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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

ENDOGENOUS MECHANISMS OF PLASTICITY OF NEUROMODULATION OF THE VISUAL ANALYZER

Specialty:	2411.01-Human and animal physiology
Scientific area:	Biology
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GENERAL CHARACTERISTICS OF THE RESEARCH

The actuality of the theme. It is known that one of the current problems of modern neurophysiology is the plasticity of neural processes, or more precisely, the ability to adapt the nervous system through optimal structural and functional reconstruction[1,2,3].The monoaminergic (MA-ergic) neuromodulatory system of the brain is considered to be one of the important components of the endogenous mechanisms of plasticity regulation. Until now, the literature has collected a large amount of experimental material on the characteristics of cellular and systemic mechanisms of the participation of MA-ergic neurotransmission in the regulation of neuron plasticity and inter-neuronal connections. It was found that the participation of MA-ergic neurons in the plastic supply mechanisms of neural processes is due to their iono and metabotropic effects.

Of particular interest is the fact that MA-ergic neurons irritate all structures of the brain by creating a network of distributed terminals within the framework of the problem under discussion. The existence of a distributed terminal network indicates that these neurons are involved in a wide range of neural processes, or more precisely, they are multifunctional in nature.

In addition, this fact undoubtedly shows that they play an important role in the mechanisms of regulation of the joint activity of various structures of the brain.

It turns out that the morphological features of the organization of MA-ergic neurotransmission based on the phenomenon of spatial organization of neural processes

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[1] Романчук, Н.П., Пятин, В.Ф., Волобуев. А.Н. Нейропластичность: Современные методы управления // – Москва, Здоровье и образование в XXI веке, , – 2016. №9, – с.92-94.

[2] Харченко, Е.П., Тельнова, М.Н. Пластичность мозга: ограничения и возможности //– Москва, Ж. невр.и и психатрии, – 2017.т. 1, №2, – с.8-13.

[3] Харченко, Е.П., Тельнова, М.Н. Пластичность мозга: ограничения и возможности //– Москва, Ж. невр.и и психатрии, – 2017.т. 1, №2, – с.8-13.

demonstrate the need to study their role in plastic mechanisms[4]. For some reason, the sensory system, including the visual system of the brain, is a more suitable model for experimental research in this area. Thus, in recent years, the study of plastic innovations in the visual system has become widespread, not only of theoretical interest in terms of neurophysiology, neuropathology and psychophysiology, but also of practical application, as it helps to purposefully search for ways to optimize visual function[5]. Despite the successes achieved with the improvement of modern research methods, some aspects of this problem still require experimental research. On the other hand, the results of experimental studies prove once again that the dynamic changes that occur at different levels of the visual analyzer system are associated not only with the morphofunctional features of its cellular organization, but also with the activation of various non-specific regulatory centers[6]. Two-way close connections between the MA-ergic system and not only the central but also the peripheral structures of the vision analyzer have been established. In this regard, the study of the mechanisms and patterns of 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. In considering the above, the presented dissertation work is devoted to the comparative study of neurophysiological mechanisms of the participation of the MA-ergic neuromodulator system in the plastic properties of the central structures of the visual analyzer in the correction of

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[4] Freitas, R.L. Serotonergic neurotransmission in the dorsal raphe nucleus recruitsin situ 5-HT(2A/2C) receptors to modulate the postictal antinociception //– New York, Exp. Neurol., –2008. vol.213, №2, –p. 410-418.

[5] Yokogawa, T, Hannan, M.C., Burgess, H.A. The dorsal raphe modulates sensory responsiveness during arousal in zebrafish//– Washington, J.Neuroscience,–2012. vol.32, №43.–p. 15205-15215.

[6] Miryusifova, Ch.M. Role of serotonin and noradrenalin in mechanisms of hypothalamic regulation of experimental dystrophy of the retina /Ch. M. Miryusifova, S.I. Mohammadova, A .A. Azizov [et al.]// SAJEB: –Hamelmalo: –2015.vol.5, №4, –p. 137-142.

dysfunction arising in the conditions of experimental pathology of the visual analyzer.

The purpose and the duties of the research. The main purpose of the dissertation is to study the role of neurophysiology in the plastic properties of the visual analyzer of the serotonergic (5-HT-ergic) and noradrenergic (NA-ergic) components of the MA-ergic neuromodulatory system in the correction of dysfunction in experimental retinal dystrophy (ED). To achieve this purpose, methods of spectral-coherent analysis of the electroencephalogram (EEG) in the central structures of the vision analyzer were used.

To achieve this purpose, the following studies were carried out:

1. Spectral-coherent analysis of the spatial organization of the EEG during normal and sensory stimuli in the central structures of the visual analyzer system and neuromodulatory centers (nucleus rafa-nR, locus coeruleus-LC).
2. The study of the dynamic features of the restructuring of interstructural relationships in the visual analyzer under conditions of experimental pathology of the retina.
3. Comparative analysis of the effect of electrical stimulation of neuromodulatory centers (nR, LC) on the plastic properties of the visual analyzer under conditions of experimental pathology.
4. Based on the results obtained and the available information about the synaptology of MA-ergic neurons, ultrastructural organization, ideas are formed about the role of MA-ergic neuromodulatory systems in the regulation of endogenous mechanisms of plasticity of the central structures of the optic nerve analyzer of the brain.

Scientific innovation of the research. The dissertation implements a new approach to the concept of spatial organization of the electrical activity of neuronal processes, modulated by various neuromodulatory systems of the brain.Studies have shown for the first time that the normalization of such indicators as coherence relations and the spectral composition of the electrical activity of the central structures of the visual analyzer can be a sufficient criterion for analyzing the features of the development of compensatory processes in the development of functional disorders. In the model of retinal ED, the differential role of 5-HT- and NA-ergic neuromodulatory systems in the regulation of plasticity of the central structures of the visual system of the brain was determined by spectral-coherent EEG analysis.

Theoretical and practical significance of the research. The approach to the analysis of the electrical activity of the brain used in the study makes it possible to reveal the spatial features of the EEG during the development of functional disorders.This feature is of particular importance when using MA-ergic neuromodulating centers to regulate the dynamics of the development of the brain's plastic capabilities to compensate for lost functions. Based on the results of the study, the neurophysiological aspects of the participation of various components of the MA-ergic neuromodulating systems in the regulation of the functional plasticity of the peripheral and central structures of the CNS visual analyzer are clarified, and the possibilities of using endogenous principles of neuromodulation in ophthalmology are significantly expanded.

The main provisions of the dissertation defended :

1. The spatial organization of the EEG potentials of the central structures of the visual analyzer of intact rabbits forms stable synchronization patterns characteristic of this analyzer.The formation of pathology on the periphery of the analyzer leads to a restructuring of coherent connections between structures and a violation of their spatial organization.

2. Activation of neuromodulatory centers of MA-ergic nature and resulting electrical processes of different composition of EEG,coherence (Coh) potentials in the delta frequency region under the influence of nR, electrical processes in the theta and alpha frequency regions under the influence of LC correlate with changes in the level of relationships.

3. In contrast to LC, stimulation of nR has a modulating complex effect on the synchronization of EEG potentials of the

structures of the visual analyzer under conditions of dysfunction of the visual system brings the overall picture of the distribution of connections closer to the indicators of background activity. The increase in the summary amplitude of the ERG observed in this case clearly indicates the activation of endogenous compensatory processes under the influence of 5-HT-ergic systems of the brain.

Approbation and application.

Important results of the dissertation work, scientific novelty and main provisions at the"XIV International Conference on Biology and Medical Sciences" (Vienna, 2017), "II International Science Conference General question of world science" *(*Amsterdam, 2017), "Scientific research of our time: problems and solutions" (Ivanovo, 2018), "I international scientific and practical conference", "Scientific areas dedicated to the 95th anniversary of Z. Aliyeva" (Baku, 2018), "Modern trends and prospects for the development of science, technical, technology" (Belgorod, 2019), "Advances in Science and Technology" (Moscow, 2019), "XVIII International Conference international scientific-practical conference dedicated to the 100th anniversary of the Department of Human Anatomy and Medical Terminology of AMU" (Baku, 2019), "İnternational scientific-practical congress Actual problems of medicine 2021" (Baku, 2021), were discussed.

The organization where the work is performed. Laboratories of "Neurophysiology" and "Molecular bases of integrative activity" of the Institute of Physiology named after academician Abdulla Garayev of ANAS.

Publication of dissertation materials.

Published works. 7 articles (6 abroad) and 9 theses (5 abroad) on the topic of the dissertation were published.

The structure and volume of the dissertation.

The dissertation consists of 200000 characters, illustrated with 21 graphics and 2 figures.It includes the introduction of the dissertation (9500 characters), literature review (70000 characters), research materials and methods (12000 characters), results of personal research and their discussion (106000 characters), results (2500 characters), the bibliography includes 172 sources (52 in Russian, 120 in English).

MATERIALS AND RESEARCH METHODS

The study was carried out on 38 mature male rabbits kept under standard vivarium conditions at all stages of the experiment. Experiments in all electrophysiological studies (2010/63/EU) were conducted under the humane treatment of animals in accordance with generally accepted international principles of the European Convention. Scalping and implantation of macroelectrodes were performed under nembutal anesthesia (35mg/kg) and local anesthesia (0.5% novocaine solution). The coordinates of the cerebral cortex (field 17) and subcortical structures (LGB, SC, nR, LC) were applied nixrom electrods. 2.0% mono iodine acetat acid (MIAA) was used to create ED in the retina. The amount of monoamines in the studied structures of the brain of control and experimental animals was determined by the fluorimetric method.The statistical analysis of the obtained results was performed on the basis of Student's t-criterion.

The spectral-coherent analysis method was used for processing and analyzing the EEG potential of the studied structures,to analyze evokes potential (EP) the method of synchronous collection was used along with the program according to the **BRAINSYS** system. Coh.coefficients were calculated using standard EEG ranges.The reliability of intragroup and intergroup comparisons of EEG parameters was determined using the **ANOVA** program package.

RESULTS AND DISCUSSION

First of all, we investigated the characteristics of the EEG spectral composition of the visual analyzer and neuromodulation centers of the brain.The results of the research showed that one of the characteristic features of the normal EEG (the background of EEG) of vision analyzer structures is the change in the configuration of slow potentials determined by the difference in their spectral composition.Despite the fact that the EEG recordings in the studied structures are very similar at first glance, as can be seen from the results of the correlative-spectral analysis, there are noticeable differences in their spectral composition.These differences are mainly observed in the intensity of EEG waves and the amplitude of the wave frequency dominance spectrum. First of all, it should be noted that the maximum level of the spectral properties of the total potentials of the analyzer structures, which have slight differences, is mainly concentrated in the delta and theta frequency range of EEG. The differences are noticeable mainly in the peak spectral level of the EEG amplitude that we studied.

It has been established that the maximum intensity of the amplitude of the visual cortex (VC) is characterized by the distribution of frequencies at 2-3 Hz and 5-6 Hz, and, as a rule, the EEG delta rhythm predominates.

A similar picture is also observed in subcortical structures, which is characterized by the fact that the maximum potential density of (SC) is at 3–4 Hz and 7–8 Hz, and that of (LGB) at 4–5 Hz and 9–10 Hz. It should also be noted that if the maximum values of the EEG spectra for nR are in the delta range, then theta rhythms are more typical for the generation of the corresponding LC EEG potentials.

In contrast to the central structures of the vision analyzer, a different picture is observed in the distribution of maximal spectral signs of potentials of neuromodulatory centers.Although there is a bimodal picture of the EEG spectra of these structures, we have revealed some fundamental differences.Thus, from the results of statistical calculations of EEG potentials of LC and nR neuromodulatory centers, it was revealed that the maximum spectral level in 5 HT-ergic centers is 4-5 Hz, and the second peak is 8-9 Hz, while the maximum spectral level for NA-ergic center is distributed in frequencies of 2-3 and 6-7 Hz.It should also be noted that while the maximum values of EEG spectra for nR are in the delta range, for LC, theta rhythms are more characteristic for the generation of corresponding potentials of EEG.

Thus, the results of the comparative analysis of the EEG spectral characteristics of the studied structures of the vision analyzer and neuromodulator centers demonstrate that the maximum distribution level of the spectral composition of the total potentials corresponding to the delta and theta ranges of the background EEG andshows that it is bipolar in nature.The distribution of maximal levels of biopotentials in spectrograms of neuromodulatory centers is more multidirectional characteristic of LC neuronsunlike high-frequency activity,by the fact can be explained that nR neurons generate rhythmic activity in the range of 4-5 Hz.

Electrical stimulation of neuromodulation centers in the current research area of special interest is the comparative analysis of the effect of vision analyzer structures on EEG spectra. At the same time, taking into account the peculiarities of the ultrastructural organization and synaptology of MA ergic neurons, the main attention was focused on EEG analysis during the effect of stimulation of nR and LC neurons.

The results of the experimental research showed that the electrical stimulation of the neuromodulator centers significantly changes both the EEG itself and its statistical character in the stage after the stimulation.In addition, it turned out that the effect of electrical stimulation on nR and LC that we found is completely different.Thus, during the activation of NA-ergic neurotransmission, the composition of some frequencies of potentials occurs both in the visual area of the cerebral cortex and in the subcortical structures.

Bimodal spectra of cortical and subcortical structures under the influence of LC of maximum distribution of EEG theta frequencies transformed into unimodal character (Fig. 1).

During the activation of LC neurons, the distribution of spectral power amplitudes at the level of 6-7 Hz is observed in the visual cortex.A partially similar change to the maximal level of spectral amplitude redistribution at the stage following LC stimulation is also observed in SC and LGB potentials.

Thus, after the effect of electrical stimulation of NA-ergic neurons, a certain regulation occurs in the frequency of EEG potentials generated both at the level of the primary visual cortex of the brain and in the subcortical structures of the visual analyzer.

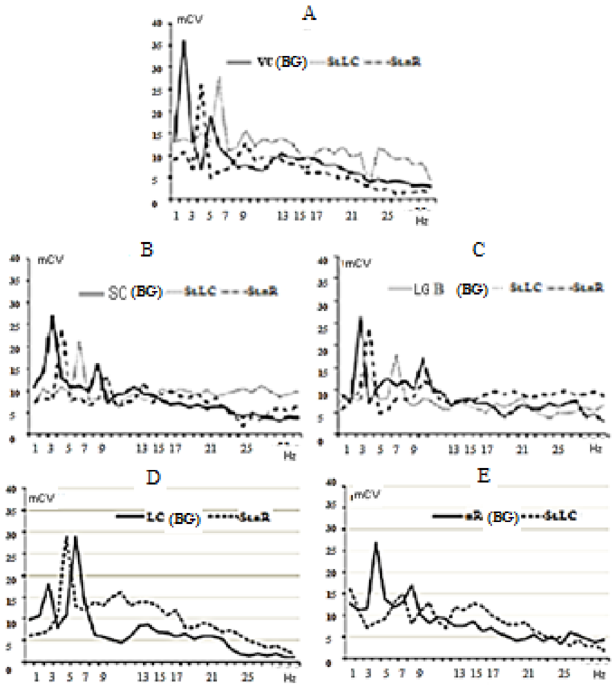

Figure 1. Comparative analysis of the effect of electrical stimulation of neuromodulation centers nR and LC on the spectral characteristics of the background EEG structures of the visual analyzer. A- VC, B - SC, C - LGB, D - LC, E - nR.

Contrary to the above, as the frequency content of EEG potentials undergoes a deeper reorganization during nR stimulation, the initial rhythmic activity at the level of 4-5 Hz is divided into several high-frequency components, covering both theta and alpha ranges of EEG. The point of special interest here is that the effects of NA-ergic stimulation at the nR level do not resemble any of the effects at the level of visual analyzer structures, but rather resemble the phenomenon of desynchronization.

In a corresponding case, the rhythmic nature of EEG generation in one of the central nuclei of the 5-HT-ergic neuromodulatory systems of the brain, arising during the background activity phase, is completely disrupted.The reason for such a situation can be explained by the mutual functional effect between nR and LC.So, based on the known literature data, it can be assumed that LC neurons have an inhibitory effect on nR neurons because the synchronous activity of nR neurons is disrupted after the effect of LC stimulation.

A different picture of the distribution of the dominant EEG frequency is observed in the EEG spectra after exposure to electrical stimulation of the 5-HT-ergic system of the brain. In the corresponding case, during the effect of electrical stimulation of nR on VC and SC, the polymodality of the spectra is disturbed, the maximum level of the spectra shifts to higher EEG frequencies and is located between 4-5 Hz and 9-10 Hz.

A slightly different picture is observed in the potential spectra of LGB.In this case, the high peak of the spectrum amplitude in the 4-5 Hz region of the bimodal spectrum is transformed into a monomodal one.

During the stimulation of each of the neurotransmitter centers, the effects of its influence on other centers are very interesting.Thus, the effect differences in the MA-ergic centers that we determined in the research process are primarily related to the dominance of the peak frequency of the EEG amplitude spectra.Stimulation of the nucleus rapha intensifies the synchronization of locus coeruleus potentials and it should be noted that LC stimulation produces desynchronization in nR.

Of particular interest is the fact that stimulation of the 5-HT-ergic system changes the synchronization of the LC potential to a higher frequency range.In contrast, the frequency composition of the nR potential under the influence of LC stimulation undergoes a sharper reorganization, as a result of which the initial rhythmic activity in the region of 4-5 Hs is divided into several high-frequency components, covering both theta and alpha EEG ranges. (Fig.1E and F).

Naturally, according to the spectral characteristics of the EEG, one can analyze the degree of potential synchronization only within the studied brain structures. Subsequent experiments on the analysis of the features of the participation of neuromodulation centers in the mechanisms of spatial synchronization of the potentials of the visual analyzer Coh. dedicated to the study of relationships. During the background activity phase,the highest Coh.coefficient were observed between VC and LGB potentials in the EEG alpha range but the relationship between VC and SC was found to be somewhat weak.In this case, Coh.coefficient between the potentials of neuromodulation centers during the background activity phase values do not increase more than 0.3 and remain at the minimum level (fig. 2 B). Subsequent studies have shown that electrical stimulation of the ascending components of the 5-HT-ergic system significantly enhances the rearrangement of brain structures.As can be seen from the presented histograms, at the initial stage of the stimulation of nR the values of the Coh.coefficients among the studied structures, significant decreases were directly observed (fig. 3C).

A similar response to nR stimulation, characteristic of all the studied pairs of conducting electrodes, indicates a decrease in potential synchrony between the studied structures.

The second phase of the reaction is observed during the subsequent effect of nR stimulation, which is counter-diametric in nature.This stage is characterized by an increase in the level of significant connections between the studied structures. At the same time, the highest Coh. the values vary from the alpha range to the lower frequency range and are localized in the EEG delta interval (fig. 2,C).

It should be noted that in this case there is an increase in the average values of the coherence coefficients both between the cortex-subcortex structures and between the subcortex structures of the vision analyzer.If we compare the average values of coherence during direct stimulation and the stage after its impact, we can see not only clearly expressed effects of restoration of the shape of the distribution of Coh. coefficients,at the same time, it is possible to observe a significant (up to 0.8) increase in Coh.values in the delta range of EEG.It can be assumed that the subsequent effects of nR stimulation are related to the participation of 5 HT-ergic neurons of the visual system of the brain in the regulation of EEG spatial synchronization.

In contrast to nR, electrical stimulation of the LC completely rearranges the synchronization of the spatial potential in the visual system, which is oriented uniformly for all pairs under consideration.A distinctive feature of the changes observed in this situation is Coh. coefficients are a decrease in the values. (fig. 2 E, F).

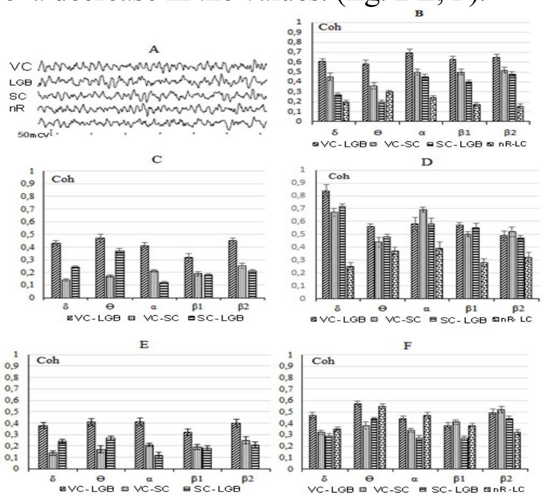

Figure 2.Under electrical stimulation of nR and LC influence between the structures of the visual analyzer distributed comparative analysis the average value of Coh.coefficients. A-

background, B - during nR stimulation, C - after exposure to electrical stimulation on nR, E - during LC stimulation, and F - after LC exposure

Thus, the following results were determined by summarizing the scientific evidence collected after the analysis of the indicators obtained from the research conducted with the methods of spectral and coherent analysis of EEG potentials in the central structures of the vision analyzer:

1. Arousal of the nR and LC neuromodulatory centers leads to a complex reconstruction of the spectral characteristics of the EEG potentials of the structures of the vision analyzer at the stage after the effect of stimulation.At this time, while high-frequency EEG recording in the alpha frequency range is characteristic for the NA-ergic system, the delta range frequencies are dominant in the EEG spectra of the visual structure of the brain under the influence of nR.

2. Even in the absence of sensory arousal, nR and LC neurons have a complex regulatory effect on the overall level of arousal of the structures of the brain's visual system, which is reflected in the level of coherent connections between them.

It can be assumed that changes in the spatial organization of EEG potentials observed after the effect of electrical stimulation of neuromodulation centers may be the result of ultrastructural organization and synaptology of LC and nR neurons that synthesize biogenic monoamines (BMA) [7,8].

At the same time, it should be noted that in order to better understand the nature of the participation of various components of the MA-ergic neuromodulatory system in the neurophysiological mechanisms of the spatial synchronization of

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[7] Aston-Jones, G., Waterhouse, B. Locus coeruleus: from global projection system to adaptive regulation of behavior // – Amsterdam, Brain Research,–2016.vol.1645, –p.75-78.

[8] Sinakevitch, I.T. Biogenic amines and neuromodulation of animal behavior/ I. T. Sinakevitch, H W.Gabriella, P. Hans-Joachim H S.Brian [et al.]// Front Syst Neurosci:–2018. –p.1-3.

EEG potentials, it is not enough to study this problem only at the level of the background activity of the brain.Therefore, in the further study of the current problem, we studied the characteristics of the formation and formation of trace processes formed in the structures of the visual analyzer in response to sensory stimulation, as well as conducted a comparative analysis of the role of the MA-ergic neuromodulator system in these processes.

The first, we considered the effect of sensory stimulation on the spectral characteristics of EEG potential.We have shown the most typical effects of the rhythmic photo stimulation (PS) effect on the EEG spectral characteristics of the analyzed structures of the analyzer.At this time, the well-known effect of mastering the rhythm of sensory stimulation is observed in all analyzed structures

Thus, while the spectral amplitude character dominance at frequencies 3-5 Hs and 4-6 Hs is typical for the background activity of VC, at the stage after the effect of PS, the maximum level of the spectrum shifts to the frequency range of sensory stimulation and remains in that ranger.

A similar picture is observed in SC. That is, under the influence of sensory stimulation, the initial bimodal pattern of spectral power distribution at frequencies of 3-9 and 7-8 Hz is transformed into a unimodal pattern with maximum spectral power in the range of 4-5 Hz.In contrast to this, in the current experimental situation, the formation of a bimodal picture of the EEG spectral power distribution under the influence of rhythmic sensory stimulation at frequencies of 4-5 and 9-10 Hz in the LGB is more characteristic..

At the same time, when studying the effects of rhythmic photostimulation on the spectral composition of the EEG potentials of nR and LC neuromodulatory centers of the brain, based on the observed picture, it was found that the formation of the maximum amplitude spectrum of LC and nR EEG potentials corespond to the frequency of retinal photostimulation.

The results of the conducted experiments unequivocally show the active involvement of the studied structures in the processing of visual information, as a result of which a specific resonance effect (mastery of the rhythm) occurs according to the frequency of sensory stimulation.

A picture analogous to the reconstruction of the spectral characteristics of the EEG is also observed in the potentials of the neuromodulatory centers of the brain.Based on the above, it can be assumed that the changes in the spectral characteristics of the EEG can be reflected at the level of coherent connections between the studied structures. The experimental facts listed below also unequivocally confirm this hypothesis.Thus, after the effect of rhythmic sensory stimulation, the average coefficients of Coh.between the potentials of all studied structures of the analyzer increase significantly.Interestingly, the increase in Coh's average coefficients is more typical for the theta range of the EEG.

At this time, the connection between the subcortical structures of the visual analyzer (SC - LGB) is increased. The fact that there are certain changes in coherent connections between neuromodulatory centers is also of great interest.The maximum frequency of joint activity in this EEG pair is located in the delta range of EEG, and the increase in average Coh. coefficients for this pair of transmitting electrodes is not typical.The maximum frequencies of the spectral character of the neuromodulator centers are located in the theta range, which corresponds to the frequency of sensory stimulation.Although the spectral nature of delta frequencies is insignificantly noticeable, higher levels of coherent connections were found precisely in this frequency range.

Analysis of the effect of MA-ergic neuromodulatory centers on trace processes in the visual system of the brain is of particular interest within this research. We have previously established that there are fundamental differences in the effects of LC and nR on the effects of rhythmic sensory stimulation on the retina. In contrast to LC, during electrical stimulation of nR, spatial synchronization of EEG potentials of central structures of the visual analyzer and increase of Coh coefficients between the studied brain structures were observed.

From this point of view, a natural question arises about the influence of the potentials of the visual system of the brain on coherent relationships under the conditions of the formation of trace processes of neuromodulation centers. It has been established that activation of 5-HT-ergic neurotransmission against the background of photostimulation changes the pattern of distribution of coherent bonds. As a result, the maximum level passes into the delta frequency region of the EEG, while the connections in the high frequency range of the EEG are significantly weakened. A different feature is observed in the action of electrical stimulation of LC neurons. The results of the experiment show that the increase in NA-ergic neurotransmission against the background of photostimulation leads to a violation of the distribution law of the Coh. values of the average coefficient developed during the background activity phase.

Thus, while the connections in the theta frequency region dominate only during the influence of photostimulation, the spatial synchronization of potentials is disturbed when LC is activated, as a result of which the Coh. level of the studied EEG potentials reaches minimum values in the entire range (fig. 3).

Thus, the results of experimental studies in this series clearly demonstrated an increase in the spatial synchronization of the EEG potential of the structures of the visual analyzer in response to adequate sensory stimulation during the formation of trace processes.This sign was first shown by the results of the EEG spectral analysis, which demonstrated the phenomenon of mastering the sensory signal rhythm. The results of coherent analysis also prove the enhancement of the generalization of synchronization of EEG potentials in response to sensory stimuli of the visual system. As shown, in this case, among all the central structures of the analyzer, only in the EEG theta range there is an increase in associated activity in visual structures.

It should be noted that in this experimental situation, a similar picture of synchronization is also observed in the spectrograms of neuromodulation centers of the brain. In addition to the above, the influence of the various components of this system on the above-mentioned characteristics of EEG synchronization is ambiguous.In contrast to the effects of LC, it was found that the effect of the 5-HT-ergic system led to the formation of fairly clear coherent connections in the delta frequency region of the EEG, not at the frequency of sensory stimulation in the visual system.

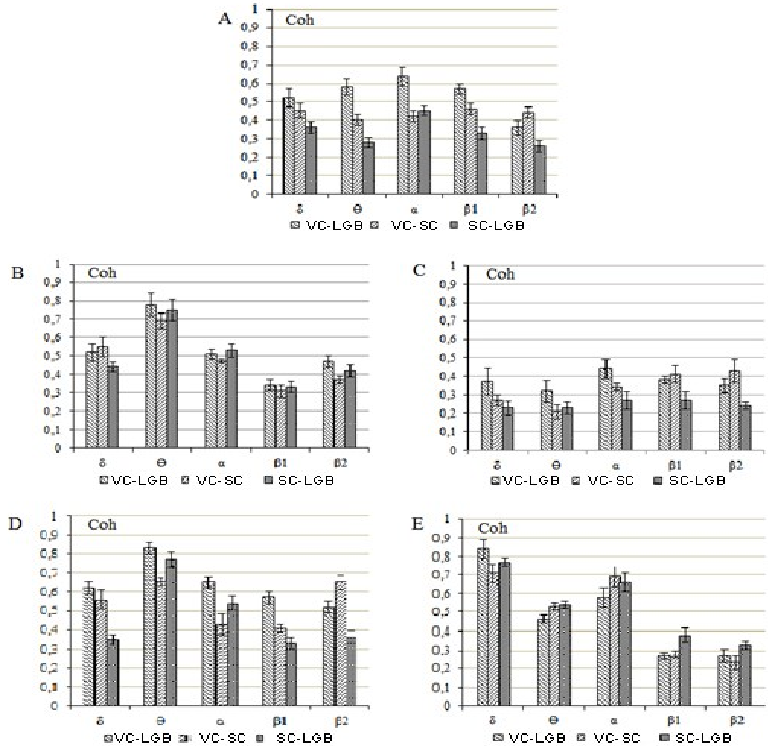

Figure 3. Comparative analysis of the effect of LC and nR on the redistribution of coherent average coefficients between the central structures of the visual system against the background of rhythmic sensory stimulation of the retina. A –background

activity; B - effect of rhythmic sensory stimulation; C- Influence of LC on the effects of photostimulation.D and E - nR effects on the background of PS.

Interestingly, stimulation of the LC in a similar situation produces the opposite effect.In this case, disorganization of the spatial synchronization of potentials developed under the influence of rhythmic sensory stimulation of the retina is observed.

The question of the presence of various components of neuromodulation centers in the regulation of plastic abilities at the level of the visual system, as well as their use for the activation of compensatory processes during the development of various dysfunctions in the visual system of the brain, is fully substantiated.Based on the foregoing, the results of experimental studies presented below are devoted to a comparative analysis of the role of MA-ergic centers of neuromodulation in the regulation of compensatory processes in the visual system.

As an experimental model of dysfunction of the visual system of the brain, we used an experimental model of retinal dystrophy.

The data obtained show that the dynamics of changes in the amplitude parameters of ERG potentials in response to the use of MİAA is long-term and phase-specific.The peculiarity of this process is that the initial stage of the reaction to the drug begins immediately after the application of MİAA and is characterized by a significant decrease in the ERG amplitude (fig. 4).

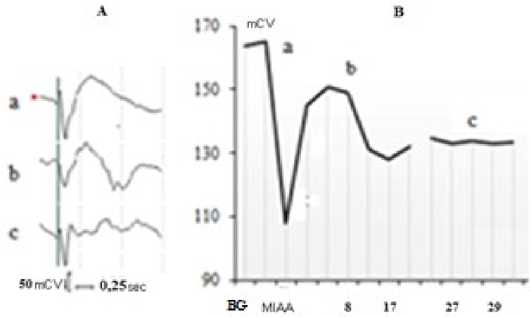

Figure 4. Changes in the total ERG amplitude under the influence of rhythmic photostimulation during the development of reticular ED. A - ERG potentials, B - dynamics of changes in the total ERG amplitude under the influence of MİAA: c - the initial phase of the reaction during MİAA, b - the recovery phase, a - the stabilization phase of the ERG amplitude.

Further studies were devoted to the analysis of the role of neuromodulation centers in the regulation of the plasticity of the structures of the visual system of the brain.In this case, the main attention was paid to the study of the characteristics of the spectral-coherent parameters of the potential of the analyzed structures of the analyzer.

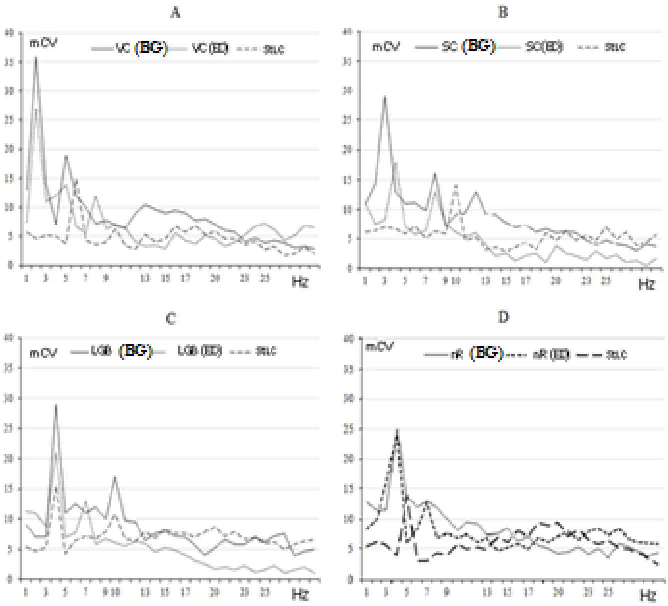

Figure 5. Influence of electrical stimulation of the LC on the spectral properties of the EEG of the central structures of the visual analyzer against the background of retinal dystrophy.

The results of the study showed that during the formation of ED, not only the amplitude parameters of retinal reactions change, but also the spectral characteristics of the EEG potential of the structures under study.An analysis of the spectral nature of the EEG showed that as a result of dysfunction at the level of the visual cortical analyzer, the amplitude of the main peak in the delta frequency range of the EEG spectrum and the level of the second maximum in the theta range decreases.Against this background, under the influence of stimulation of LC neurons, the potential spectra of the cerebral cortex undergo significant changes, which have acquired a unimodal character with a less noticeable maximum level at a frequency of 6.0 Hz.Similar changes are also observed in the subcortical spectra of the visual analyzer. In particular, under the influence of ED, there is a decrease in the amplitude of the main spectral peak at the LGB level and a shift of the second significant peak to the low-frequency region.Similar changes are fixed on the SC spectrograms. At the same time, it should be noted that the effect of LC stimulation on the background of ED leads to the development of rhythmic activity of nR potentials (fig. 5).

Compared to LC, the effects of electrical stimulation of the 5-HT-ergic system were found to be radically different.Under the current experimental conditions, the observed changes in the EEG spectra of the studied structures were of a similar nature, while an increase in potential generation was observed mainly in the EEG delta range. These signs manifested themselves, especially at the level of potentials of the cerebral cortex. At the same time, despite the fact that the rhythmic activity of LC is generated at a level of 3–4 Hz, some weak effect on its potentials was observed.

With the development of pathology, it turns out that the influence of neuromodulation centers does not have an unambiguous effect on the spectral composition of the EEG in the central structures of the analyzer. At the same time, in contrast to the features of EEG regulation of the studied structures under the influence of LC stimulation, activation of 5-HT-ergic neurotransmission leads to the formation of the same spectral character of the EEG potential.A feature of the latter is the enhancement of rhythmic EEG processes in the same delta frequency range, which indicates an increase in the concomitant activity of the studied structures.To test this hypothesis, further experimental studies were devoted to the analysis of spatial synchronization of the EEG potential of vision analyzer structures under the influence of neuromodulatory brain centers in pathological conditions.

Analysis of the distribution of EEG potentials against the ED background of Coh values under pathological conditions revealed significant changes in the level of correlated activity between all structures (fig. 6B).

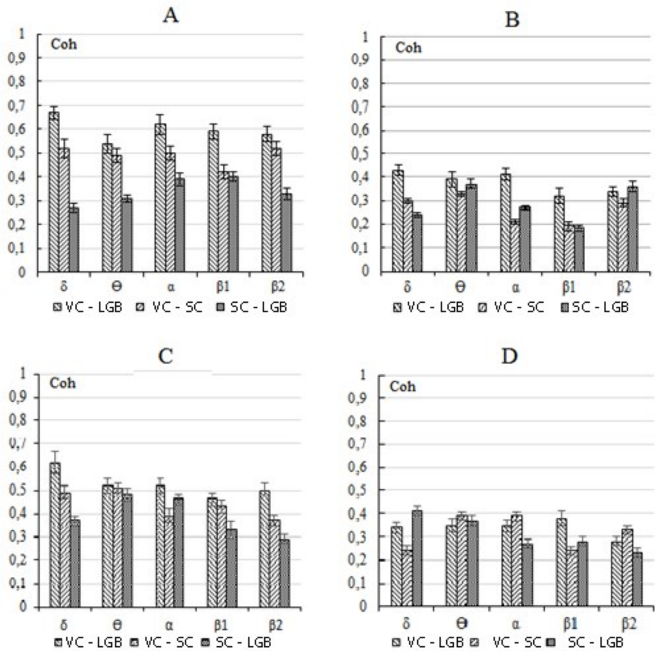

Figure 6. Redistribution of values of average values Coh between the structures of the visual analyzer under the influence of electrical stimulation on the nR and LC against the background of ED. A - distribution of Coh coefficients in the background activity phase, B - in conditions of retinal dystrophy, C - effects of nR electrical stimulation on the background of pathology, D - effects of LC electrical stimulation on the background of pathology.

It was found that stimulation of nR neurons against an appropriate background leads to an increase in Coh values between both cortical-subcortical and between subcortical structures of the analyzer.At this time, relatively high values of Cohare observed in the VC-LGB pair in the delta range, which is a characteristic sign of background activity of the analyzer. One of the interesting factors is that the strengthening of coherent bonds under the action of nR is typical for all the studied pairs.

On the contrary, after LC stimulation, serious changes in the redistribution of Coh coefficient was not observed (fig. 6 C, D).It is clear that the restoration of the statistical parameters of the EEG potential may be indirect evidence of the activation of compensatory processes at the functional level.To clarify this very complex issue, we conducted a special experimental study to analyze the dynamics of changes in ERG amplitude parameters against the background of the development of pathology.The results of the study showed that the total amplitude of ERG potentials after stimulation nR and LC varies on average by 13-15%, which indicates the interaction of the nature of the impact of neuromodulation centers.At the same time, activation of 5-HT-ergic neurotransmission significantly increases the ERG amplitude, which leads to some recovery at the level of spatial synchronization of the potentials of the analyzer structures.In contrast to the effects of nR, activation of NA-ergic neurotransmission causes side effects. Under the influence of electrical stimulation of the MA-ergic nuclei nR and LC, post-stimulation effects are more pronounced, demonstrating a cumulative effect that persists for some time (fig. 7A).

It can be assumed that the reason for the observed changes in the statistical parameters of EEG potentials of vision analyzer structures is primarily an increase in the amount of biogenic monoamines in the studied structures under the influence of electrical stimulation of neuromodulation centers. To experimentally confirm this hypothesis, we carried out a special study to determine the amount of 5-HT and NA in the structures under study under specific experimental conditions considered by us.

The study found that the development of pathology is accompanied by slight changes in the amount of 5-HT and NA in the central structures of the analyzer. One of the features of these changes is that the amount of 5-HT decreases simultaneously with a slight increase in the amount of NA. However, sharper changes in the amount of biogenic monoamines were found against the background of ED after exposure to electrical stimulation of neuromodulatory centers.As can be seen from Figure 7B, after exposure to nR stimulation, a significant increase in the amount of 5-HT was observed in all structures of the analyzed analyzer.

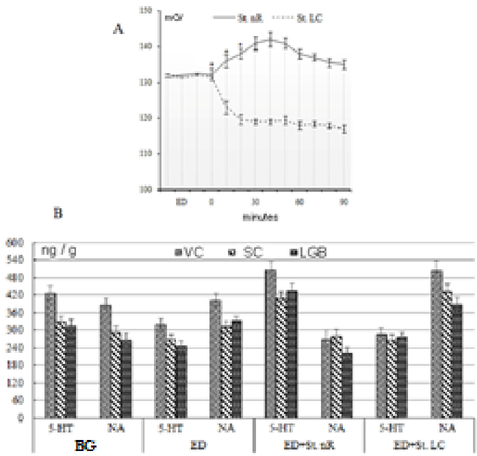

Figure 7. Dynamics of ERG amplitude (A), distribution of 5-HT and NA (B) amounts in the central structures of the visual system of the brain under different experimental conditions ($p \leq 0.01$).

At the same time, the amount of NA in these structures decreases insignificantly. A similar picture is also observed during stimulation of LC neurons. At the same time, there is a tendency to a decrease in 5-HT, while the amount of NA increases significantly.Thus, the observed changes in the statistical parameters of the EEG potential in the structures of the visual analyzer are primarily the result of an increase in the amount of biogenic monoamines in the studied structures under the influence of electrical stimulation of neuromodulation centers.Unlike NA, the 5-HTergic system clearly has a complex modulating effect on the synchronization of the EEG potential of the central structures of the visual analyzer under ED conditions, and a coherent relationship between the structures is clearly expressed, activity indicators close to the background, indicating the activation of endogenous compensatory processes in visual system of the brain.

CONCLUSIONS

1. In chronical experiments on rabbits, it was shown that the spatial organization of the EEG potentials of the structures of the visual analyzer of the brain is characterized by the stability of the level of coherent connections in the entire studied frequency range (δ, Θ, α, β1 and β2). At the same time, the maximum level of coherence between the initial VC and LGB is observed in the EEG alpha range, and the minimum levels of contact are more characteristic of the EEG theta frequencies between the subcortical structures of the analyzer [1,2,3,10].
2. The results of the spectral-coherent analysis showed that the formation of ED of the retina is accompanied by the reconstruction of the spatial synchronization of EEG of the central structures of the visual analyzer. At this time,the coherence levels of potentials against the background of dysfunction show high stability depending on time [12].
3. It has been established that the dysfunction of the peripheral part of the visual analyzer is accompanied by a redistribution of the BMA content in the structures of the visual system and is multifaceted. At the same time, in all the structures studied, a decrease in the amount of 5-HT was observed, as well as an increase in the amount of NA in LGB and SC. More changes are registered in the initial VC of the brain [14].
4. The results of the study showed that the formation of retinal ED under the influence of MİAA is accompanied by a restructuring of the level of coherent correlations of EEG potentials between the centers of neuromodulation (nR, LC) and the central structures of the vision analyzer [12].
5. At the start of the reactionit has been established that with direct stimulation of nR, a characteristic decrease in the level of Coh is observed. The second stage of the reaction is observed in the post-stimulation phase, characterized by a significant increase in Coh values in the range of all EEG

frequencies, both between the cortical and subcortical structures, and between the cortical structures of the visual analyzer, which clearly indicates the activation of compensatory processes in the visual system of the brain [4, 5, 6,7,8, 13, 14,15, 16,17].

LİST OF PUBLİCATİONS ON THE TOPİC OF THE DİSSERTATİON

1. Ганиева, Ф.И., Мамедов, А.М. Анализ когерентных связей ЭЭГ ядер шва и структур зрительной системы мозга // - Москва, Естественные и технические науки, -2017, №6,- с. 19-22.
2. Mamedov, A.M., Ganiyeva, F.I. Distribution levels of coherence relations of EEG nucleus rapher and locus coeruleus with the strucures of visual system of brain // South Asian Journal of Experimental Biology, -2017, vol. 7, (1),- p. 9-12.
3. Mamedov, A.M., Ganiyeva, F.I. The distribution of coherence relations of the rapher nucleus and structures the visual system of quiet wakefulness in rabbits // XIV International Conference on Biology and Medical Sciences, - Австрия, 2017, - с.60-68.
4. Мамедов, А.М., Ганиева, Ф.И. Когерентные связи МА-эргических ядер мозга с центральными структурами зрительного анализатора // II Intern. Sci. Conf. «General question of world science»,-Amsterdam, 2017, - с. 15-17.
5. Мамедов, А.М. Особенности участия ядер шва в регуляции когерентных связей ээг в зрительной системе мозга /А.М. Мамедов, Ф.И. Ганиева, А.Г. Агаева [и др] // Ж. Наука и образование сегодня, - Москва: 2018, №3 (26), - с.13-16.
6. Ганиева, Ф.И. Влияние стимуляции locus coeruleus на когерентные связи структур зрительной системы мозга // Z.Əliyevanın 95 illiyinə həsr olunmuş elmi konfransın materialları. - Bakı, 2018, - s.22-24.
7. Ганиева, Ф.И. Сравнительный анализ влияния нейромодуляторных центров на когерентные связи ээг в зрительной системе мозга //- Москва, Естественные и технические науки,-2018, № 5, - с.25-29.

8. Ганиева, Ф.И. Агаева, А.Г. Влияние электрической стимуляции ядер шва на когерентные связи ээг в зрительной системе мозга // I Межд. Научно-практическая конференция Научные изыскания современности: проблемы и решения, - Иваново (Россия):-2018, - с.11-13.
9. Ганиева, Ф.И. Гасанова, Г.А. Велиева, Г.Д. Влияние биогенных моноаминов на синхронизацию потенциалов ЭЭГ в зрительной системе мозга // Мат. конф. Актуальные тренды и перспективы развития науки, техники, технологий. – Белгород:-2019, -с. 26-28.
10. Ганиева, Ф.И. Влияние МА-эргических ядер мозга на когерентные связи ЭЭГ в зрительной системе на фоне патологии сетчатки //-Москва, «Совр. проблемы науки и образования», -2019, №2, (https://science-education.ru/ article/view?id=28779).
11. Ганиева, Ф.И. Компенсаторные процессы в зрительной системе в условиях патологии сетчатки под влиянием ядер шва //XVIII Межд. Конф. Advances in Science and Technology, - Москва:-2019, -с 25-27.
12. Qəniyeva, F.İ. Beynin görmə sistemindəki kompensator proseslərin MA-ergik tənzimlənməsi //-Bakı, Nəzəri, klinik və eksperimental morfologiya jurnalı, -2019, cild1, № 2,- s. 55-61.
13. Ganiyeva, F.İ. Agayeva, A. H., Eyvazova, Sh. R. Participation of seam nuclei in regulation of coherent eeg relations under conditions of experimental retinal dystrophy // İnternational Conference on Applied Biosciences. Karachi, - Pakistan:-2019, - p. 35.
14. Ганиева,Ф.И., Гасанова, Г.А., Юсифова, С.Г., Агаева, А.Г. Влияния электрческой стимуляции ядер шва на компенсаторные процессы в зрительной системе мозга // ATU-nun İnsan anatomiyası və tibbi terminalogiya kafedrasının yaradılmasının 100-illiyinə həsr olunmuş beynəlxalq elmi-praktik konfransın materiallar toplusu, - Bakı:-2019, -s. 113- 114.
15. Qəniyeva, F.İ. Nucleus raphe və locus coereleusun elektrik stimullaşdırılmasının görmə analizatorunun coherent əmsallarının dəyişilməsinə təsiri // Əməkdar elm xadimi, prof. T.Ə.Əliyevin

anadan olmasının 100 illiyinə həsr olunmuş “Təbabətin aktual problemləri 2021” mövzusunda beynəlxalq elmi-praktik konqresin materialları. -Bakı:-2021, - s. 313.

16. Qəniyeva, F.İ. Sinir proseslərinin formalaşmasının neyrofizioloji əsasları // Psixologiyanın aktual problemləri: yeni perspektivlər, yeni mülahizələr və yeni düşüncələr beynəlxaq konfransı. – Bakı:-2021, -s. 260-262.

LİST OF ABBREVİATİONS

5-HT	- serotonin
BG	- background
BMA	- biogenic monoamines
CNS	- central nervous system
Coh	- coherence
ED	- experimental dystrophy
EEG	- electroencephalogram
EP	- evoked potential
ERG	- electroretinogram
LC	- locus coeruleus
LGB	- lateral geniculate body
MA-ergic	- monoaminergic
MIAA	- mono iodine acetat acid
NA	-noradrenaline
nR	- nucleus rapha
PS	- photostimulation
SC	- superior colliculus
VC	- visual cortex

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