject's alpha EEG oscillator. In the second case (double feedback), such musical stimulation was supplemented by rhythmic light stimuli generated by on-line transformations of the native EEG of the subject. **Results.** Comparison of the effects of both experimental conditions with the control one allowed us to establish that only in the presence of feedback from the EEG, there is a significant increase in the power of alpha EEG rhythm, accompanied by positive emotional reactions, a decrease in the level of disadaptation and stress, as well as a significant increase in the assessments of health and mood of the subjects. The most pronounced psychophysiological effects were recorded under light-music stimulation with double feedback from the EEG. **Conclusion.** The obtained results make it possible to suggest the described methods of adaptive neurostimulation as a means of psychotherapeutic correction of PTSD and PBS, especially during the COVID-19 pandemic.

Keywords: adaptive neurostimulation, musical feedback, electroencephalogram (EEG), light-music stimulation, correction of stress-induced states, post-traumatic stress disorder (PTSD), professional burnout syndrome (PBS).

List of Abbreviations

EEG – electroencephalogram

PTSD – post-traumatic stress disorder

PBS – professional burnout syndrome

Introduction

The human body is constantly exposed to stress factors, which, when chronically compounded, can cause a violation of adaptation mechanisms, a failure of the body's defense systems and various stress-induced disorders' development (Esin *et al.*, 2020). In the time of COVID-19 pandemic, the growth of stress-induced disorders such as post-traumatic stress disorder and professional burnout syndrome is of particular concern to specialists (Restauri & Sheridan, 2020). These disorders' formation is especially typical for medical workers who constantly experience stress and emotional exhaustion when communicating with patients (Orru

et al., 2021). Significant stress factors are the potential danger of a virus infection, media coverage of events, changes in the usual way of life and the economic consequences of the epidemic (Bykhovets & Kogan-Lerner, 2020). Timely psychotherapeutic correction of functional states formed under stress is essential in these conditions (Solovieva *et al.*, 2020).

The modern set of methods and means for suppressing everyday stress is wide enough. A literature review shows that to date, biofeedback (Dillon *et al.*, 2016; De Witte *et al.*, 2019; Can *et al.*, 2020) and music therapy (Paszkiel *et al.*, 2020; De Witte *et al.*, 2020) are the most developed means of psychotherapeutic correction of stress-induced states. However, the use of these methods for the treatment of post-traumatic stress disorder (Miao *et al.*, 2018; Leem *et al.*, 2020) and professional burnout syndrome (Reed *et al.*, 2020; Kacem *et al.*, 2020) revealed

the need to develop new approaches to improve their effectiveness (Panisch & Hai, 2020; Steingrimsson *et al.*, 2020).

Previously, we have developed and successfully tested an original approach to the correction of stress-induced states, which combines the advantages of neurofeedback and music therapy (Fedotchev *et al.*, 2016). The approach is an adaptive neurostimulation with feedback from an electroencephalogram (EEG) based on the principle of automatic modulation of sensory stimulation by human rhythmic processes. The developed musical feedback method consists in presenting stressed subjects with music-like signals, resembling flute sounds in timbre, which smoothly vary in pitch and intensity directly depending on the current amplitude of the subject's dominant rhythmic EEG component (alpha EEG oscillator).

Later, a modification of the described method of adaptive neurostimulation was developed and successfully tested. It is a double EEG feedback method in which music-like stimuli controlled by alpha EEG oscillators are supplemented by rhythmic light stimuli controlled by the subject's total EEG (Fedotchev *et al.*, 2019).

The presented study aimed to assess the effectiveness of the developed methods of adaptive neurostimulation in the correction of stress-induced states in biomedical professionals showing signs of post-traumatic stress disorder and professional burnout. For this purpose, each of the 17 stressed subjects participated in three examinations, alternated in random order. In one of the surveys (control), pre-prepared musical compositions were used, presented without feedback from the subjects' current bioelectrical activity. The other two surveys used either the musical feedback method using music-like stimuli controlled by the subject's alpha EEG oscillators or the double EEG feedback method, where music-like stimuli formed on the basis of the alpha EEG oscillator are complemented by rhythmic light stimuli controlled by the subject's total EEG.

Materials and Methods

The study involved 17 subjects aged 38 to 60 years old, employed at the Pushchino Scientific

Center of the Russian Academy of Sciences, who approached the psychological counselling office about the psycho-emotional exhaustion and stress caused by the forthcoming report. During the initial interview, the subjects also revealed the evident signs of post-traumatic stress disorder and professional burnout such as psychological disadaptation and depression, subjective feelings of helplessness and anxiety, loss of work motivation and negative feelings about the results of their work that are known from the literature (Nagornova, 2019).

The study was performed in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the Institute of Cell Biophysics of the Russian Academy of Sciences. After clarifying the potential risks, benefits and nature of the upcoming study, each participant provided voluntary written informed consent to participate in three studies.

At the beginning of each survey, in order to assess the initial functional state of the subjects, they were interviewed and psychologically tested using three previously approved tests (Kataev *et al.*, 2017): 1) the "LED" test, which allows determining the current level of a person's emotional disadaptation, 2) the "LS" test, which is a modification of the "LED" test and allows assessing the current level of stress, 3) the "HAM" test, in which the subjects assess their current state of health, activity and mood.

After the initial testing, the subjects were fitted with EEG sensors (the active electrode placed in the Cz lead, the reference and ground electrodes – on the earlobes), as well as stereo headphones (Philips SBC HL140) and tinted glasses, in which red Light Emitting Diodes with a power not exceeding 100 μ W were embedded. The subjects were not given any task but were asked to sit quietly with their eyes closed during the entire examination.

Each experiment began with a 30-second recording of the background electrical activity of the brain with an EEG filtering range of 2–32 Hz and a signal sampling frequency of 100 Hz, during which the dominant narrow-frequency (0.4–0.6 Hz) spectral component in the EEG alpha range (8–13 Hz) – the alpha EEG oscillator – was determined using an original modifica-

tion of dynamic spectral analysis based on fast Fourier transforms (Fedotchev *et al.*, 2016).

The further course of the examination depended on the experiment's conditions, which alternated in random order for each subject.

In the experiment without feedback (the «Control» series), subjects were presented with a pre-prepared 10-minute composition from the popular classical works by Tchaikovsky, Mozart, Bach and Schubert.

In the experiment with musical feedback (the «Musical Feedback» series), subjects were presented with music-like signals resembling flute sounds in timbre, which smoothly vary in pitch and intensity in direct dependence on the current amplitude of the subject's detected alpha EEG oscillator.

In the experiment with double, light-music EEG feedback (the «Double feedback» series), subjects were simultaneously presented with music-like signals, formed on the basis of the alpha EEG oscillator, and rhythmic light stimulation, controlled by the subject's total EEG. This was achieved by normalizing the digitized EEG values, at which the largest negative value of the EEG signal corresponding to the minimum and the largest positive value – to the maximum LED glow.

At the end of the stimulation, EEG recording was continued for 2 minutes to measure the aftereffects, after which the subjects were re-tested and questioned about their feelings during the therapeutic sessions.

Statistical processing of the results was performed using the SigmaPlot 11.0 software package. The Shapiro-Wilk test was used to assess the normality of the distribution. Since all samples satisfied a normal distribution, the mean values (M) and standard errors (m) of each indicator before and after exposure were used as the main characteristics in assessing the treatment procedures' effectiveness. The differences between these characteristics were assessed using the two-sample t-test. Differences were considered statistically significant at $p \leq 0.05$.

Results

First of all, the dynamics of EEG theta and alpha rhythms before and after each examination was analyzed (Fig. 1). It was found that under the influence of all three types of stimulation, the studied EEG rhythms change differently: the theta rhythm power decreases, while the alpha rhythm power increases. The most pronounced changes occur in the power of the EEG alpha rhythm, but they reach a level of significance only under the influence of automatically controlled by the EEG feedback signals. The maximum increase in the EEG alpha rhythm was noted under the light-music stimulation used in the double feedback method.

When analyzing the results of psychological testing (Table 1), it was found that under the influence of the undertaken sensory stimuli, there are positive changes in most indicators. Thus, as a result of treatment procedures, the levels of emotional disadaptation and stress decrease, and the subjects' assessments of their health and mood increase. However, significant changes in these indicators are observed only when applying adaptive stimulation methods using feedback from the rhythmic components of the EEG. The maximum positive shifts in these indicators were registered under the light-music stimulation used in the double feedback method.

Questioning the subjects about the subjective feelings in the course of the stimuli revealed that most of them rated the conducted treatment sessions positively and found the performed stimuli pleasant and calming. All subjects reported a decrease in stress level and an improvement in their emotional state. Experiments with double EEG feedback, where music-like sound stimuli formed by transforming the alpha EEG oscillator into a sound series were complemented by pleasant play of a multi-colored background arising from perception through closed eyes of light flashes formed on the basis of the current EEG, were evaluated particularly positively.

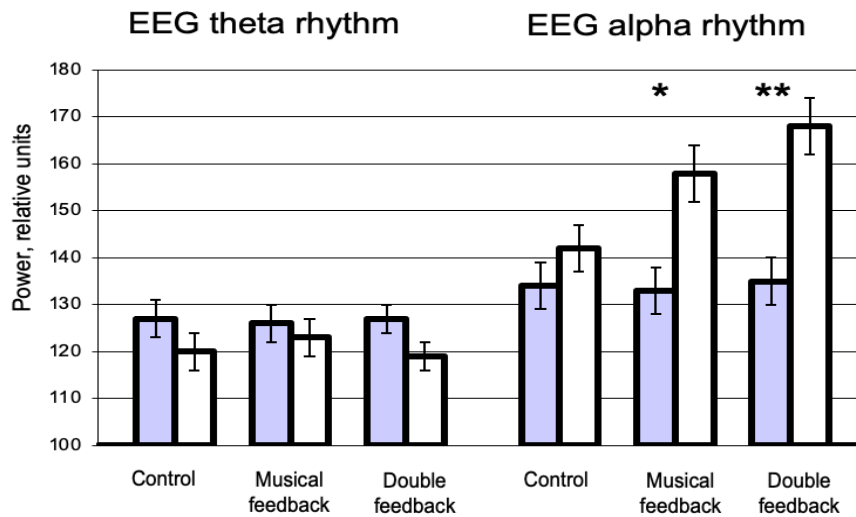


Fig. 1. The EEG theta and alpha rhythms before (dark columns) and after (light columns) exposure in the control series and in the series with musical and double feedback. Note: * – $p < 0.05$; ** – $p < 0.01$

Table 1

Indicators (scores) of psychological testing ($M \pm m$) before and after treatment procedures in three series of experiments

Test indicators	Serie					
	Control		Musical feedback		Double feedback	
	before	after	before	after	before	after
The “LED” test – level of emotional disadaptation	1.8±0.3	1.3±0.4	1.8±0.3	1.2±0.2	1.8±0.3	0.9±0.2
The “LS” test – level of stress	1.6±0.4	1.2±0.4	1.5±0.3	0.6±0.2	1.6±0.3	0.5±0.2
The “HAM” test – level of health	46.1±0.9	45.2±0.8	46.0±1.0	50.0±1.2	46.1±1.1	51.9±1.1
The “HAM” test – level of activity	43.8±0.6	43.2±0.6	43.9±0.6	44.6±0.7	43.8±0.7	44.0±0.7
The “HAM” test – level of mood	47.1±0.5	46.9±0.4	46.6±0.7	50.5±0.8	47.2±0.7	52.0±0.8

Note: the compared pairs of values with a significance level of differences $P < 0.05$ are marked in bold.

Discussion

A comparison of the effects of both experimental influences with control with no feedback made it possible to determine that only in the EEG feedback presence, there is a significant increase in the power of the EEG alpha rhythm, which is accompanied by positive emotional reactions, a decrease in the level of disadaptation and stress, as well as a significant increase in the assessments of health and mood of the subjects. The most pronounced psycho-

physiological effects were registered when exposed to light-music stimulation with double EEG feedback.

The established EEG effects in the form of a simultaneous decrease in EEG theta and an increase in the alpha rhythm are typical for the relaxation state development (Zaccaro et al., 2018). In our case, when using the methods of adaptive neurostimulation with EEG feedback, the formation of a relaxation state, confirmed by the results of a survey of the subjects, was accompa-

nied by a significant decrease in the level of disadaptation and stress, as well as an improvement in health and mood of the subjects.

There are examples of successful treatment of post-traumatic stress disorder using methods of adaptive neurostimulation in the literature. Thus, it has been shown that clinically significant reduction of post-traumatic stress symptoms is achieved after several sessions of exposure to acoustic stimuli generated in real time by a program-controlled transformation of the subject's dominant EEG rhythms into a sound series (Tegeler et al., 2017; Shaltout et al., 2018). The authors concluded that the rapid renewal of one's own rhythmic patterns and the resonance between audible sound signals and oscillatory brain networks provide the organism with the ability to auto-calibrate and self-adjust to achieve relaxation and overcome stable pathological conditions (Tegeler et al., 2020).

An important advantage of the methods of adaptive neurostimulation we used, which ensured the presence of significant therapeutic effects already after a single correction procedure, is the use of musical or light-music feedback from the EEG. It is known from the literature that musical stimulation has a number of cognitive, psychosocial and behavioral advantages, especially for people with neurological disorders, providing a basis for the development of non-drug therapies (Brancatisano et al., 2020).

According to our data, the most effective correction of stressful states is achieved using bimodal (light-music) EEG feedback, in which some EEG characteristics (EEG oscillators) control sound (musical) stimulation, and other EEG characteristics (total EEG) simultaneously control light stimulation. This combination ensures the normalization of the functional state under the influence of light-music effects due to the joint participation of multisensory integration processes (Roy et al., 2021), neuroplasticity mechanisms (Voropaev et al., 2019) and res-

onance mechanisms of the central nervous system (Fedotchev, 2019).

Conclusions

The presented data convincingly testify to the efficiency of adaptive neurostimulation methods, in which the adjustment of the parameters of the therapeutic effect, controlled by musical feedback signals from the current EEG values, is carried out automatically, without human consciousness and volitional efforts. Due to the self-tuning of musical or light-music stimulation to the physiological changes occurring in the human body, reflected in the EEG, such influences have a number of advantages:

- 1) high personalization through the use of feedback from the patient's bioelectric characteristics;

- 2) joint participation of mechanisms of multisensory integration, neuroplasticity and resonance mechanisms of the brain, ensuring the normalization of the functional state under the influence of treatment procedures;

- 3) automatic, without the patient's conscious efforts, control of therapeutic sensory influences, which makes it possible to use adaptive neurostimulation to correct adverse state shifts in patients with an altered level of consciousness, the elderly and children.

Proven methods can be effectively used for the timely correction of stress-induced conditions in post-traumatic stress disorder and professional burnout syndrome, which is especially important during the COVID-19 pandemic.

Acknowledgements

This research was funded by the Russian Foundation for Basic Research (project No. 19-013-00095) and government procurement for Lobachevsky State University of Nizhny Novgorod (project No. 0729-2020-0062).

The authors declare that there is no conflict of interest.

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