

METHODS OF MUSIC THERAPY AND EXPERIMENTAL STUDY OF BIOELECTRICAL ACTIVITY OF STUDENTS' BRAINS WHILE LISTENING TO THE MUSICAL COMPOSITION OF THE AUDIBLE FREQUENCY SPECTRUM

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ABSTRACT

The object of the study. Experimental research of music therapy methods.

The problem to be solved. Determining the influence of selected musical composition of the audible frequency spectrum on the bioelectrical activity of students' brains, in particular alpha-, beta- and theta-rhythms.

Main scientific results. The dependence of the influence on the bioelectrical activity of the brain of the compositions of the three frequency bands both individually and the composition as a whole is revealed. The dependence of alpha, beta and theta rhythms is shown.

The area of practical use of the research results. Medical institutions specializing in the treatment of disorders of the central nervous system, organic brain damage, stress, and its effective psychological rehabilitation.

An innovative technological product. A technique of music therapy that allows to determine how different frequency ranges affect the bioelectrical activity of the human brain.

The area of application of an innovative technological product. Clinical practice of using a music therapy.

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1. Introduction

Music is an important model system for the study of rhythmic communication, because its rhythmic structure is well understood. Musical rhythms usually perceive the main rhythm in the range of about 0.5–4 Hz. Rhythmic patterns are also perceived in the group of phrase structures. Language just like a music, is usually hierarchic, where syllables (4–8 Hz) are grouped into lexical and phrasal units on slower time scales (<4 Hz). However, hierarchically embedded auditory cortical rhythms are captured by both musical and speech rhythms [1].

Electroencephalography (EEG) is a routine method of examination of neurological patients in modern clinical practice. Most often, the bioelectrical activity (PEA) of the brain is registered in a state of relaxed wakefulness, in particular in the state of rest with closed eyes. Methods of computer processing of EEG data have become widely available in recent years. However, in clinical practice the traditional visual analysis of the received data in connection with insufficient development of criteria of norm and pathology concerning spectral characteristics of PEA dominates. [2]

1. 1. The object of the research

A method for studying selected musical compositions for influencing brain biorhythms, in particular alpha-, beta-, delta- and theta-rhythms, has been developed. And the analysis of experimentally obtained changes in the parameters of biorhythms and the localization of areas of musical compositions that the most effectively affect the alpha and beta rhythms of the human brain.

1. 2. Problem description

Research on the neurophysiological aspects of music perception is a relatively young and rapidly evolving field of scientific interest [3]. However, most domestic researchers and a number

of foreign authors, touching on the perception of the music, as a stimulating material using full-fledged musical compositions of various genres. Such approach does not help to understand how different musical components interact with each other, leads to confusion and many different, often contradictory, theories of music perception [4]. In addition, this version of the study virtually eliminates one of the main tasks facing this field of knowledge: to identify those physical characteristics of musical compositions that play the most important role in the transmission of semantic and aesthetic (emotional) information [3].

1. 3. Suggested solution to the problem

The solution of this problem becomes possible only when considering music as a complex physical signal, characterized by different component-structural composition, in isolation from its cultural and historical value [5].

The aim of our research is to study the spectral characteristics of the bioelectrical activity of students' brains when listening to the complex audio signals, namely, musical compositions of different component-structural composition, characterized by the presence of a melodic component and playback speed.

2. Materials and methods

The task of the experiment is to test the influence of a number of musical compositions on brain rhythms, in particular alpha, beta and theta rhythms. In the case of a general positive effect to analyze in detail the changes in rhythm parameters and localize areas of musical compositions that the most effectively affect the rhythms of the human brain, in order to treat central nervous system disorders, organic brain damage, stress, and its effective psychological rehabilitation [6].

2. 1. Experimental methodology

When conducting research on the stimulation of the central nervous system of man with complex audio signals, use musical fragments of different component and structural composition. All fragments are recorded in mp3 format [6].

Based on the spectral analysis, the characteristic frequencies with the largest amplitude in relation to the entire frequency spectrum for each of the compositions were established. We chose a time interval of one minute, where these frequencies occur, and divided the compositions into three frequency groups: low-frequency (LF) in the range from 20 Hz to 300 Hz, medium-frequency (MF) – from 300 Hz to 3 kHz, and high-frequency (HF) – from 3 kHz to 20 kHz. The results are shown in the **Table 1** [6].

Table 1

The name of the compositions

No.	Composition	Frequency with A_{max}	Frequency group
1	«Bohren Und Der Club of Gore» On Demon Wings	80 Hz	LF
2	«Little Walter» BlueLight	110 Hz	LF
3	«Prayer for Ukraine» M. Lysenko	420 Hz	MF
4	«Melody» M. Skoryk	450 Hz	MF
5	«Gag» – Chimaira	1.76 kHz	HF
6	«Highway to Hell» – AC/DC	2.1 kHz	HF

Ten volunteers – students participated in the experiment, on voluntary consent, in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki), which are regulated by international documents. All students do not have a special music education.

Studies of the effect of complex audio signals on the electrical activity of the cerebral cortex were conducted in a certified muffled room of the Department of Acoustic and Multimedia Electronic Systems National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, electroencephalography (EEG) was performed with a computer electroencephalograph “BRAINTEST-16”, Ukraine, Kharkiv) – (**Fig. 1**).



Fig. 1. Silenced room of the Department of Acoustic and Multimedia Electronic Systems NTUU “Igor Sikorsky Kyiv Polytechnic Institute” to study the effect of complex audio signals on the electrical activity of the human cerebral cortex

Silver cup electrodes located in 16 standard leads were used (Fr1, Fr2, F3, F4, F7, F8, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6) – (see **Fig. 2**), the location of which was determined according to international system “10 – 20”. Separated ear electrodes were used as a reference. EEG recording was performed in the bandwidth from 3 to 30 Hz.

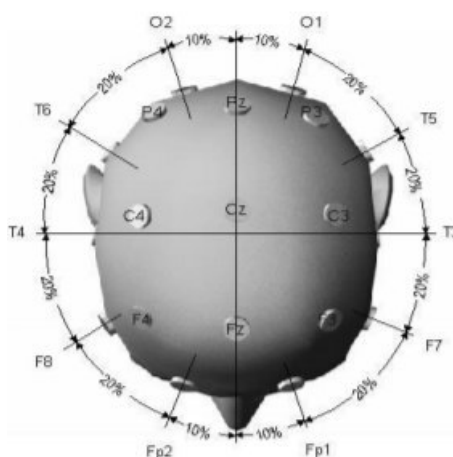


Fig. 2. Scheme of application of electrodes according to the scheme 10–20

The research was conducted in a comfortable environment in the afternoon. At the beginning of each examination, the EEG was recorded at rest with the closed eyes for one minute. These data were considered as background. In the main part of the experimental study, EEG recording was performed during listening to the different compositions. Musical compositions of the whole spectrum of frequencies acted as loading options. The modulated audio signal was a sequence of 2 signals of each frequency spectrum: low-, medium- and high-frequency, where between each song a minute of silence. As a result, the necessary balance between the musical sound and the state of rest after. When creating the final composition, the signal volume was taken into account, which was aligned with standard software environments. The musical composition was listened by the examinee for twelve minutes with closed eyes and listening to everyone took place three times with an equal interval of time during the month.

Statistical analysis of the results of the study was performed using application packages Microsoft Excel and PHPStorm 2019.3 for Windows and included several stages. The variance method was used as the main statistical method.

3. Results

According to the results of analysis of variance EEG data, it was possible to assess statistical significant changes in PEA of the brain, associated not only with the influence of individual char-

acteristics of the listened compositions, but also to identify their mutual influence on the emotional state of man. Regardless of the presence of the melodic component in the listened samples led to a decrease in the spectral power of the alpha rhythm and theta rhythm in the symmetrical occipital leads *O1* and *O2* ($P(\alpha 0)=118.75 \mu\text{W/Hz}$, $P(\alpha 6)=65.5 \mu\text{W/Hz}$; $P(\alpha 0)=184.29 \mu\text{W/Hz}$, $P(\alpha 6)=136.97 \mu\text{W/Hz}$ and $P(\theta 0)=95.86 \mu\text{W/Hz}$, $P(\alpha 6)=65.5 \mu\text{W/Hz}$, $P(\alpha 0)=160.99 \mu\text{W/Hz}$, $P(\alpha 6)=151.11 \mu\text{W/Hz}$), as well as in the parietal lead of the left hemisphere *P3* ($P(\alpha 0)=65.68 \mu\text{W/Hz}$ $P(\alpha 6)=44.94 \mu\text{W/Hz}$ and $P(\theta 0)=62.68 \mu\text{W/Hz}$ $P(\theta 6)=27.73 \mu\text{W/Hz}$).

Similar changes were registered in the temporal-parieto-occipital leads of both hemispheres alpha, beta and theta rhythms *T5* and *T6* ($P(\alpha 0)=50,788$, $P(\alpha 6)=17,038$ and $P(\alpha 0)=50,788$, $P(\alpha 6)=17.038 \mu\text{W/Hz}$; $P(\beta 0)=35.21$, $P(\beta 6)=23.79 \mu\text{W/Hz}$ and $P(\beta 0)=35.21$, $P(\beta 6)=23.79 \mu\text{W/Hz}$; $P(\theta 0)=33.77 \mu\text{W/Hz}$, $P(\theta 6)=25.31 \mu\text{W/Hz}$ and $P(\theta 0)=33.77 \mu\text{W/Hz}$, $P(\theta 6)=25.31 \mu\text{W/Hz}$) (**Fig. 3, a–c**).

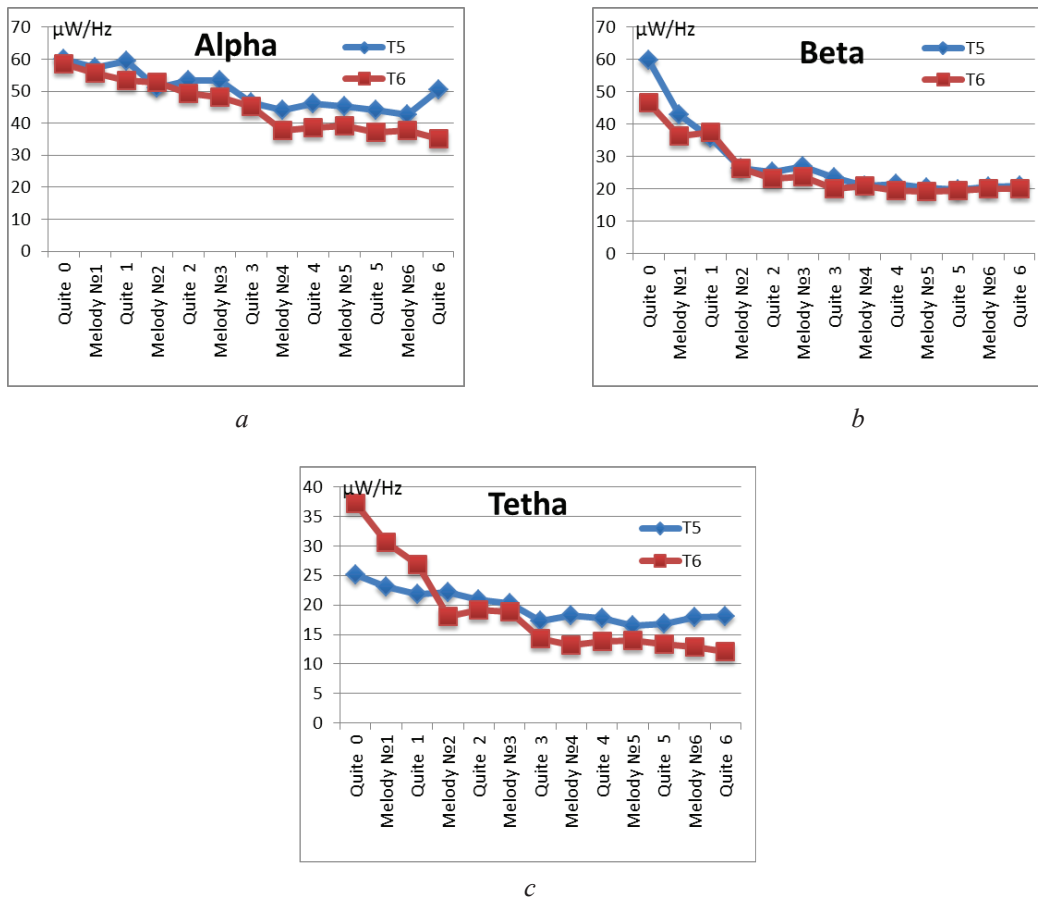


Fig. 3. Spectral powers of EEG rhythms in symmetrical temporal-parieto-occipital leads of both hemispheres of rhythms *T5* and *T6*: *a* – alpha-rhythms; *b* – beta- rhythms; *c* – theta-rhythms

Listening to the composition was characterized by lower values of the spectral power of the beta range in symmetrical temporal leads ($P(\beta 0)=23.56$, $P(\beta 6)=14.84 \mu\text{W/Hz}$ and $P(\beta 0)=29.93$, $P(\beta 6)=25.08 \mu\text{W/Hz}$), in the left hemisphere of the parietal region ($P(\beta 0)=35.61$, $P(\beta 6)=28.9 \mu\text{W/Hz}$) and in the left hemisphere of the occipital leads ($P(\beta 0)=38.94$, $P(\beta 6)=32.08 \mu\text{W/Hz}$).

In addition, in the alpha range, a similar reaction was observed in the front areas, namely in the frontal *Fp1* and *Fp2* ($P(\alpha 0)=29.68$, $P(\alpha 6)=17.25 \mu\text{W/Hz}$ and $P(\theta 0)=33, 72 \mu\text{W/Hz}$, $P(\theta 6)=16.55 \mu\text{W/Hz}$) (**Fig. 4**).

The cross-action of resting factors and melody, revealed by the results of analysis of variance, was manifested in the relative increase in the spectral power of EEG rhythms. An increase in the power of the alpha and theta rhythm in the right hemisphere was noted: significant differences are shown in the central *C4* ($P(\alpha 0)=30.06$, $P(\alpha 6)=33.29 \mu\text{W/Hz}$ and $P(\theta 0)=33.77 \mu\text{W/Hz}$, $P(\theta 6)=45.31 \mu\text{W/Hz}$), parietal *P4* ($P(\alpha 0)=115.9$, $P(\alpha 6)=148.09 \mu\text{W/Hz}$ and $P(\theta 0)=56.07 \mu\text{W/Hz}$, $P(\theta 6)=63.01 \mu\text{W/Hz}$).

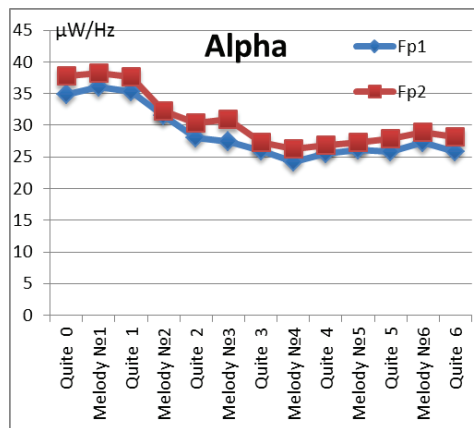


Fig. 4. Spectral powers of EEG alpha rhythms in the anterior regions in the frontal leads Fp1 and Fp2

The melodic component in the composition had a statistically significant effect on the severity of alpha-, beta- and theta-rhythm in the anterior temporal leads (see Fig. 5). For clarity. So the most significant decrease in spectral power is visible in the right hemisphere.

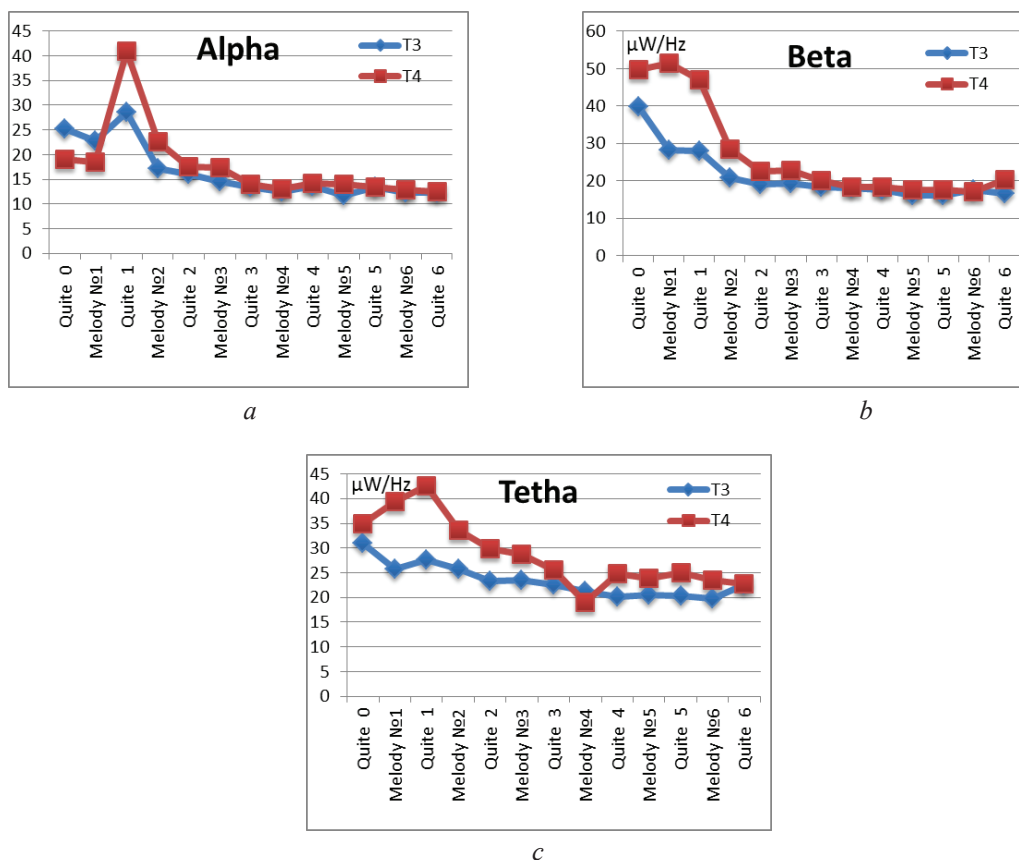


Fig. 5. Spectral powers of symmetrical temporal anterior leads T3 and T4: *a* – alpha-rhythms; *b* – beta- rhythms; *c* – theta-rhythms

4. Discussion of research results

It is well known that the brain has the properties of a three-dimensional conductor, which allows the propagation of currents at almost the same speed in all directions from the point of their generation. The meninges and skull bones have an averaging effect on the distribution of potentials, smoothing the spatial variations in current density and their local inhomogeneities. As a result, the electric fields recorded during EEG recording have a much wider distribution topography than

when recording in close proximity to the source. Bio-electrical activity taken from electrodes located at a small distance from each other is often a wave of general genesis [7, 8].

According to the EEG data processing, it was possible to estimate statistically significant changes in PEA of the brain, one of the theta-rhythm generators projected its activity on the temporal-parieto-occipital (*T5–T6*) region of the cortex. The maximum of coherent interaction between the leads involved in this factor was reached at the level of 3–4 Hz. This suggested that the source of theta oscillations is a number of subcortical anatomical structures, including the nucleus of the medial septum. The role of these formations in the generation of low-frequency theta rhythm has been repeatedly shown in the works of Russian and other foreign authors [9–11].

The second generator system, the activity of which was recorded in the theta band, is located in the occipital regions of the brain (*O1–O2*) and combines the occipital leads of both hemispheres. The maximum of coherent interaction between the regions was observed at the level of 11–12 Hz, forming alpha- like complexes of theta oscillations. It is important to note that to date there is no consensus on the frequency limit of theta and alpha bands.

Lower values of the spectral power of the alpha rhythm in the central (*C3–C4*) and post-central (*T5–T6*) regions of the cortex, which are registered when listening to the melody, indicate high activity of specific subcortical nuclei of the thalamus. The functional role of these generator structures is to control many sensory flows from peripheral receptors to the projection zones of the cortex of the large hemispheres [3].

The results of the spectral power of the beta rhythm revealed two independent groups of leads (see **Fig. 3** (Beta), 5 (Beta)). The maximum low values of spectral power in the first of them fell on the temporal region of the cortex (*T3–T6*), which indicates the registration of Roland beta-rhythm, the frequency of which, does not exceed 20 Hz, as a rule. Another source of beta rhythm, apparently, were the polymodal associative regions of the cortex of the large hemispheres.

According to the obtained data, it is important to note that listening to the melody entails the activation of mainly the right hemisphere, which is associated with a decrease in the spectral power of the beta rhythm in the corresponding leads. This indicates the priority role of the right hemisphere in the perception of the melodic component.

Study limitations. The main restrictions on the use of the results here are:

- 1) age category from 17 to 25 years old;
- 2) all volunteers did not have a musical education, as this significantly affects the perception of musical fragments;
- 3) musical fragments are selected in a certain sequence - increasing the frequency group from low to high frequencies.

The prospect for further research is to reduce the number of audio signals in each frequency band and increase the rest time between them. Moreover, increase the number of volunteers and the number of trials for each volunteer.

5. Conclusions

1. The selection of musical compositions was carried out taking into account the audible frequency range according to the obtained spectral characteristics.
2. The activity of the occipital associative areas of the cortex of the large hemispheres increases, regardless of the presence or absence of a melodic component in the musical composition when listening.
3. Perception of melodies is characterized by a high degree of activity of the temporal system, which is due to the complexity and diversity of the frequency spectrum of the melodic component in comparison with its absence.
4. When listening to melodies, the neural structures of the right hemisphere play an important role in processing the perception of the signal.
5. After listening to the first low-frequency musical composition and in the absence of a melodic component, the activity of the temporal system of both hemispheres decreases with listening to each subsequent melody. The activity decreases gradually.

Conflict of interests

The authors declare that there is no conflict of interests.

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