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ANALYSIS OF ELECTROGENESIS' CHANGES IN MENTAL RETARDATION PERSONS BY USING COMPUTER ELECTROENCEPHALOGRAPHY

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Abstract

Justification. Mental retardation is a persistent decrease in human cognitive activity against the background of organic damage to the central nervous system. Neurophysiological diagnostics, in particular electroencephalography (EEG), most adequately reflects the morpho-functional state of the central nervous system, which is the basis of the mechanisms of mental activity, and the originality of the bioelectrical activity of the brain can be considered as the main indicator that determines a decrease in the level of intellectual development and, thereby, characterizes this state. This provision actualizes the search for highly informative indicators of the originality of the bioelectrical activity of the brain in children with intellectual disabilities. **Purspose.** With the use of periodometric analysis investigate EEG's indicators and interhemispheric asymmetry of rhythms amplitudes in MR patients. **Materials and methods.** The EEG was recorded in a state of calm wakefulness with closed eyes with Neuron-Spectrum-2 electroencephalograph. Differences in indicators were

tracked using the calculation of the coefficient of compliance (CC), EEG functional asymmetry coefficients in amplitude were determined, too. **Results.** It was revealed that in MR patients the amplitudes of the rhythms were greater than in healthy subjects. The greatest increase was determined in theta rhythm in the anterior temporal and posterior temporal leads in the left hemispheres. Duration indices in the delta, theta and alpha ranges of the EEG in mental retardation compared with the control group were increased, and the indices of the duration of beta rhythms - decreased. When analyzing FMPA in MR persons it turned out that in right-handers the negativeness of FMPA indices increased, and in left-handers there was an increase in the positivity of FMPA indices. **Conclusions** 1. With mental retardation, the amplitudes of the rhythms were greater than in healthy people. The greatest increase was determined in theta rhythm in the anterior temporal and posterior temporal leads in the left hemispheres. 2. The indices of duration in the delta, theta and alpha ranges of the EEG of MR subjects were increased, and the indices of the duration of beta rhythms – decreased. 3. When analyzing FMPA in MR persons, it turned out that in right-handers the negativeness of FMPA indices increased, and in left-handers there was an increase in the positivity of FMPA indices.

Key words: mental retardation; half-period analysis; amplitude index of EEG rhythms duration; interhemispheric asymmetry.

Relevance. Mental retardation is a group of various hereditary, congenital or early acquired states of general mental underdevelopment. According to ICD-10, mental retardation is a state of delayed or incomplete development of the psyche, which is primarily characterized by impaired abilities that manifest themselves during maturation and provide a general level of intelligence, that is, cognitive, speech, motor and social abilities. For coding the diagnosis of mental retardation in ICD-10, it is proposed to use section F7 (F70 - 79). The term "mental retardation" means a persistent decrease in human cognitive activity against the background of organic damage to the central nervous system [9]. Neurophysiological diagnostics, in particular electroencephalography (EEG), most adequately reflects the morpho-functional state of the central nervous system, which is the basis of the mechanisms of mental activity, and the originality of the bioelectrical activity of the brain can be considered as the main indicator that determines the decrease in the level of intellectual development and, by that, characterizes this condition.

This provision actualizes the search for highly informative indicators of the originality of bioelectrical activity (BEA) of the brain in children with intellectual disabilities. Electrophysiological examination of children with mental pathology, which is included in the

mandatory set of diagnostic procedures, often comes down to only identifying epileptic activity. However, electroencephalography (EEG) contains a much larger amount of information, which is extremely useful for assessing the child's condition, the compliance of his EEG with the age norm, for diagnosing syndromic forms of mental disorders, but this information is almost completely ignored in the analysis [8]. More and more researchers are beginning to believe that the background activity of the brain should be reflected in the effectiveness of mental activity [38, 40]. This hypothesis is supported by the existence of genetically determined features of the functional organization of the background activity of the central nervous system.[32, 33].

In the sixties of the last century, G. Walter (24) expressed a rather revolutionary idea that the pattern of the background EEG is similar to fingerprints; in this regard, it seems possible to associate the individual parameters of the EEG signal with the characteristics of mental activity.

Significant progress in understanding the neurobiology of mental disorders requires improved methods for diagnosing mental illness, in which the quantitative EEG method also plays an important role. A quantitative assessment of EEG indicators by age makes it possible to establish the parameters of normality at any age, which can be used as a reference when children demonstrate delays in the development of their abilities and / or other atypical and maladaptive forms of behavior. A review of the current literature on the use of quantitative EEG techniques (QEEG), which serve as an aid to identifying these children as distinctly different from normal, and in some cases different from other clinical manifestations, showed sufficient sensitivity and specificity to merit consideration. as a diagnostic tool in assessing clinical developmental abnormalities. In addition, QEEG scores can provide a means of determining the effectiveness of treatment for overt brain dysfunctions underlying these childhood disorders[30].

Numerous studies of electroencephalogram (EEG) at rest with eyes closed in subjects with learning disabilities most often reported excessive slow activity, mainly in the theta frequency range [31] and alpha activity deficit [29] compared to normal children. Excessive delta activity has been reported in severe disability [34]. Spectral analysis of EEG with mental retardation reveals a more significant severity of slow frequencies on the resting electrocephalogram and an immature form of activation [10]. Children with learning difficulties showed higher absolute power in frequencies in the delta and theta ranges in the left frontotemporal region and lower values of the absolute power of the gamma rhythm [39]. It has been shown that the frontal lobes, mainly their prefrontal parts, are affected, regardless

of the etiology, in subjects with mental retardation [36]. A distinctive feature of children 8.5-10 years old with learning difficulties is a significant severity of slow frequencies on the background EEG in the anterior (in particular, the left frontal) areas of the cortex. The results obtained are considered as a reflection of the lagging behind the age norm in the functional maturation of brain structures. According to L.I. Redelivery et al. [18] there is a relationship between a decrease in cognitive activity in primary schoolchildren with speech impairments and insufficient formation of alpha activity in the cerebral cortex. The immaturity of the cortical-subcortical connections is also evidenced by the fact that in all children with impaired memory and attention functions there is a greater, in comparison with the norm, power of theta rhythms in the occipital and central regions of the cortex.[17, 18].

With dementia in the EEG, a shift of the background frequency in the delta and theta ranges and a decrease or drop in the central alpha frequency are noted. The resulting decrease in alpha and beta activity has been observed in various studies published over the past decade. In addition, the alpha rhythm can be a diagnostic marker, since there is a decrease in the alpha frequency to 6.0-8.0 Hz with a mild degree of dementia.

The question of the peculiarities of interhemispheric relations in the clinic of organic lesions of the central nervous system is of considerable interest. The conclusions of individual researchers on this issue contradict each other.

The asymmetry of interhemispheric relations is associated with the functional state of a person and is a fundamental property of the human brain [2]. According to the World Health Organization, approximately 20% of children with mental retardation (MDD) have visible signs of left-handedness (in scientific terminology, right lateral profile, or left-handedness). Thus, there are specific scientific data on a greater percentage of left-handed children among mentally retarded children, children with mental retardation, children with learning difficulties in writing and reading, compared with the same among right-handed children. Research Moskvin V.A., and Moskvina N.V. [15] using the questionnaire of A.P. Chuprikov (1987), 14.1% of the mentally retarded were found to be left-handed, compared with 2.5% of left-handers among healthy schoolchildren.

It is known that the presence of left-handedness in children with mental retardation complicates the process of their learning, especially when mastering the skills of asymmetric activities - reading and writing. The peculiarities of interhemispheric asymmetry can also explain "mirror writing", which is also more common in children with CRD than in normally developing peers [4].

In children with delayed development, significant differences from the norm were revealed for various forms of perceptual activity; there is a weakening of the inclusion of the associative structures of the left hemisphere in the activity. The isolation of significant signals, the assessment of the significance of the signal, judging by the shifts of the amplitude-time parameters of the EP, are carried out mainly in the structures of the right hemisphere. In the left hemisphere, there were no significant differences in EP for significant and insignificant signals [28]. The author believes that in children with delayed development, the structural and functional maturation of the left hemisphere, especially its higher parts, is slower in comparison with the norm. [28].

Physiologists, neuropsychologists and morphologists obtained data indicating the later formation, in children with mental retardation, of the functions of the frontal lobes of the left hemisphere. They have slowed down, in comparison with the norm, the structural and functional maturation of the left hemisphere, especially its higher parts [3, 20, 25].

Currently, physiologists reveal a direct relationship between the degree of asymmetry and the mental abilities of a person. Labor skills, speech, thinking, memory, attention, imagination - all this began to develop so rapidly in a person due to the plasticity of his brain and the innate predisposition of the hemispheres to the division of duties.

As a rule, in preschool age, the lateralization process is not yet complete. Research on the functional asymmetry of the cerebral hemispheres allows specialists to better understand the objective causes and mechanisms underlying disorders and deviations in the cognitive activity of children with mental retardation [5].

In children with mental retardation, judging by the characteristics of the evoked potentials, the activation of the left hemisphere upon stimulation of the right hemisphere is significantly weakened in comparison with the norm. This apparently reflects a decrease in the reactivity of the left hemisphere to information coming along the callosal pathways from the right hemisphere. Analysis of the time of interhemispheric information transfer in the process of perception indicates a slowdown in the development of evoked potentials in the structures of the right hemisphere upon stimulation of the left hemisphere, which reflects, to a certain extent, a slowdown in the transfer of information from the left hemisphere to the right. [5].

However, the study of neurodynamic mechanisms in mental retardation was not carried out in the mode of periodometric analysis of EEG mapping. At the same time, this technique of computed electroencephalography is one of the most informative [16] and

promising in terms of identifying pathognomonic electroencephalographic features. with mental retardation [14].

Aim. Comparative study using periodometric analysis of EEG indicators (amplitude, frequency, duration index), interhemispheric asymmetry of EEG rhythm amplitudes.

Materials and methods

65 patients with a diagnosis of mental retardation (according to ICD-10 heading F70) at the age of 16-18 years were examined - the main group of those who were undergoing inpatient examination and treatment at the Communal non-profit enterprise "Odessa Regional Center for Mental Health" of the Odessa Regional Council. The control group consisted of 34 people aged 16 to 24 years. EEG recording was carried out in a state of calm wakefulness with closed eyes on an electroencephalograph "Neuron-Spectrum-2" at a sampling frequency of 500 Hz using a bipolar annular mounting 16.

The electrodes were placed according to the "10-20%" system in the l6 zones of the cortex. EEG was recorded according to the international system "10% -20%" from frontal (F3, F4), central (C3, C4), parietal (P3, P4), occipital (01, 02), anterotemporal (F7, F8), middle temporal (T3, T4) and posterior temporal (T5, T6) cortical zones (odd numbers indicate the areas of the left hemisphere, even - the right). Bipolar ring mounting was used 16. Bandwidth 0.5-35 Gy, sampling rate 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.

EEG functional asymmetry coefficients in amplitude were determined by the formula:

$U_{ac}=(L – P)/(L+P)*100$,

Where:L –left hemisphere indicator, P–right hemisphere indicator.

Thus, positive values mean a predominance of the amplitude of the left hemisphere, negative values of the right hemisphere.

Differences in indicators were monitored using the calculation of ratio coefficients (RR). CS was obtained by dividing the larger value of the compared indicators by the smaller one. [35].

Own research

Statistical analysis of the differences in the amplitudes of the EEG rhythms (Table 1) revealed that with mental retardation, the amplitudes of the rhythms were determined to be 1.16–1.78 times greater than in healthy subjects. The greatest increase in theta rhythm was observed in (FP1-F7) anterior temporal and (T3-T5) posterior temporal leads in the left hemispheres.

The increase in beta = LF was greatest in lead (T4-T6) of the posterior temporal right, and beta-HF rhythm in lead (F3-C3). frontal central left lead.

Table 1

Statistically significant coefficients of the ratio of the amplitudes of the EEG rhythms in mental retardation compared with the control group

Leads	Delta-rhythm	Theta rhythm	Alpha rhythm	Beta-low frequency (LF) rhythm	Beta-high frequency HF) rhythm
C3-P3					
C4-P4					
F3-C3		1,48			1,52
F4-C4		1,39			
F7-T3	1,33	1,60		1,27	
F8-T4		1,42*		1,24*	1,34*
FP1-F3		1,37			1,24
FP1-F7		1,78*		1,34	
FP2-F4		1,40			
FP2-F8		1,41			
P3-O1		1,38*		1,22	1,44
P4-O2		1,33*			
T3-T5		1,53*	1,44*	1,36*	1,26*
T4-T6		1,41*	1,46*	1,44*	1,60*
T5-O1				1,17	1,16
T5-O2					

*- P<0,05, rest <0,1

In the delta range in the lead (C3-P3) in the central parietal left, the frequency of the delta rhythm is observed to be reduced. and in the leads (P3-O1) parieto-occipital left, (T4-T6) the posterior-temporal right, the frequency of the delta rhythm was observed to be increased. In theta range in leads (P4-O2) parieto-occipital right, (T4-T6), posterior temporal right (T5-O1) temporo-occipital left. the frequency of the rhythm was observed to be reduced in comparison with the controdem. An increase in the frequency of the alpha rhythm was observed in the (F4-C4) frontal-central right lead.

Beta-lowfrequencyrhythm (table 2) in (C3-P3) in the central parietal left lead, the rhythm frequency is observed to be reduced, and in the leads (F7-T3) temporomandibular left (F8-T4). temporo-central right (FP2-F8) front-temporal right (T3-T5) posterior-temporal left

(T4-T6) postero-temporal right (T5-O1) temporooccipital left frequency in beta-high frequency rhythmrange was determined by increased.

Beta- highfrequencyrhythm ranges in leads (C3-P3) central parietal left (F7-T3) temporo-central left (FP2-F8) the anterior-temporal right rhythm frequency was determined by a decreased compared with the control.

Table 2.

Statistically significant coefficients of the ratio of the frequencies of EEG rhythms in mental retardation compared with the control group

Leads	Delta-rhythm	Theta rhythm	Alpha rhythm	Beta-LF rhythm	Beta-HF rhythm
	-1,02			-1,06*	-1,24
C4-P4					
F3-C3					
F4-C4			1,02		
F7-T3				1,02*	-1,13
F8-T4				1,02*	
FP1-F3					
FP1-F7					
FP2-F4					
FP2-F8				1,01*	-1,03*
P3-O1	1,09*				
P4-O2		-1,02			
T3-T5				1,02*	
T4-T6	1,13*	-1,02		1,01*	
T5-O1		-1,03		1,01	
T5-O2					

*- P<0,05, restP<0,1.

Duration indices in the delta, theta and alpha ranges of the EEG in mental retardation compared with the control group were determined to be increased, and the indices of the duration of beta rhythms - decreased (Table 3).

As a criterion for the lateralization of the hemispheres (right-handedness-left-handedness), the mean FMPA value of the amplitude of the alpha rhythm for all leads was used. In those cases when this value in the right hemisphere prevailed over the same value in the left hemisphere, the subject was defined as an electroencephalographic right-hander. When analyzing FMPA without dividing into left-handed-right-handers, as can be seen from Figure 1, the value of FMPA indicators in persons suffering from mental retardation in the

delta and theta ranges of the EEG compared with similar indicators in the control group was less in magnitude, and in the alpha and beta ranges - more.

Table 3.

Statistically significant coefficients of the ratio of the indices of the duration of EEG rhythms in mental retardation compared with the control group

Leads	Delta-rhythm	Theta rhythm	Alpha rhythm	Beta-LF rhythm	Beta-HF rhythm
C3-P3	5,44*	3,32*	3,49*		-2,64*
C4-P4	5,13*	3,33*	3,82*		-3,30*
F3-C3	5,50*	3,46*	3,17*		1,86*
F4-C4	5,41*	3,65*	3,17*		-1,88*
F7-T3	2,35*	3,38*	2,40*	-1,19*	
F8-T4	3,99*	2,85*	2,41*	-1,22*	
FP1-F3	5,43*	3,71*	2,52*	-1,46*	
FP1-F7	1,96	3,51*	2,51*	-1,15	
FP2-F4	6,52*	3,83*	2,61*	-1,32*	-1,39*
FP2-F8		3,18*	3,01*		
P3-O1	3,24*	3,11*	4,04*		-2,66*
P4-O2		2,93*	4,02*		-2,64*
T3-T5	3,25*	2,58*	2,76*		
T4-T6	3,82*	2,72*	2,94*		
T5-O1		2,33*	3,64*	1,14*	
T5-O2		2,53*	3,87*		-1,38*

*- P<0,05, rest<0,1

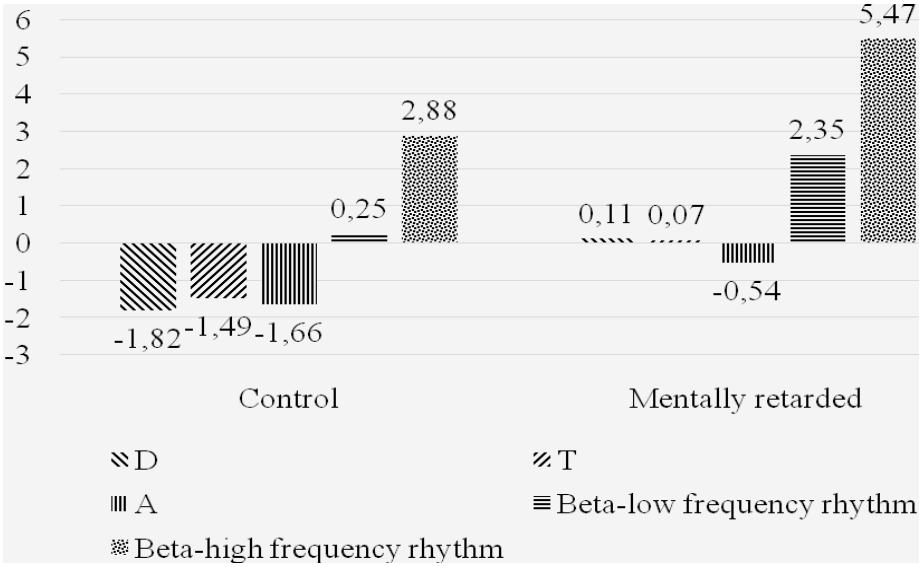

Figure 1. FMPA indices in healthy people and with mental retardation without taking into account lateralization.

Designations: D – delta rhythm, T – theta rhythm, A – alpha rhythm, B-L–beta -Lrhythm, B-H- beta -Hrhythm.

Table 4.

Indicators of functional interhemispheric asymmetry in the control group and in the mentally retarded persons

Leads	Delta-rhythm		Theta rhythm		Alpha rhythm		Beta -HF-rhythm		Beta -HF- rhythm	
	Control	The main	Control	The main	Control	The main	Control	The main	Control	The main
FP-F	-2,5	0,35	-0,32	-1,09	-2,3	-0,72	-2,92	2,88	3,54	9,44
FP-F	-3,14	-3,08	-3,63	0,58	-4,08	-0,26	-3,8	2,43	1,2	3,93
F-C	-1,88	-0,07	0,87	2,31	-0,78	0,91	2,3	1,33	-1,79	6,98
F-T	-0,41	4,39	-1,56	-0,10	1,09	-2,70	2,08	3,60	7,63	0,36
P-O	6,9	-0,11	1,97	3,48	-1,87	3,50	0,14	4,45	-6,15	10,00
T-T	-10,38	-0,27	-6,84	-2,01	-2,44	-1,01	1,79	0,85	3,98	-0,87
C-P	-3,17	-2,02	-2,4	-3,68	-2,88	-3,50	2,39	1,16	6,61	8,44
Medium	-1,82	-0,11	-1,49	-0,07	-1,66	-0,54	0,25	2,39	1,88	5,47

The analysis of FMPA in persons suffering from mental retardation compared with the control group, taking into account the lateralization (left-handedness-right-handedness), showed that negative FM indices increased in right-handers, while in left-handers there was an increase in positive FMPA indices (Table 5, Fig. 2).

Table 5.

Indicators of functional interhemispheric asymmetry in the control group and in the mentally retarded, taking into account lateralization

	EEG rhythms				
	Delta	Theta	Alpha	Beta-LF	Beta-HF
Right-handed control	-1,09	-0,12	-0,41	0,22	-0,18
Lefty control	-0,62	-0,98	0,96	0	1,45
Right-handed UO	-1,24	-2,9	-3,44	-2,74	0,33
Lefties UO	2,11	4,19	4,66	4,73	3,36

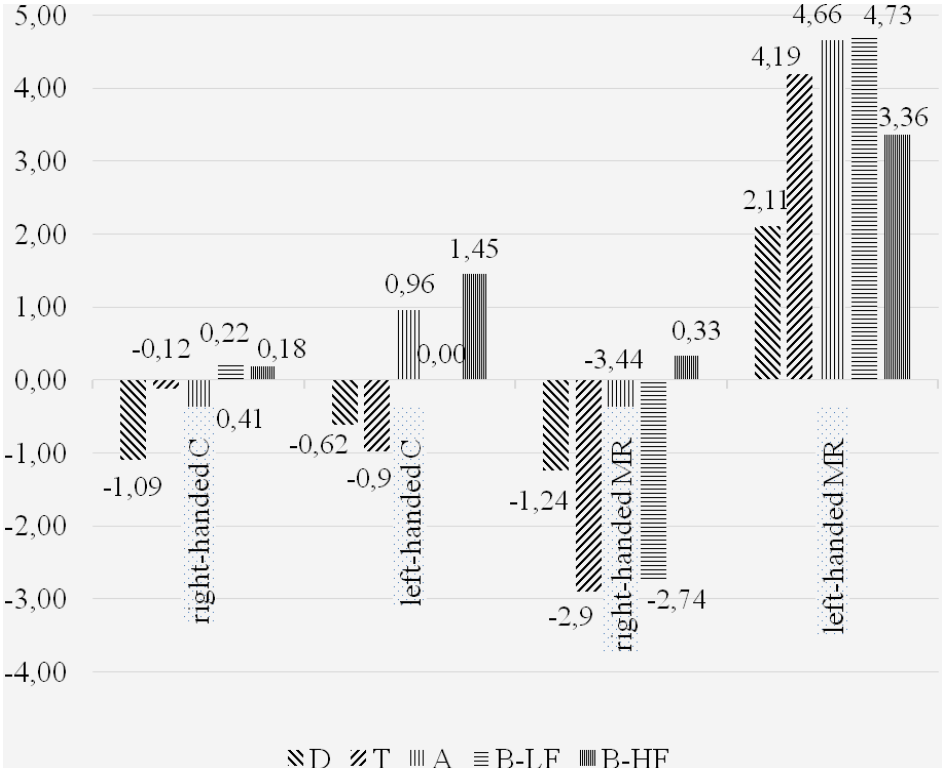

Figure 2. FMPA indices in healthy people and with mental retardation, taking into account lateralization.

Legend: D - delta rhythm, T - theta rhythm, A - alpha rhythm, B1 - beta-LF rhythm, b2 - beta-HF rhythm; right-handed C - right-handed control, left-handed C - left-handed control right-handed MR - right-handed mentally retarded, left-handed MR - left-handed mentally retarded.

Discussion. With mental retardation, the amplitudes of the EEG rhythms were determined to be greater than in healthy people, that is, the electroencephalogram was determined more synchronized.

Our studies [13] have shown that in both right-handers and left-handers, during periods of desynchronization, the number of statistically significant regression coefficients from the amplitudes of EEG rhythms to the indicators of Eysenck's and SMIL tests was determined to be greater than during periods of synchronization.

This may indicate that the implementation of mental acts and states, verified by the indicators of the applied tests, is carried out mainly during periods of desynchronization. It can be assumed that the increased synchronization of the EEG in persons suffering from mental retardation prevents the formation of mental acts and states and provides a decrease in the level of intellectual development.

Indexes indices in the delta, theta and alpha ranges of the EEG in mental retardation compared with the control group were determined to be increased, and the indices of the duration of beta rhythms - decreased. This may indicate a decrease in the functional activity of the ascending activating reticular formation of the brainstem, or an increase in the functional activity of thalamic structures.

Our studies [35] showed that when comparing the features of the periods of desynchronization in the ECoG taken from the intact brain and the isolated forebrain, in which the intercollicular transection of the brainstem was performed with the amplitude of beta-1-, alpha-, theta- and delta-rhythms in conditions of an isolated anterior brains in both hemispheres were noticeably smaller than in an intact brain. Based on this, it can be assumed that the increase in EEG synchronization in the mentally retarded is due to the activity of the thalamic structures of the brain.

In the group of persons suffering from mental retardation, an increase in the amplitude of theta rhythm was observed in 14 EEG leads, while an increase in other rhythms was noted in 2-7 leads.

According to research by E.P. Stankova (23), the analysis of the statistical relationship between the theta range power and the parameters of the correction test revealed the following tendency: with an increase in the spectral power of the theta range oscillations, the number of missing letters increases, and the coefficient of correctness of the correction test decreases. This trend has been observed for the frontal, inferior frontal, and temporal leads.

Theta rhythm plays a large role in orienting a person when performing many types of activities. Cognitive activity, intellectual tension lead to an increase in the power and spatial synchronization of theta waves. The severity of the theta rhythm depends on the nature of the activity and clearly increases with mental and emotional stress. In children with a relatively more pronounced theta rhythm, the likelihood of manifestation of traits of imbalance and aggressiveness is increased, which indicates the difficulty of social adaptation.Intellectual tension leads to an increase in the spectral power of theta waves and an increase in spatial synchronization between them[21].

In persons suffering from mental retardation, a decrease in functional asymmetry in the delta, theta and alpha ranges of the EEG and an increase in interhemispheric asymmetry in the beta ranges were revealed.

One of the fundamental principles of mental development is the principle of epigenesis, which is a general systemic principle of progressive development, the formation of systems of ever increasing complexity with the transition to higher levels of organization

by integrating old ways of organization with new ones with their subsequent modification [19]. More than a century history of anatomical, morphofunctional, biochemical, neurophysiological and psychophysiological studies of the asymmetry of the cerebral hemispheres in humans indicates the existence of a special bilateral principle of construction and implementation of such important brain functions as perception, attention, memory, thinking and speech [27]*КУРЦ)*

Recent advances in neuroscience indicate that interhemispheric asymmetry makes a significant contribution to the manifestation of human high intelligence [37].

Maturation of FMPA seems to be one of the key moments of change at different stages of ontogenesis of intercentral relations, which acts as the leading mechanism of age-related development of the psyche [6, 7]. The formation of FMPA has an undoubted connection with age-related characteristics of perception and thinking, which underlie the formation of typological characteristics of a person,including with the development of an individual-typical cognitive style (both preferred perceptual strategies and information processing strategies), with the development of an intellectual style [1] and, more broadly, with the formation of an individual style of activity closely related to the typological properties of the nervous system [11, 27].

Based on the foregoing, it can be assumed that the violation of the interhemispheric asymmetry revealed in those suffering from mental retardation is a significant reason for the violation of mental activity in them.

Conclusions

1. With mental retardation, the amplitudes of the rhythms were determined to be greater than in healthy people. The greatest increase was determined by the increase in theta rhythm in the anterior temporal and posterior temporal leads in the left hemispheres.

2. The indices of duration in the delta, theta and alpha ranges of the EEG with mental retardation compared with the control group were determined by increased, and the indices of the duration of beta rhythms - decreased

3. When analyzing FMPA in persons suffering from mental retardation compared with the control group, taking into account lateralization (left-handedness-right-handedness), it turned out that in right-handers the negativeness of FMPA indices increased, and in left-handers there was an increase in the positivity of FMPA indices.

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