

Brief report

Music of the brain approach to health protection

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Abstract

“Music of the Brain” is based on musical or music-like stimulation organized in close accordance with the biopotentials of a subject’s brain. Initial studies of the “Music of the Brain” approach were analyzed and limitations were noted. To enhance the efficiency and usability of the approach, several combinations of music therapy with a neurofeedback technique – musical neurofeedback were developed. Enhanced efficiency of the approach has been shown for the correction of functional disturbances during pregnancy and for elimination of stress-induced states in high technology specialists. The use and advantages of musical neurofeedback technology for increasing human cognitive activity, correcting sleep disturbances, and treatment of disorders of attention were verified. After further development and testing the approach may be suited for a wide range of therapeutic and rehabilitation procedures in the public health arena.

Keywords

Music; brain biopotentials; biofeedback; functional disturbances; musical neurofeedback technology; correction

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1. Introduction

Modern society is characterized by a number of factors that induce stress-related disorders and pose a significant threat to public health, including humanitarian crises that directly affect millions of people through conflict or environmental disasters [1], and unemployment, which is a major concern due to its association with high mortality risk and mental health problems [2]. A more significant factor is work-related stress. In modern society the working conditions of specialists have become increasingly complex and occupational exposure to stress has risen [3]. High workload is known to be negatively associated with several indices of psychological and physical well-being [4], and work-related stress has become, either directly or indirectly, the primary cause of illness in the workplaces of Europe [5].

The above mentioned factors are accompanied by plenty of stress-induced states due to terrorism, economic problems, natural and technogenic disasters, traffic accidents, and violence, among other factors [6]. Moreover, the problem of adaptation of people experiencing situations associated with risk to life and health, or the problem of stress of life-threatening conditions is currently of interest [7]. The chronic complex action of work-related and background stress causes a disruption of coping mechanisms and may lead first to functional disorders, and then to serious disease, including hypertonic disease, stroke, heart attack, cancer, etc [8]. Since the efficacy of pharmacological therapy in these cases is rather doubtful, the development of non-drug methods for prevention and timely correction of stress-induced functional disturbances is now highly desirable.

“Music of the Brain” presents one such approach that was developed to both prevent and correct functional human disturbances. It is fully consistent with the concepts of personalized medicine [9]

and prevention neuroscience, the latter being a new field of scientific inquiry arising from the intersection of the neurosciences and public health [10]. To enhance the efficiency of the technique, unique combinations of music therapy and neurofeedback were developed and experimentally tested for several different clinical conditions.

The term “Music of the Brain” was first used by Levin [11] to describe a method of treatment for insomnia subjects. The method is based on transforming the EEG into music by use of a special algorithm developed by Levin. For this, a multichannel EEG is recorded from a subject during sleep. Under off-line analysis, the EEG segments corresponding to different sleep phases are identified and transformed into music. Subsequently, subjects listened to the resulting audio cassettes before going to sleep. Listening to the “music” of their own brain at bedtime was found to have positive effects in more than 80% of insomniac subjects. The high efficacy of “brain music” in subjects with insomnia was associated with an absence of side effects and complications [11].

The method developed by Levin [11] was later modified by using the Brain Sound Compiler to convert EEG patterns into synthesizer-based music, tailored to the subject, and recorded to CD [12]. The Brain Sound Compiler is capable of creating changes to musical tempo, varying the volume of each channel, transposing the music of each channel to different octaves, changing musical parameters (e.g. legato to staccato), adding major and minor chords and analyzing note patterns of each channel. Recorded EEG patterns are converted into personalized music files. After using the Brain Sound Compiler to transform the EEG into a musical map representing the EEG pattern, the subject receives a CD with two musical tracks for relaxation and activation along with instructions for use. In several double blind studies this method was shown to have 82% to 85%

efficacy and to cause not only significant improvement of sleep, but also decreased levels of depression and anxiety, and increased levels of selective attention [12].

These results clearly indicate that exposure to music may cause marked psychophysiological effects if it is organized in accordance with the bioelectric characteristics of the subject's brain – the music of the brain. However, one disadvantage of the method as described is the use of a pre-recorded EEG obtained from the subject, rather than employing the subject's EEG to directly control each musical stimulus. To overcome this shortcoming, a unique combination of music therapy with neurofeedback techniques has been developed.

2. Combination of music therapy with neurofeedback techniques – Musical neurofeedback

Two advanced non-pharmacological methods employed to regulate human functional status are: music therapy (MT) and neurofeedback training (NFB). MT is listening to and playing music to alleviate physical and mental symptoms [13]. NFB training employs the current amplitude of particular EEG rhythms – theta, alpha, beta, etc. These are reflected in the parameters of a sound or light feedback signal. When presented to a subject, these feedback signals can be used to obtain the required therapeutic effects. This occurs when a subject consciously controls the signal intensity and thus the intensity of their own EEG components [14].

Though MT [15–17] and NFB [18, 19] are used to correct stress-induced disturbances, both methods also have considerable limitations. For example, maximal personalization of NFB is accompanied by the difficulty of awareness and active use of feedback signals from brain biopotentials which evolutionally are not designed for voluntary control [20]. Similarly, the advantage of unconscious perception of musical sounds in MT is combined with the difficulty of individual selection of music corresponding to the psycho-physiological features of the subject [21]. Therefore, it seems appropriate to combine the advantages of these two methods, while minimizing their shortcomings.

A method of musical NFB, combining maximal personalization of NFB with unconscious perception of MT, has been developed and tested [22, 23]. A group of 65 pregnant women suffering from stress-induced complications of pregnancy participated in the study. Subjects assumed a comfortable position with their eyes closed in an armchair or on a couch. During treatment sessions, the occipital EEG was recorded and processed on-line to measure the current amplitudes of the theta, alpha and beta EEG rhythms. Classical music served as a feedback signal. Music was presented only when the subject (using individual strategies to attain the necessary degree of relaxation) was able to change a continuous EEG rhythm in the desired manner. The task of the subject was to feel, realize, and remember her own sensations when hearing the music so that the music would not stop.

It was found that subjects could learn to voluntarily control their own EEG activity via musical feedback. Questioning and testing of subjects revealed their positive attitude to training sessions, a decrease in stress level, and positive changes in their psycho-emotional status. However, the effectiveness of training subjects to control their own EEG rhythms was relatively low. This was attributed to the high heterogeneity of the traditional EEG rhythms used in the study. It was determined that only narrow-band EEG components should be

used for musical NFB efficiency enhancement [22]. This conclusion served as a base for development of the innovative “Music of the Brain” approach now described.

3. “Music of the Brain” therapy based on utilization of individual EEG oscillators

It is known that a serious drawback of the majority of NFB methods is the use of predetermined, excessively wide-frequency (3–5 Hz) and polyfunctional EEG rhythms – theta, alpha, beta, etc. [24]. As shown by more recent research, traditional EEG rhythm is not a unitary phenomenon; rather it is comprised of different oscillations with different frequencies across a broad range [25]. Therefore, the use of traditional EEG rhythms in the NFB procedures can be compared to playing the piano in mittens – trying to press the right keys the pianist will inevitably also play adjacent keys and cause a cacophony of sound.

An original method of EEG processing has been developed to allow the narrow-band EEG waveforms of a subject to be used, instead of the excessively wide-band, traditional EEG-rhythms [26]. The narrow-frequency part of a subject's EEG that was meaningful and significant to them was extracted from their EEG waveforms. The method employs a fast Fourier transform procedure on short (4–5 sec) periods of background EEG recordings, which are sequentially shifted relative to each other with 50% overlap. To suppress the level of noise, a selection of only the most pronounced spectral peaks is used. When such spectral peaks are sequentially accumulated for the whole period of background EEG recording, the resulting spectrum is based on the summation of a large number of individual short-term spectra, it has high (0.2–0.25 Hz) frequency resolution and provides information on stable and specific narrow-band EEG oscillations important to the subject.

This methodology has been tested in two studies using different versions of musical neurofeedback. In the first study [27] individual narrow-band EEG waveforms generated by a subject were used to control presentations of classical music. In the second study [28] transformation of EEG oscillator amplitude into music-like signals was employed. Results of both studies are now described.

3.1. Presentations of classical music controlled by subject's EEG waveform

A group of computer and internet database specialists participated in the study. They complained about the urgency and magnitude of their workload and voluntarily agreed to participate in two surveys. After initial psychological testing, the dominant narrow frequency (0.4–0.6 Hz) EEG waveforms in the theta (4–8 Hz) and alpha (8–13 Hz) EEG bands were identified in each subject. Subjects were each then presented with a stimulus comprised of classical music. The stimulus was interrupted for three seconds when the amplitude of the subject's theta EEG oscillator became larger than that of the initial amplitude, and the alpha EEG oscillator did not reach the initial amplitude. Subjects were instructed to devise their own strategy to maintain the condition whereby the stimulus melody sounded continuously. In the first case this was achieved by suppression of the theta EEG-oscillator, in the second case it was achieved by activation of the alpha EEG-oscillator.

Analysis showed subjects coped successfully with the given task, i.e. to achieve continuous music playing by voluntarily regulating their own biopotentials. In both surveys the duration of music in-

interruptions did not exceed 25% of the total duration of the music stimulus. The most marked and significant ($p < 0.05$) changes of the EEG power occurred in the direction predicted by the procedure protocol: The power of theta EEG rhythm reliably reduced in the trials to suppress the theta EEG waveform, and the power of the alpha EEG rhythm reliably increased in the trials that activated the alpha EEG-waveform. Post-treatment reports and psychological testing showed had a positive attitude to the therapeutic procedures. This included reporting lowered stress levels and positive psycho-emotional changes as treatment results.

Two limitations of the musical neurofeedback methodology reported here have been identified. Firstly, interruptions of music were used as an informational feedback signal, which may have lead to negative emotional reactions for some patients and increased the difficulty of the neurofeedback process. Secondly, the technology used preselected musical compositions, i.e. the task of optimally selecting music for each subject was unresolved. This seemed to be particularly important, as presenting music that matches the brain rhythms of a subject gives marked therapeutic effects via involvement of brain-rhythm synchronization and plasticity mechanisms [29].

To overcome these limitations, another version of the musical neurofeedback technology was developed and tested [28]. Instead of interrupted classical music presentations it used rhythmical music-like stimuli that resembled the sounds of a flute that were produced by the on-line transformation of the EEG current amplitude into feedback signals.

3.2. Transformation of EEG oscillator amplitude into music-like signals

The study involved 15 high technology specialists. They complained of psycho-emotional stress due to the urgency and magnitude of their workload and they voluntarily agreed to participate in the study. After initial psychological testing, 30-second background EEG was recorded during which the dominant narrow-band (0.4–0.6 Hz) spectral component in the range of alpha EEG rhythm (8–13 Hz) was determined for each subject. The treatment mode was then switched on for 10 minutes. During this time, the current amplitude of the EEG oscillator was transformed on-line into music-like signals with a timbre resembling the sound of a flute. These sounds were controlled by the current amplitude of the EEG waveform. They varied smoothly in pitch and intensity and were accompanied by weak clicks, given at a frequency of 1 Hz.

Growth of EEG alpha rhythm power relative to the background was observed in 93% of subjects as a result of treatment. Psychological testing showed significant positive shifts in self-assessments of health, mood, and emotional maladaptation after a single treatment procedure. The positive results obtained suggest this method could be further developed for application in a number of therapeutic and rehabilitation procedures. In particular, the advantages of using musical neurofeedback technology for increasing human cognitive activity [30], correcting sleep disturbances [31] and treatment of disorders of attention [32] have been demonstrated.

4. Discussion and conclusion

Music itself is known to have a “magical” power [33] and to improve human well-being and quality of life [34]. It is also known to be a universal attribute of human society capable of evoking strong emotions, changing mood, and helping with the treatment of psychiatric

and neurological diseases [35]. However, when music is employed as feedback controlled by specific components of an individual’s EEG, it can lead to enhanced healing effects.

These studies show that with the presentation of music, or music-like stimuli, feedback controlled by EEG waveforms of the subject, a decrease of stress level, normalization of the EEG, and positive shifts in psycho-emotional status of human subjects can be demonstrated. The effects are evoked by the interaction of music with the regulatory systems of the brain as a result of music presentations that match relevant and meaningful bioelectric characteristics of the subject. It is assumed [36] that in this case the conditions are created for the involvement of integrative, adaptive, and resonance mechanisms of the central nervous system in the reactions of a complex organism to low-intensity environmental influences. The optimal conditions for such effects are the use of a subject’s own narrow-band waveforms from theta or alpha EEG ranges.

According to modern concepts [25], alpha EEG oscillations play an active role in cognitive processes and functional state self-regulation, and demonstrate a strong frequency-dependent character. Therefore, any strategies of neuronal activation by neurofeedback might benefit from the individual frequency characteristics of an EEG. In previous studies by the authors [28, 36] the amplitude of the narrow-frequency part of a subject’s EEG that is meaningful and significant for the subject, has been directly transformed into music-like signals.

Data obtained on the increase of alpha EEG rhythm intensity, accompanied by positive shifts in psychophysiological characteristics, may indicate the formation of a so-called “alpha state”, characterized by general relaxation and reduced signs of stress, apprehension, and depression [37]. It is important to emphasize that the positive effects reported here were observed after only a single treatment procedure, whereas similar data are usually achieved only after 10–12 treatment sessions by MT [34] or NFB [14].

The findings revealed by these studies suggest the possibility of the successful use of the reported musical neurofeedback technology in a wide range of therapeutic and rehabilitation procedures for the maintenance of public health.

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Conflict of Interest

All authors declare no conflicts of interest.

Compliance with ethical standards

The studies were performed in accordance with ethical principles established by European Convention for the Protection of Vertebrata used for Experimental and other Scientific Purposes (the Convention was passed in Strasburg, March 18, 1986, adopted in Strasburg, June 15, 2006). Written informed consent was received from all subjects.

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