

Increasing the Reliability of Human Operator by Combination of Music Therapy with Neurofeedback

Sang Joon Oh

Department of Biomedical Engineering, Bauman Moscow State Technical University, Moscow, Brigadirsky lane, Russian Federation

Abstract The results of human functional state correction by music influences feedback controlled by narrow-band (0.4-0.6 Hz) electroencephalographic (EEG) oscillators of the patient are presented. It is established that the utilization of narrow-band oscillators from the theta (4–8 Hz) and alpha (8–13 Hz) EEG ranges causes a normalization of the EEG, reduction of stress sensations and positive shifts in mental and emotional state of the patient by the end of the first treatment procedure.

Keywords Reliability of human operator, Musical influences, Biofeedback, Electroencephalogram (EEG), Narrow-band EEG oscillators, Stress-induced functional disturbances, Correction

1. Introduction

Among the most important trends of modern psychological research there is the problem of reliability of a human operator. The latter is defined as a set of properties of the person providing him to perform the required functions in the "man-machine" system. The main content of this research line is to create conditions and methods of psychological safety support in different types of work, including psychological security as the preservation of optimum conditions of workers and their mental health. Mental health promotion and prevention of psychogenic disorders called a priority in the European Declaration on Mental Health [1]. The problem of human operator reliability includes two components: the biological reliability, taking into account sustainable human failures as a result of illness, sleep, fatigue, etc., and psychological reliability, taking into account errors in operator's work [2].

Reliability of a human operator is not constant, but varies over time. This is due to changes in terms of activities and fluctuations of operator functional state. Work in stressful conditions involves the mobilization of psychological and physiological reserves, reduces the effectiveness of specialist work and is accompanied by the appearance of inadequate functional states [3]. According to recent studies, it is the negative impact of psychosocial stressors that is becoming the first cause of illness in the workplaces in Europe [4]. In this situation it is important to consider a variety of means, which may contribute to the formation of anti-stress behavior

and actually help eliminate one or more stressors [5].

It should be emphasized that the pharmacological correction of stress-induced states inevitably impairs cognitive function of the operator and is often accompanied by side effects and addiction [6], which makes drug treatment a futile path. Therefore, extremely popular there are the technologies of health promotion, taking into account the psychological factors of occupational health and functional states of the employee in the workplace [7, 8], as well as non-drug means of systemic influences to overcome the negative effects of stress [9].

Among such non-drug means there are two most advanced approaches: music therapy (MT) and biofeedback technology (BFB) based on the electroencephalogram (EEG). MT is a system of psychosomatic regulation of functions of the human body with the help of musical-acoustic influences [10]. In the method of EEG-BFB, usually called «Neurofeedback», the current amplitude of a particular EEG rhythm is reflected in the parameters of the sound or visual feedback signals presented to a patient for the purpose of conscious control of expression of its own rhythmic EEG components to achieve the desired therapeutic effects [11].

Important advantages of both these approaches there are its non-invasiveness, lack of contraindications and focus on central regulatory mechanisms of the brain. EEG-BFB due to feedback signals from directly recorded EEG rhythms of the patient has additional advantages – extreme individuality and active participation of the subject in the optimization of own condition. However, EEG-BFB has also a significant limitation. It is the difficulty of understanding and active use of feedback signals from the brain biopotentials that are evolutionarily not intended to arbitrary control. In addition, serious disadvantage of usual EEG-BFB procedures there is utilization of the predefined traditional EEG rhythms (theta,

* Corresponding author:

oh_sang_joon@hotmail.com (Sang Joon Oh)

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alpha, beta, etc.) that are actually functionally heterogeneous and individual [12]. In MT, there are also unresolved issues, among which the central place is occupied by the problem of adequate selection of music for each patient to enhance the effectiveness of medical procedures [13].

This paper presents an original musical EEG biofeedback technology, combining the utmost individuality of EEG biofeedback with unconscious perception of MT. For correction of adverse functional states, the technology uses classical music that is turned on or off depending on the biopotentials of patient's brain. Instead of predefined excessively broad-band traditional EEG rhythms, the technology is based on automatically real time detected, characteristic and meaningful for the individual narrow-band frequency (0.4-0.6 Hz) EEG oscillators. The purpose of the study was to assess the applicability and efficacy of described technology when correcting stress-induced functional disturbances.

2. Materials and Methods

The study involved 22 subjects aged 18 to 60 years. These were students, engineers and researchers who have applied to the psychological relief service due to mental and emotional stress and voluntarily agreed to participate in the two experimental sessions. The study complies with the Declaration of Helsinki (the Declaration was passed in Helsinki, Finland, June, 1964, and revised in October, 2000, Edinburgh, Scotland) and was performed following approval by the ethic committee of the Institute of Cell Biophysics of RAS. Written informed consent was obtained from every patient.

At the beginning of each trial the dominant narrow frequency (0.4-0.6 Hz) EEG oscillators of the patient in the theta (4-8 Hz) and alpha (8-13 Hz) EEG ranges have been determined. In the course of each treatment session the patients were exposed to classical music. However, music interrupted for 3 seconds depending on current amplitude of the EEG oscillators. In one trial it happened when the amplitude of theta EEG oscillator exceed the initial level, in another trial it happened when the amplitude of alpha EEG oscillator was lower then initial one. Subjects were asked to find and maintain a condition in which the melody sounds continuously. In the first case, this was achieved via the suppression of theta EEG oscillator, in the second one – via the activation of alpha EEG oscillator. Details of EEG registration and analysis are described previously [14].

Two objective criteria of efficiency were used: music playing time (% of total session duration) and the shift of EEG rhythm power during the treatment procedure relative to the initial level (%). For subjective evaluation, standard Russian visual analog scale (VAS)-like test SAN was used before and after each treatment. The test consists from 30 questions. Answering to them, a subject makes decisions about own current level (by 7-point scale) of health, arousal and mood [15].

Statistical analysis was performed using the software package Origin 6.0. Average values (M), standard errors (m) and Student's t-criterions were calculated. When analyzing the results obtained in the dynamics of one group (indicator shift after treatment relative to the initial background), criterion t was calculated as $t = M/m$. In all cases, accurate values were recognized with a significance level of $p < 0.05$.

3. Results and Discussion

Quantitative data obtained during correcting the stress-induced disorders by music influences directed to suppress theta EEG oscillator or to activate alpha EEG oscillator of the patient are shown in Table 1.

Based on objective criteria (Table 1), subjects quite successfully coped with their task - to achieve continuous playback of music, arbitrarily adjusting own condition and biological potentials of the brain. Thus, in both procedures, the total duration of music interruptions does not exceed 25% of the total treatment time. In addition, the most pronounced changes in the EEG rhythm power occurred in the required direction: theta EEG rhythm was significantly suppressed under condition of theta EEG oscillator suppression, and EEG alpha rhythm was significantly increased under condition of alpha EEG oscillator activation.

Table 1. Objective and subjective indicators for two sessions of correction of stress-induced disturbances

№	Indicators	Procedure direction:	
		Theta EEG oscillator suppression	Alpha EEG oscillator activation
1	Music playing time (%)	79,5±2,3	75,7±2,3
2	Shift of theta EEG power under treatment (%)	-3,1±0,7 *	-2,1±0,8
3	Shift of alpha EEG power under treatment (%)	2,3±1,4	3,3±1,0 *
4	SAN test: change of health rating (points)	1,8±0,6 *	1,8±1,3
5	SAN test: change of activity rating (points)	1,2±0,8	2,3±1,6
6	SAN test: change of mood rating (points)	1,1±0,6	2,2±0,9

• - $P < 0,05$

According to the subjective reports, positive attitude of the patients to the therapeutic sessions, lowering stress level and positive psycho-emotional changes as a result of the treatment have been observed. This was confirmed by the results of SAN test shifts (Table 1). Under treatment, positive changes in all indicators have been revealed. Moreover, subjective ratings of health showed a significant increase under procedures directed to suppress theta EEG oscillator.

It is known from the literature that positive results during

correction of psychological and physiological problems in humans could be achieved with the help of music therapy [16]. Music itself is known to play a positive role in the treatment of affective disorders such as depression, anxiety, and posttraumatic stress disorder [17], to improve human well-being and quality of life [18], and to reduce the level of stress [19].

Psychological status of human subjects could be also improved by the use of music in the procedures of EEG biofeedback. For example, in one study music turned on, when current amplitude of alpha EEG rhythm of the subject exceed a predetermined threshold, and turned off, when it was under threshold [20]. Subjects were asked to find a state in which the melody sounds continuously. Presentation of music in accordance with a predetermined level of alpha-rhythm of the patient led to the normalization of the EEG and subject's mental state.

With regard to our study, it should be noted that these results are preliminary and need further analysis. First, in further experiments it is necessary to extend the sample size of subjects and to characterize the main effects for each of age group. Second, as is known from the literature, the correction of stress-induced disorders can be achieved with the help of both technologies - MT [19] and EEG biofeedback [11]. Therefore, to elucidate the contribution of each of the technologies in the obtained effects, further research into the effects of music on brain wave activity and behavior in humans is required. However, it is important to emphasize that the positive effects are usually achieved as a result of 10-12 treatment sessions of MT [18] or EEG biofeedback [21], whereas in our study similar results were observed after 1-2 treatments.

Enhanced efficiency of music-EEG biofeedback technology and its positive effect on functional status of patients may be related to the presentation of music in strict accordance with relevant brain bioelectric characteristics of the individual. As shown previously [22], in this case the conditions are created for the involvement of integrative, adaptive and resonance mechanisms of the central nervous system in complex organism's reactions to low-intensity environmental influences.

4. Conclusions

With presentations of music, controlled by a feedback from EEG oscillators of the patient, a decrease of stress level, normalization of the EEG and positive shifts in psycho-emotional status of human subjects are observed. These effects are based on the interaction of music with the regulatory systems of the brain as a result of music presentations in strict accordance with relevant bioelectric characteristics of the individual. Optimal condition for such effects is to use subject's narrow-band oscillator from theta or alpha EEG ranges. The findings suggest the possibility of the successful use of music-EEG biofeedback technology to increase the reliability of a human operator, as well as in a

wide range of psychological rehabilitation procedures.

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