Lobasyuk B. A., Bartsevich L. B., Zamkova A. V. Network semantic-topological model of electrogenesis. Journal of Education, Health and Sport. 2023;13(5):105-115. eISSN 2391-8306. DOI http://dx.doi.org/10.12775/JEHS.2023.13.05.015
https://apcz.umk.pl/JEHS/article/view/44533
https://zenodo.org/record/8033322

The journal has had 40 points in Ministry of Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of December 1, 2021. No. 32343.
Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical Culture Sciences (Field of Medical sciences and health sciences); Health Sciences (Field of Medical Sciences and Health Sciences).

Punkty Ministerialne z 2019 - aktualny rok 40 punktów. Załącznik do komunikatu Ministra Edukacji i Nauki z dnia 1 grudnia 2021 r. Lp. 32343. Posiada Unikatowy Identyfikator Czasopisma: 201159.
Przypisane dyscypliny naukowe:Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).

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The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 28.04.2023. Revised: 19.05.2023. Accepted: 31.05.2023.

Network semantic-topological model of electrogenesis

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Abstract

A network semantic-topological model of electrogenesis is proposed. This line of research can be considered as network neurophysiology. When building the model, using the calculation of multiple linear regression coefficients, we studied the interactions (functional relationship) between the amplitudes of EEG rhythms in the entire lead between different EEG rhythms and within the same rhythm between different EEG leads in right-handed and left-handed. Multiple regression equations were geometrically interpreted using polycyclic multigraphs. As a result of the conducted research and calculations, it turned out that left-handed people have more multiple regression coefficients, both when calculating within the limits of a complete lead between different EEG rhythms, and within the limits of one rhythm between different EEG leads. It is assumed that the central-parietal leads C3-P3 are the center of influence of generators of various EEG rhythms in the left hemisphere, both in right-handed and left-handed people. The obtained results indicate that beta-LF and beta-HF

rhythms are the control integrative rhythms of electrogenesis in right-handed people in the left hemisphere and in left-handed people in both hemispheres. The controlling integrative rhythm in right-handed people in the left hemisphere is the delta rhythm.

Key words: different regression; polycyclic multigraphs; limits of one rhythm; limits of one lead.

Introduction. To understand the nature and mechanisms of the genesis of the electroencephalogram (EEG), a method widely used in clinical practice, is extremely relevant. However, the mechanisms of EEG generation remain unclear.

In neurophysiology, the concept of the multidimensionality of the physiological space (the presence of additional dimensions in it) remains completely undeveloped. The assumption of the multidimensionality of the internal space requires the development of mathematical models in which this phenomenon would be visualized and studied.

The problem of the theory of multilevel systems, which received the name “the problem of the hierarchy of living systems” in medical and biological interpretations, is an important stage in the development of the general theory of systems [1, 5].

The structure is an integral property of the system and represents a certain type of relationship between its elements.

There are a number of definitions of the concept of "space", which suggests it is appropriate to define the one we use. Space is a set of objects between which relationships are established that are similar in structure to ordinary spatial relationships such as neighborhoods, distances, etc. Topology deals with problems of this nature. For the first time the term "topology" appeared in 1847 in Listing's work [4]: "By topology we mean the doctrine of the modal relations of spatial images, or the laws of connectivity, mutual position and succession of points, lines, surfaces, bodies and their parts or their combination in space, regardless of the ratios of measures and magnitudes.

The leading role in the work of the brain should be played by dynamic functional connections between different parts of the cortex and subcortical structures, and the problem of intercentral relationships of biopotentials occupies one of the leading places [8].

The formation of a functional connection between brain regions can be judged by the synchronization of their electrical activity [6, 9]. For these purposes, the calculation of the two-dimensional correlation coefficient is used. However, with this approach, it is impossible to determine the direction of influence, because correlation coefficient Rx/y=Ry/x. To solve the problem, you can use the classical methods of mathematical statistics: multiple regression and correlation methods of analysis [3]. When applying this method of analysis, all the resulting connections-relations are oriented, that is, directed from one object to another, direct (not indirect). This area of research can be considered as network neurophysiology.

The system approach is based on the study of the properties of the whole as a whole. A possible way to solve the problem of synthesizing objects of multidimensional research is the geometric interpretation of multiple linear regression equations using polycyclic multigraphs - a mathematical language for a formalized designation of concepts related to the analysis and synthesis of structures, systems and processes - with the aim of their subsequent structural analysis [3].

The aim of the work is to investigate, using multiple linear regression of connections-relationships between the amplitudes of EEG rhythms both within the same lead, i.e. between different rhythms, and within the same rhythm, between different leads. This approach will allow an integrative assessment of the features of electrogenesis.

Materials and methods. A group of 34 humans aged 16 - 24 years old, who were on an inpatient examination at the Municipal Non-Profit Enterprise "Odessa Regional Mental Health Center" of the Odessa Regional Council, were examined in connection with the call to the Armed Forces of Ukraine. No pathology was revealed in all examined during the psychological and psychiatric examination. Right-handers were identified 20 people, left-handers -14. EEG lateralization was determined using Neuarosoft software.

The EEG was recorded in a state of calm wakefulness with closed eyes on the Neuron-Spectrum-2 electroencephalograph at a quantization frequency of 500 Hz using a montage: bipolar ring 16.

The electrodes were placed according to the "10-20%" system in l6 cortical zones. EEG recording was carried out according to the international system "10%–20%" [23] from the frontal (F3, F4), central (C3, C4), parietal (P3, P4), occipital (01, 02), anterior temporal (F7, F8), middle temporal (T3, T4) and posterior temporal (T5, T6) cortical zones (odd numbers indicate areas of the left hemisphere, even numbers - right). A bipolar ring assembly was used. 16 The bandwidth was 0.5-35 Gy, the sampling frequency was 500 Hz.

The analysis was performed using periodometric analysis in five standard frequency ranges: σ 0.5–4 Hz. Θ 4-8 Hz,. α 8=13 Hz, β1 13-20 Hz, β2 20-32 Hz using the Neurosoft program.

Differences in performance were tracked using the calculation of ratio coefficients (RC). CS was obtained by dividing the larger value of the compared indicators by the smaller one [6].

Each of the set of indicators selected for analysis (amplitudes and frequencies of EEG rhythms) was considered as a target feature (Y-s), and the remaining indicators were considered as influencing variables (sets of X-s) and equations of multiple linear regression of the form were constructed:

$$Y1 = a0 + b1X1 + b2X2\ldots + bnXn,$$

where a0 is a free member, coefficients b1,b2…., bn are regression indicators reflecting the degree of influence on the analyzed indicator of the remaining elements of the set, x1, x2…, Xn indicators.

We studied regression connections-relations between the amplitudes of EEG rhythms within the same rhythm between different leads and within the same lead between different EEG rhythms.

The probability of manifestation of influence, i.e. the adequacy of the regression coefficients was assessed using the sigmal deviations of the regression coefficients, and the effectiveness of the regression as a whole was assessed by calculating the multiple correlation coefficient [8]. One of the possible ways to solve the problem of synthesizing objects of multidimensional research is the geometric interpretation of multiple linear regression equations using polycyclic multigraphs [4].

Own research. Left hemisphere. In total, between the amplitudes of EEG rhythms within one derivation, i.e. between different rhythms, 44 regression connections-relations were determined in the left hemisphere in right-handed people (Fig. 1, A) and 62 in left-handers in the same situation (Fig. 1, C).

Between the amplitudes of EEG rhythms within the same rhythm between different leads in right-handers in the left hemisphere, 36 regression relationships were determined (Fig. 1, B), and in left-handers in the same situation, 42 (Fig. 1, D).

Left hemisphere, right-handers. Within the full lead between different EEG rhythms in right-handers in the left hemisphere, the largest number of regression relationships was determined in lead C3-P3-central-parietal 12, and the smallest in leads P3-O1-parietal-occipital and T5-O1-temporoccipital 2 connections-relationships each (Fig. 1, A).

In right-handers in the left hemisphere, within the same rhythm between the amplitudes of different leads, the largest number of regression relationships was determined in beta-LF 14 and alpha and beta-HF rhythms 10 each, and the smallest in the range of delta 0 and theta rhythm 2 (Fig. 1, B).

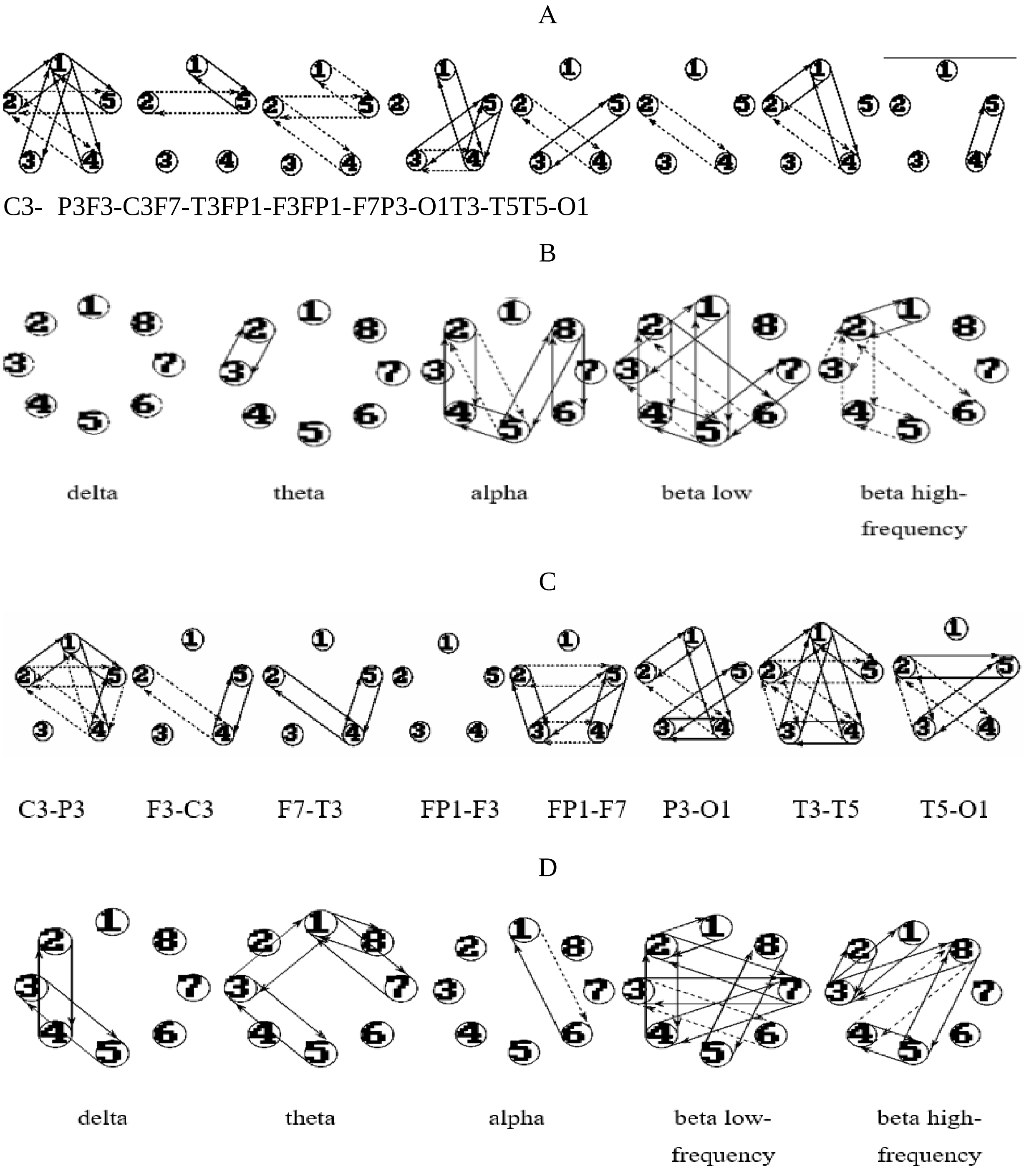

Fig. 1. Polycyclic multigraphs reflecting the relationship between the amplitudes of EEG rhythms within one lead (A, C) and within one rhythm (B, D) in right-handers (A, B) and left-handers (C, D) in the left hemisphere.

Leads: (A, B) 1-C3-P3 Central-parietal, 2-F3-C3 Frontal-central 3-F7-T3 Temporal-central, 4-FP1-F3 Frontal, 5-FP1-F7 Anterior-temporal, 6 -P3-O1 Parietal-occipital, 7-T3-T5 Posterior-temporal, 8-T5-O1 Temporoccipital.

EEG rhythms: (B.D) 1-delta, 2-theta, 3-alpha, 4-beta low-frequency, 5-beta high-frequency. The numbers in the nodes of the graphs on A and C EEG rhythms, and inThe nodes of graphs B and D are assignments.

Solid lines are positive influences, dashed lines are negative.

Left hemisphere, left-handers. In left-handed people in the left hemisphere, within the full lead between different EEG rhythms, the largest number of regression relationships was determined in the T3-T5-posterior-temporal lead 14 and C3-P3-central-parietal lead 12, and the smallest number in the FP1-F3 frontal lead (Fig. 1, C).

In left-handed people in the left hemisphere, within the same rhythm, between the amplitudes of different leads, the largest number.

Regression connections-relations were determined in beta-LF and beta-HF rhythms by 14, and the least in the range of alpha rhythm 2 (Fig. 1, D).

Right hemisphere. In total, between the amplitudes of EEG rhythms within one derivation, i.e. between different rhythms, 32 regression relationships were determined in the right hemisphere in the right hemisphere (Fig. 2, A), and in left-handers in the same situation - 72 (Fig. 2, C).

Between the amplitudes of EEG rhythms within the same rhythm between different leads in right-handers in the left hemisphere, 22 regression relationships were determined (Fig. 2, B), and in left-handers in the same situation - 44 (Fig. 2, D).

Right hemisphere, right-handers. Within the full lead between different EEG rhythms in right-handers in the left hemisphere, the largest number of regression relationships was determined in lead F8-T4-temporocentral 12, and the smallest in leads C4-P4-central-parietal, -FP2-F4-frontal, FP2 -F8-anterior-temporal (Fig. 2, A).

In right-handers in the right hemisphere, within the same rhythm between the amplitudes of different leads, the largest number of regression relationships-relations was determined in the delta rhythm 14, and the smallest in beta_LF and Beta-HF rhythms-0 (Fig. 2, B).

Right hemisphere, lefties. In left-handers in the right hemisphere, within the full lead between different EEG rhythms, the largest number of regression relationships was determined in the T4-T6-posterior-temporal lead 18, and the least in the FP2-F4-frontal lead. (Fig. 2, C).

In left-handers in the right hemisphere, within the same rhythm between the amplitudes of different leads, the largest number of regression relationships-relations was determined in the beta-LF rhythm 18, and the smallest in theta and beta-HF rhythms 4 each (Fig. 2, D).

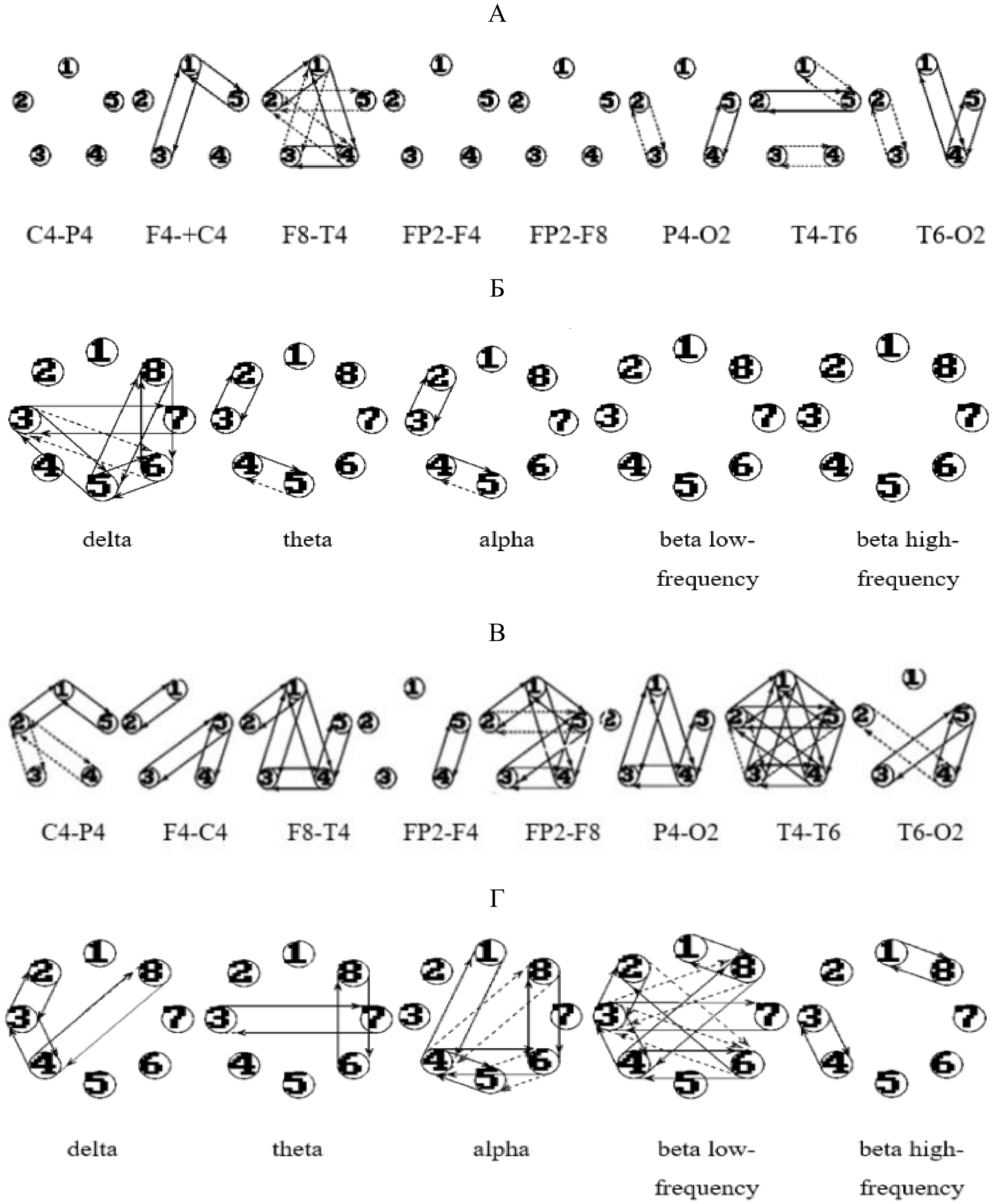

Fig. 2. Polycyclic multigraphs reflecting the relationship between the amplitudes of EEG rhythms within one lead (A, C) and within one rhythm (B, D) in right-handers (A, B) and left-handers (C, D) in the right hemisphere.

Leads: (A, C) 1-C4-P4 Central-parietal, 2-F4-C4 Fronto-central 3-F8-T4 Temporal-central, 4-FP2-F4 Frontal, 5-FP2-F8 Anterior-temporal, 6- P4-O2 Parietal-occipital, 7-T4-T6 Posterior-temporal, 8-T6-O2 Temporoccipital.

EEG rhythms: (B.D) 1-delta, 2-theta, 3-alpha, 4-beta low-frequency, 5-beta high-frequency. The numbers in the nodes of the graphs on A and C are the EEG rhythms, and in the nodes of the graphs B and D are the leads.

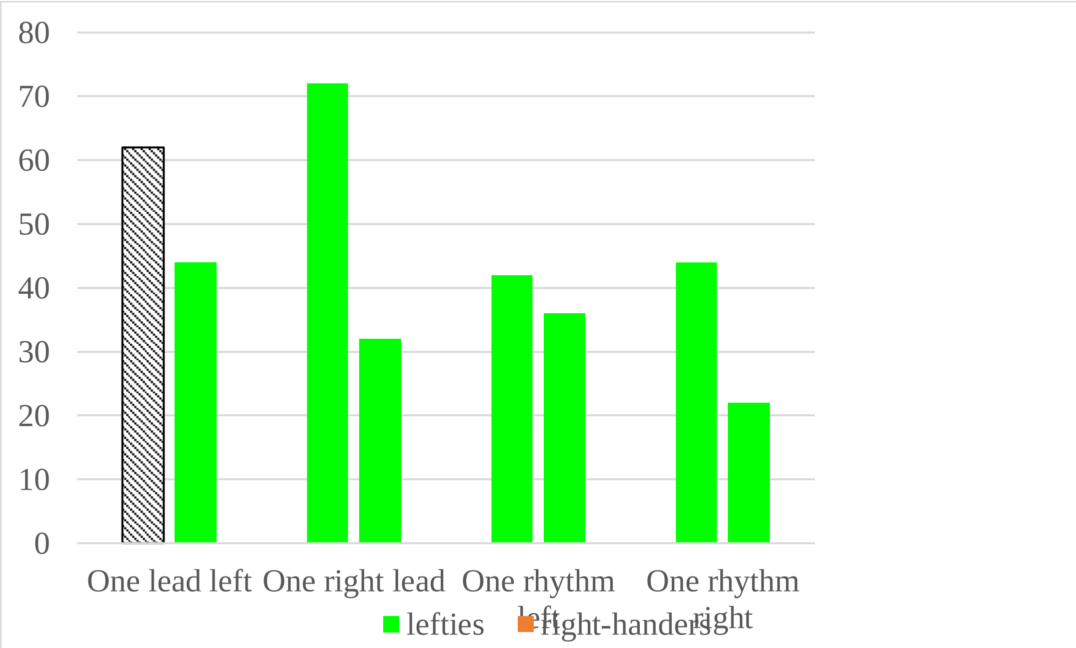

Fig. 3. Number of regression relationshipswithin one lead and one rhythm.

Designations: left - left hemisphere, right - right hemisphere.

Discussion. When calculating the regression coefficients between the amplitudes of EEG rhythms within the same rhythm in left-handed people in the left hemisphere, 1.16 more regression coefficients were determined, and in the right hemisphere 2 times more.

When calculating the regression coefficients between the amplitudes of EEG rhythms within the same lead between different EEG rhythms, 1.4 times more regression coefficients were determined in the left hemisphere, and 2.25 times more in the right hemisphere than in right-handers. Thus, both within the same EEG rhythm and within the same lead between different rhythms, the number of regression coefficients between the amplitudes of EEG rhythms in left-handers was greater than in right-handers. This feature of electrogenesis was shown by us in [8].

According to our studies [3], an increase in the number of correlations between various EEG components reflects an increase (in general) in cortical tone, while a decrease reflects a decrease in this tone.

Both in left-handers and right-handers, the largest number of connections-relations in the left hemisphere within one lead was determined in the central-parietal lead C3-P3. It can be assumed that this lead is a kind of focus of the influence of generators of different EEG rhythms in the left hemisphere.

In right-handers, the largest number of connections-relations in the right hemisphere within one lead was determined in the F8-T4-temporo-central lead, and in left-handers in the T4-T6-posterior-temporal lead. . It can be assumed that these leads are a kind of focus of the influence of generators of different EEG rhythms in the right hemisphere.

When calculating the number of regression coefficients in right-handers within the same rhythm between different leads in the left hemisphere, the largest number of regression coefficients turned out to be in beta-LF, beta-HF and alpha rhythms, and the smallest in delta and theta rhythms. In the right hemisphere, opposite relationships were observed - the largest number of regression coefficients was determined in the delta rhythm, and the smallest in the beta-LF and Beta-HF rhythms.

When calculating the number of regression coefficients in left-handers within the same rhythm between different leads in the left hemisphere, the largest number of regression relationships-relations was determined in the left hemisphere, as well as in right-handers in beta-LF and beta-HF rhythms, and the smallest in alpha rhythm.

In the right hemisphere, the largest number of regression connections-relations was determined in the beta-LF rhythm, and the smallest in the theta and beta-HF rhythms. The data suggest that the beta-LF and beta-HF rhythms are the control integrative rhythms of electrogenesis in the right hand in the left hemisphere and in left-handers in both hemispheres. The governing integrative rhythm in right-handers in the left hemisphere seems to be the delta rhythm.

Based on the foregoing, it can be assumed that the structure of the electrogenesis system is reticulate (reticular), has topological properties, and the mathematical model of electrogenesis obtained by us can be classified as a labile lattice-topological structure.

Previously, we formed ideas about the unit of mental activity [2] as a psychological, psychiatric, neurophysiological construct formed on the basis of multiple regression analysis of EEG parameters and the anxiety index of the Luscher test. Considering the results obtained in this work, we can consider, as a unit of neurophysiological activity, a regression relationship-relationship between EEG parameters.

Conclusions:

1. Thus, in left-handers, the number of coefficients in the regression between the amplitudes of EEG rhythms was noted to be greater than in right-handers. It can be assumed that in left-handers, in comparison with right-handers, the tone of the cortex is increased.

2. Central-parietal lead C3-P3 is the focus of influence of generators of different EEG rhythms in the left hemisphere.

3. Beta-LF and beta-HF rhythms are the governing integrative rhythms of electrogenesis in right-handers in the left hemisphere and in left-handers in both hemispheres. The controlling integrative rhythm in right-handers in the left hemisphere is the delta rhythm.

4. The mathematical model of electrogenesis obtained by us allows us to classify it as a labile lattice-topological structure.

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