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Effects of nucleus rapher on the spectral character of electrical activity in the structures of the vision analyzer

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The present work is devoted to the study of neurophysiological mechanisms of participation of the nucleus rapher in the plastic properties of the visual analyzer in the correction of dysfunction caused by retinal dystrophy. To achieve this goal, we used the method of spectral analysis of the potentials of the electroencephalogram in the central structures of the vision analyzer. First of all, a comparative analysis of the spectral characteristics of the EEG potentials at the studied structures was carried out during the background activity of the brain. The results of the studies performed showed that one of the characteristic features of the EEG in the structures of the visual analyzer is that the maximum level of the spectrum is mainly concentrated in the delta and theta frequency ranges of the EEG. After exposure to electrical stimulation of one of the nuclei of the 5-HT-ergic system, the polymodality of spectral properties in the visual cortex (VC) and colliculus superior (CS) is disturbed. The main maximum level of the spectra after stimulation of nR the EEG waves shift to higher frequency regions (4-5 Hz and 9-10 Hz). As a result of dysfunction, the amplitude of the main peak of EEG spectral features in the delta frequency range decreases and the second maximum level of the spectrogram decreases in the range of theta. Similar changes are observed in the spectra of EEG potentials in the subcortical structures of the visual analyzer. In the case of experimental retinal dystrophy, this corresponds to an increase the generation of potentials of the EEG at the delta range after exposure to electrical stimulation of the 5-HT-ergic system.

Keywords: *EEG, nucleus rapher, serotonin, experimental dystrophy*

INTRODUCTION

One of the actual problems of modern neurophysiology is the plasticity of nervous processes, more precisely, it is the ability to adapt through optimal structural-functional reconstruction of the nervous system (Kharchenko and Telnova, 2017). The monoaminergic (MA-ergic) neuromodulatory system of the brain has been recognized as one of the important components of the endogenous mechanisms of plasticity regulation. To date, a large number of experimental materials have been collected in the literature on the characterization of cellular and systemic mechanisms of the participation of MA-ergic neurotransmission in the regulation of neuronal plasticity and interneuronal connections (Sinakevitch et al., 2018a, 2018b). It is clear that the morphological features of the organization of MA-ergic neurotransmission, based on the phenomenon of the spatial organization of nervous processes, indicate the need to study their role in the mechanisms of plasticity (Freitas, 2008).

The results of experimental studies prove that dynamic changes occurring at different levels of the visual analyzer system are not only attributed to morphofunctional features of its cellular organization. They are also associated with the activation of various nonspecific regulatory centers of the brain (Yokogawa and Hannan et al., 2012; Miryusifova et al., 2015). That is why the study of the mechanisms and patterns of

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participation of neuromodulatory centers in the functional regulation of the visual analyzer has become in recent years one of the main problems of modern neurophysiology and neuropathology. There is information in the literature about the modulating effect of nR electrical stimulation on the spectral characteristics of slow potentials in the structures of the sensory systems of the brain (Cransac et al., 1998). In addition to morphological studies, there are a large number of other studies on the role of 5HT-ergic systems in the processing of visual, auditory and gustatory information. Based on the collected experimental data, it was found that nR has both inhibitory and excitatory effects on neocortical neurons. It is believed that the multiple complex effects of 5HT on information processing in the visual cortex are associated with the effect on different types of pyramidal interneuron receptors in the fifth layer of the visual cortex. This last result is explained by the change in the amplitudes of various potentials observed due to spontaneous inhibition of postsynaptic potentials (Xiang and Prince, 2003). Based on these data, it is assumed that an increase in the spectral power of slow waves after nR electrical stimulation can be considered as a physiological equivalent of the activating effect of the 5HT-ergic system at the level of excitability of cortical neurons (Zhang and Towns, 2002). 5HT has also been found to limit the occurrence of long-term synaptic plasticity in the second and third layers of the visual cortex (Jang et al., 2012). The modern literature contains interesting data on the involvement of 5-HT-ergic neurons in the regulation of pathological processes in the CNS. In particular, it has been found that nR can be involved in the mechanisms of sleep disorders, depressive disorders, neurodegenerative diseases, and psychopathological conditions such as anxiety and depression (Son et al., 2012).

MATERIALS AND METHODS

The research has been conducted in the condition of chronic experiments on awakened mature rabbits weighing 2.5-3.5kg. All electrophysiological studies were conducted humanely in accordance with generally accepted international principles of the European Convention on Experimental Animals (2010/63/EU). Scalping and implantation of macroelectrodes were performed under Nembutal anesthesia (35 mg/kg) and local anesthesia (0.5% novocaine solution) along the coordinates of the stereotactic atlas were used to register biopotentials. Potentials of the visual cortex (VC), superior colliculus (SC), lateral geniculate body (LGB), nucleus raphersdorsalis (nR) were registered. In the experiments, the EEG recording lasted from several minutes to several hours. For analysis, we selected artifact-free 30-second segments EEG activity of animals with precisely positioned electrodes. Analyses of EEG have been conducted using the software "Brainsys" (Russia) in the frequency diapason 0.5-45.0 Hz. 2.0% monoiodoacetic acid (MIAA) has been used to induce experimental retinal dystrophy. For bipolar electrical stimulation of the neuromodulatory center (nR), a laboratory electrical stimulator ESL-2 and the following stimulation parameters were used: amplitude 3.0-5.0 V, frequency 150-200 Hz and the duration of a single impulse is 0.4 ms, the duration of one session of electrical stimulation is 4-5 minutes. The spectral composition of the EEG was analyzed using the fast Fourier transform method. The reliability of intragroup and intergroup comparisons of EEG indicators was determined using the ANOVA program package.

RESULTS AND DISCUSSION

The research was carried out in several stages. First of all, we carried out a comparative analysis of the spectral characteristics of the EEG potentials of the studied structures during background brain activity. For this, we registered background EEG in the studied structures. Although at first view they are very similar to each other, as can be seen from the results of the correlation-spectral analysis, there are significant differences in their spectral composition. First of all, it should be noted that the maximum level of spectral properties of the total potentials of the analyzer structures, which have insignificant differences, is mainly concentrated in the delta and theta ranges of EEG frequencies. Thus, characteristic signs of maximum amplitudes distribution of primary visual potentials spectra of the cerebral cortex at frequencies of 2–3 and 5–6 Hz are usually accompanied by a predominance of EEG delta rhythms. A similar figure is also observed in the distribution of peak values of spectral features amplitude for the LGB potentials. However, the maximum levels of the spectral characteristics are changed and fluctuate between 4-5 Hz and 9-10 Hz. Results of further experimental studies have shown that a somewhat different pattern of the frequency distribution of the dominant EEG waves is observed in the background of EEG spectra after exposure to electrical stimulation of the 5-HT-ergic system of the brain (Fig. 1). The results of the analysis showed that in the current experimental situation**,** in the VC and SC subcortical structures of the vision analyzer at the stage following the effect of electrical stimulation of the nuclei of the 5-HT-ergic system of the brain, the polymodality of the spectral properties is (amplitude spectra have many peaks) disturbed. With background activity in the VC, the first peak of the spectral composition of the EEG potentials fluctuates within 2–3 Hz, and the second peak, within 6–7 Hz and at the same time, the main maximum level of the spectra after stimulation nR is located in a relatively intense range, shifting to a higher frequency (4–5 Hz and 9–10 Hz) region of EEG waves (Fig. 1A, B). Considering, that distribution of the maximum amplitude levels of EEG potentials during background activity in the SC in the frequency range of 3-4 Hz and 8-9 Hz indicates the formation of a bimodal spectrum pattern and at this time, after exposure to electrical stimulation of nR neurons, it was observed that the first peak of the amplitude parameters in this structure was transformed into a high component part, starting from the frequency range of 4-5Hz and even the second and the third peaks. This, in turn, leads to the formation of a polymodal image of the EEG potentials amplitude parameters. From the results of the spectral analysis of the studies performed, it can be seen that after exposure to electrical stimulation of nR neurons, a slightly different pattern of the distribution is observed (LGB and LC).

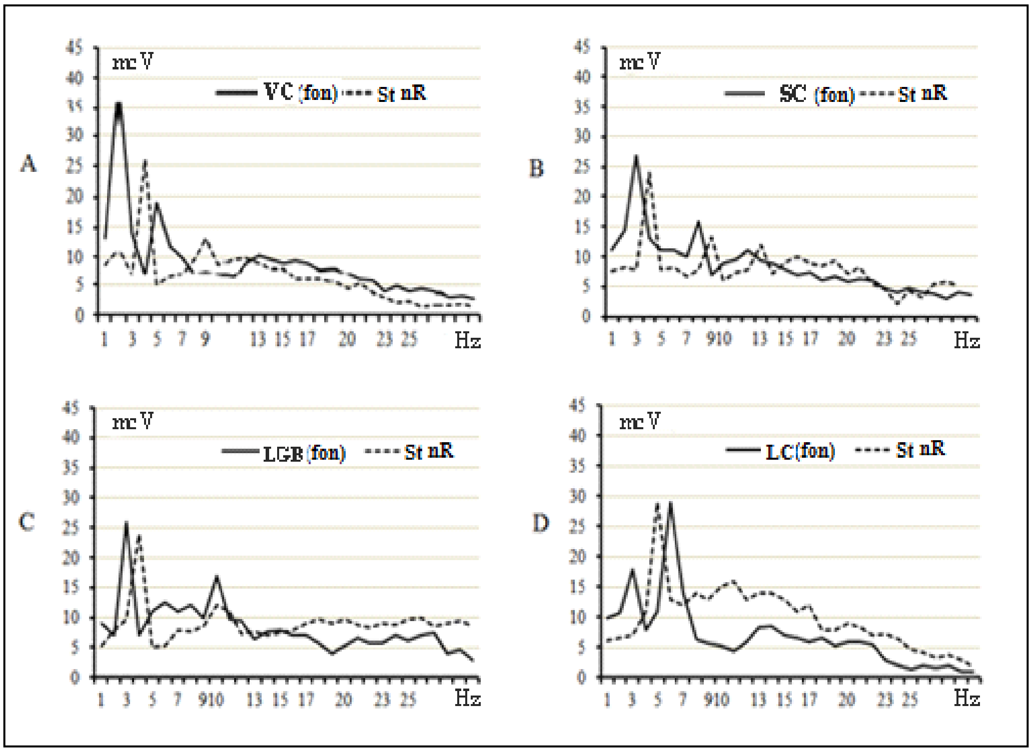

Fig. 1. Effect of nR electrical stimulation on the background spectral character of the EEG of the visual analyzer structures. A-VC, B-SC, C-LGB, D-LC.

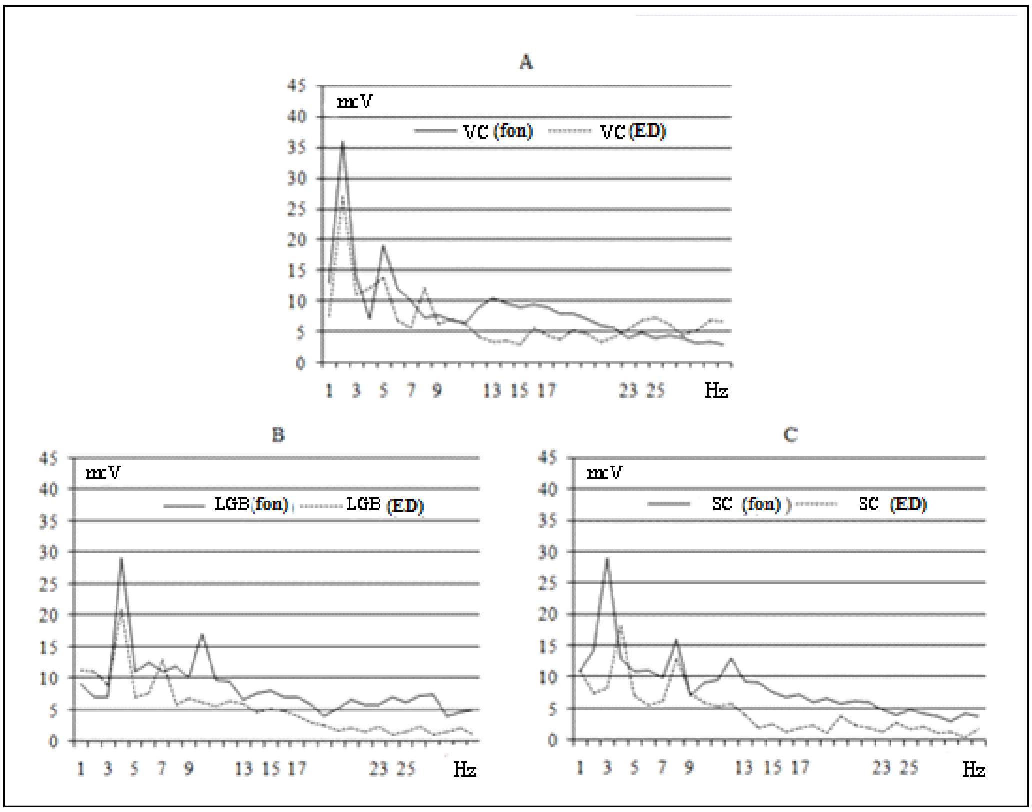

Fig. 2. Consequences of experimental retinal dystrophy change in the EEG of the central structures spectral nature of visual analyzer.

In these structures, under the influence of nR, it is important to transform the bimodal form of the spectra into a monomodal one, expressed by the peak values of the spectrum amplitudes in the range of 4-5 Hz (Fig. 1 C, D).

The formation of experimental dystrophy **(**ED) affects not only the amplitude parameters of retinal responses but also to some extent affects the spectral character of the EEG potentials of brain structures (Fig. 2).

As it can be seen from the spectral character shown in the figure at the level of the primary visual cortex as a result of dysfunction around the analyzer, the amplitude of the main peak of the EEG spectral features in the delta frequency range decreases and the second maximum level of the spectrogram decreases in the theta frequency range. Similar changes are observed in the spectra of EEG potentials of the subcortical structures of the visual analyzer.

Corresponding changes are characteristic especially for the LGB potentials and also for a noticeable decrease in the amplitude of the main peak of the spectral character and a shift of a significant secondary peak to a lower frequency range of the EEG. It is natural to expect that some changes will be found at the SC level as well. Indeed, analogous changes in dysfunction conditions of the analyzer of peripheral vision are distinctly observed on spectrograms of SC.

At the same time, during the formation of pathology in the analyzer it is necessary to pay special attention to the appearance of relatively less noticeable changes in the level of general EEG potentials of neuromodulating centers. While the amplitude spectrum of nR EEG potentials remains unchanged, for LC potentials in this case, it is clearly seen that the level of the maximum of the main spectral feature shifts somewhat and changes its position.

In the case of experimental retinal dystrophy, the effect obtained after exposure to electrical stimulation of the 5-HT-ergic system was different (Fig. 3).

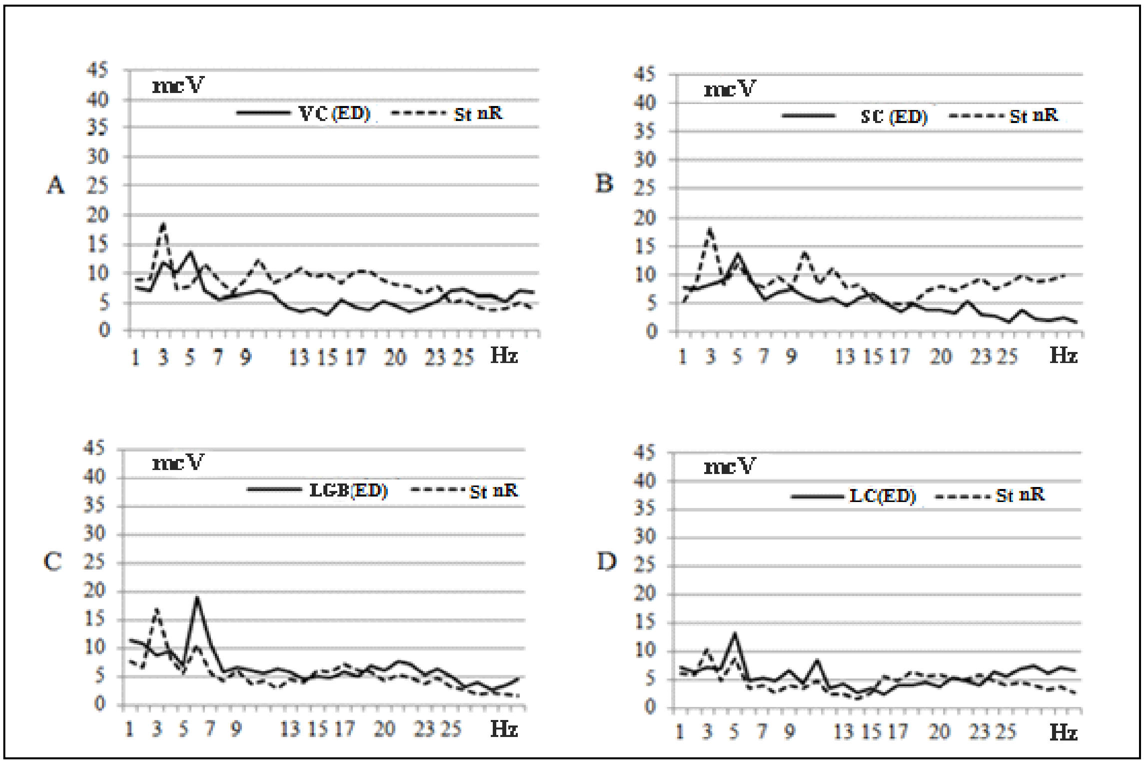

Fig. 3. In the background of experimental retinal dystrophy the effects of nR stimulation on the spectral character of EEG in the structures of the vision analyzer. A-VC, B-SC, C-LGB, D-LC.

Under this condition, the observed changes in the spectra of EEG waves have a similar characteristic and mainly correspond to the increase in the generation of potentials in the delta range of EEG waves. This sign is clearly observed mainly at the level of visual cortex potentials of the brain.

It is clear from the presented spectrograms that formed under conditions of experimental dystrophy and the maximum level expressed in the range of 2-3 Hz is kept in the same frequency interval due to the effect of nR. Similar changes are observed in the spectral character of EEG potentials at the level of SC and LGB. In this case, despite the formation of a clearly noticeable level of the spectral amplitude peak in the interval of 3-4 Hz, the level of LC potentials is somewhat weakly expressed (Fig. 3 D).

Besides, the increase in the level of synchronization of EEG potentials, first of all, should be seen as an increase in the possibility of information interaction between brain structures in different experimental situations. The process that forms the basis of the characteristics of the amplitude regulation of EEG waves against the background of retinal pathology was observed in our experimental studies. Under the influence of electrical stimulation of the 5HT-ergic system of the visual analyzer of the brain, accompanying changes in the pathology of the retina of an eye and parameters of electrical activity not only in the retina itself, but it is also reflected to some extent in the electrogenesis of the central structures of the visual analyzer.

By choosing an artificially created pathology in the visual sensor system as an experimental model addition, special attention was paid to the 5-HT-ergic neuromodulation systems of the brain. The choice of dystrophy model of vision analyzer in experimental studies is not random. Thus, the studied 5HT-ergic neuron terminals it is represented in a wide form at the level of the visual analyzer almost from the periphery to the central structures and neurotransmitters play an important role in the transmission of signals from the retina to the visual cortex. First of all, what was revealed in our research it should be especially noted that the spectral characteristics of potentials with small differences in the vision analyzer are mainly concentrated in delta and theta frequencies of the EEG. Differences mainly belong to the amplitude of the spectral character peak values of EEG. It is interesting that under the influence of 5-HT-ergic systems in the background subcortical structures (VC and SC) the maxima of the spectra shift towards higher EEG frequencies (9-10 Hz), while the spectra of LGB and LC potentials in the range of 4-5 Hs, it acquires a monomodal characteristic with clearly expressed amplitudes peak values of the spectra. The obtained results showed that the activation of 5-HT-ergic neurotransmission increases the synchronization of EEG potentials in LC. Before and after ED the fact of reestablishing relationships between the results of the spectral analysis and the studied structures of the vision analyzer this method gives reason to say that the analysis of regulatory processes is one of the important indicators. However, it should also be noted that an increase in the level of synchronization of EEG waves should be considered primarily as an increase in the probability of information interaction between the structures of the vision analyzer in different experimental situations.

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