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ELECTROENCEPHALOGRAPHIC ASSESSMENT OF CEREBRAL ACTIVITY NEURODYNAMIC COMPONENTS AND THEIR POSSIBLE ROLE IN THE DEVELOPMENT OF NEUROCOGNITIVE DEFICIENCY

© Ksenia A. Belskaya, Sergey A. Lytaev

Saint Petersburg State Pediatric Medical University. Lithuania 2, Saint Petersburg, Russian Federation, 194100

Contact information: Ksenia A. Belskaya — Candidate of Medical Sciences, Associate Professor of the Department of Normal Physiology. E-mail: belskaya.k.a@gmail.com ORCID: https://orcid.org/0000-0002-9267-0639 SPIN: 6513-7335

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Abstract. *The relevance* of this article is due to the variability of scientific ideas about the mechanisms of development of neurocognitive deficit associated with a line of psychopathological conditions. Many questions remain about the functions of individual brain structures and systems, as well as central neurodynamics in the development of cognitive defects. The question of the influence of the disorganization of vertically oriented structures of the first brain functional block (BFB) on the formation of neurocognitive deficit in mental pathology of the schizophrenic spectrum remains the least studied in modern neuroscience. ***The present research was aimed*** to assess the functional state of the first brain energy block and to determine the role of disorders in the neurodynamic components of activity in the development of neurocognitive deficit in psychopathology. ***Materials and methods.*** 40 patients with paranoid schizophrenia and 38 healthy subjects matched in age, gender ratio and educational level were examined. EEG by monopolar according to the international system 10/20 using a 21-channel system "Telepat-1" was registered. With the help of visual and spectral methods of analysis, both nonspecific physical parameters of the α-rhythm — index, frequency and amplitude, and physiological features of α-oscillations — reactivity, regularity, autorhythm (modulation) and stability of the α-rhythm were studied. The functional state of the RF was determined by the parameters of the latent periods of synchronization, desynchronization, and the depth of desynchronization in the eye opening/closing test. The tonus of the cortex by the ratio of the values of the indices of alpha- and delta-rhythms was determined. The threshold of convulsive readiness of the brain was calculated from the number of recorded flashes in the background EEG. Fluctuations in the frequency of the basic alpha rhythm exceeding 0.5 Hz were regarded as a sign of instability in the oscillatory activity of the brain. ***Results.*** It has been established that impairment of cognitive functions in schizophrenia is associated not only with cortical dysfunction (II and III BFB), but also with disorganization of vertically oriented structures of the I BFB. Revealed disorganization of the reticular formation and alpha-regulating system, decreased tone and activation of the cerebral cortex. The possible pathogenetic influence of these pathophysiological factors on the formation of neurocognitive deficit has been substantiated. The most informative diagnostic EEG-signs of disorders in the neurodynamic components of brain activity were determined.

Keywords: paranoid schizophrenia, EEG, spectral analysis, brain functional block, neurocognitive deficit

ЭЛЕКТРОЭНЦЕФАЛОГРАФИЧЕСКАЯ ОЦЕНКА НЕЙРОДИНАМИЧЕСКИХ КОМПОНЕНТОВ ДЕЯТЕЛЬНОСТИ МОЗГА ПРИ ПСИХОПАТОЛОГИИ И ИХ ВОЗМОЖНОЙ РОЛИ В РАЗВИТИИ НЕЙРОКОГНИТИВНОГО ДЕФИЦИТА

© Ксения Алексеевна Бельская, Сергей Александрович Лытаев

Санкт-Петербургский государственный педиатрический медицинский университет. 194100, Российская Федерация, г. Санкт-Петербург, ул. Литовская, 2

Контактная информация: Ксения Алексеевна Бельская — к.м.н., доцент кафедры нормальной физиологии. E-mail: belskaya.k.a@gmail.com ORCID: https://orcid.org/0000-0002-9267-0639 SPIN: 6513-7335

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Резюме. ***Актуальность*** работы обусловлена вариабельностью научных представлений о механизмах развития нейрокогнитивного дефицита, ассоциированного с рядом психопатологических состояний. Остается много вопросов о функциях отдельных структур и систем мозга, а также центральной нейродинамики в развитии когнитивного снижения. Наименее изученным в современной нейронауке остается вопрос о влиянии дезорганизации вертикально ориентированных структур I функционального блока мозга (ФБМ) на формирование нейрокогнитивного дефицита при психической патологии шизофренического спектра. ***Цель исследования*** заключалась в оценке функционального состояния первого энергетического блока мозга и определении роли нарушений нейродинамических компонентов деятельности в развитии нейрокогнитивного дефицита при психопатологии. ***Материалы и методы.*** Обследовано 40 пациентов, страдающих хронической параноидной шизофренией, и 38 здоровых испытуемых, сопоставимых по возрасту, гендерному соотношению и образовательному уровню. Регистрация ЭЭГ осуществлялась монополярно по международной системе 10/20 с помощью 21-канального аппаратно-программного комплекса «Телепат-1». С помощью визуального и спектрального методов анализа изучались как неспецифические физические параметры α-ритма — индекс, частота и амплитуда, так и физиологические особенности α-осцилляций — регулярность, авторитмичность (модуляции) и стабильность α-ритма. Функциональное состояние ретикулярной формации (РФ) определяли по параметрам латентных периодов синхронизации, десинхронизации и глубины десинхронизации в пробе с открытием/закрытием глаз. Тонус коры определяли по соотношению значений индексов альфа- и дельта-ритмов. Порог судорожной готовности мозга рассчитывали по количеству зарегистрированных вспышек в фоновой ЭЭГ. Колебания частоты базового альфа-ритма, превышающие 0,5 Гц, расценивались как признак нестабильности осцилляторной активности мозга. ***Результаты.*** Установлено, что нарушения познавательных функций при шизофрении связаны не только с дисфункцией коры (II и III ФБМ), но также с дезорганизацией вертикально ориентированных структур I ФБМ. Выявлена дезорганизация ретикулярной формации и альфа-регулирующей системы, снижение тонуса и активации коры мозга. Обосновано возможное патогенетическое влияние этих патофизиологических факторов на формирование нейрокогнитивного дефицита. Определены наиболее информативные диагностические ЭЭГ-признаки нарушения нейродинамических компонентов деятельности мозга.

Ключевые слова: параноидная шизофрения, электроэнцефалография, спектральный анализ, нейродинамика, нейрокогнитивный дефицит

INTRODUCTION

Modern civilization is based on the knowledge and processing of significant amounts of information. At the same time, the volume and speed of accumulation of new information necessary for successful functioning of society and activities of an individual are growing exponentially. That is why a modern person in order to remain professionally competent and develop his intelligence and innovative thinking, needs to acquire ever greater amounts of knowledge throughout his life [1, 10, 11].

Meanwhile, modern education system is acquiring the character of personality-oriented learning, in which cognitive development is aimed at qualitative transformation of all cognitive processes. In the age of information technology, it is not enough for a person to possess the only knowledge and skill. It is also necessary to possess such qualities of higher nervous activity as flexibility in thinking, high adaptability to changing conditions, desire to self-education and volitional qualities in achieving the goal [17].

However, literature analysis shows that cognitive impairment is associated with a significant number of neurological, mental and psychosomatic disorders. Their prevalence is increasing due to population aging. Many forms of psychopathology related to the sphere of so-called major psychiatry are in most cases also associated with neurocognitive deficit. It has often had chronic disabling nature and leads to pronounced occupational and social maladjustment. The most common disease in this category is schizophrenia.

Currently, there are about 50 million people in the world suffering from various types of dementia. The number of patients with severe cognitive disorders doubles every ten years, and by 2050 their total number in all countries of the world will reach 130 million [13]. Cognitive disorders occur in 20% of children and adolescents. This leads to learning difficulties, deviant behavior, psychoemotional disorders and, as a consequence, to social maladjustment [2, 3, 14].

In this regard, there is growing interest in cognitive psychophysiology in studying the mechanisms of cognitive dysfunction, as well as their role in the development of learning difficulties and mechanisms of neurocognitive deficit. The problem of studying the biological basis of cognitive dysfunction (especially in severe forms of psychopathology) has become one of the most pressing issues in neuroscience [10, 11]. The formation of neurocognitive deficit that occurs during the development of the schizophrenic process is one of the most complex and poorly understood problems of modern neurobiology.

According to DSM-V criteria, cognitive disorders include a decrease, compared to premorbid level, in one or more higher brain functions that ensure the processes of attention, perception, storage, transformation and transmission of information [27].

From the standpoint of the concept of three functional units of the brain according to A.R. Luria, structures of all blocks of the brain are of interest in formation of neurocognitive deficit. However, specifics and mechanisms of disorders at the level of each of them remain poorly studied [14, 19]. For this reason, establishing patterns and deciphering the mechanisms of cognitive disorganization, participation in their pathogenesis of vertically (Unit I) and horizontally (Unit II and III) oriented parts of the brain is one of the most complex and interesting issues of neuropsychology, which has both theoretical and practical significance.

An analysis of the available neuropsychological literature shows that pathogenetic significance of disorganization of central neurodynamics, which is carried out by Unit 1, in mechanisms of development of neurocognitive deficit in schizophrenia and other psychopathological conditions is also a poorly studied problem. There are few publications in literature devoted to the study of neurodynamics in cognitive dysfunction [2, 18].

The paradigm of "neurocognitive deficit" proposed at the end of the 20th century by A. Breier considers cognitive impairment as the "third key group of symptoms" of schizophrenia, along with positive and negative clinical symptoms [26]. Recently, it has been established that neurocognitive deficit in schizophrenia is observed in 94% of patients, manifests itself in the early stages, persists throughout the entire period of disease and remains in remission [13].

In clinical neuropsychology, the study of mechanisms of neurocognitive decline and, in particular, the role of neurodynamic aspects of cognitive impairment in patients with psychopathology is given undeservedly little attention. Objective neuropsychological research on brain function based on the systemic neurodynamic approach, the founder of which in the field of psychophysiology was A.A. Ukhtomsky, remains unreasonably little in demand by modern researchers. In addition, the term "neurodynamics" itself is used less and less in neuroscientific literature.

Productivity of studies of cerebral dysfunctions in neuropsychology is associated with a systemic approach. Its essence consists in constructing a holistic picture of the object of study based on the proposed systemic principle and conducting research based on this principle. Beginning with the classical works of A.A. Ukhtomsky, it was shown that brain is a complex neurodynamic system, constantly striving for integration and stereotype of unified activity [6, 24].

According to modern concepts, brain is considered as a complex computer information system with a large number of equilibrium, but variable states. Brain stability within certain functional level is a neurodynamic process that maintains physiological parameters through homeostatic regulation. Homeostatic regulation processes correct all internal fluctuations in state of the central nervous system (CNS) around the average levels [9].

The theoretical framework of this study of neuropsychological mechanisms of neurocognitive deficit was: A.R. Luria's concept of three functional units of the brain [14, 19], I.P. Pavlov's teaching on the major neurodynamic laws [23], and A.A. Ukhtomsky's theory of dominance [24].

According to the concept of A.R. Luria, all mental processes and various types of conscious human activity in normal and pathological conditions should be considered from the standpoint of functional role of three functional units or blocks of the brain. Unit I is a unit that ensures the regulation of tone and level of wakefulness. Unit II is a block for receiving, processing and storing information.

Unit III is a unit for programming, regulation and control of mental activity.

Optimal cortex tone and adequate level of wakefulness are necessary to ensure the normal speed and quality of neurocognitive processes. The brain can best receive and process information, recall necessary selective systems of connections and associations, and program activities only in such a neurodynamic state.

The fact that optimal tone of the cortex is necessary for implementation of organized and effective cognitive activity was already indicated by I.P. Pavlov, who described major neurodynamic laws. Thus, according to the neurodynamic "law of force", in a state of reduced tone of the cortex, normal ratio of excitatory and inhibitory processes. Their mobility, necessary for implementation of organized course of mental activity, is also disrupted [23].

The first energy block of the brain includes structures of the brainstem, parts of the diencephalon and mediobasal regions of the frontal and temporal lobes (Fig. 1).

At different levels of Unit I of the brain, there are three main energy sources, which provide regulatory influences on the cerebral cortex, maintenance of working tone and level of wakefulness.

The main source of maintaining tone and activation of the cerebral cortex is the brainstem reticular formation (RF). The ascending and descending reticular systems of the brainstem constitute a single self-regulating apparatus. It ensures the redistribution of tone and activation of the cerebral cortex depending on the level of its functional activity in a certain period of time. At the same time, activating and inhibitory effects of the RF affect all sensory, motor, verbal thinking, and other functions of the brain.

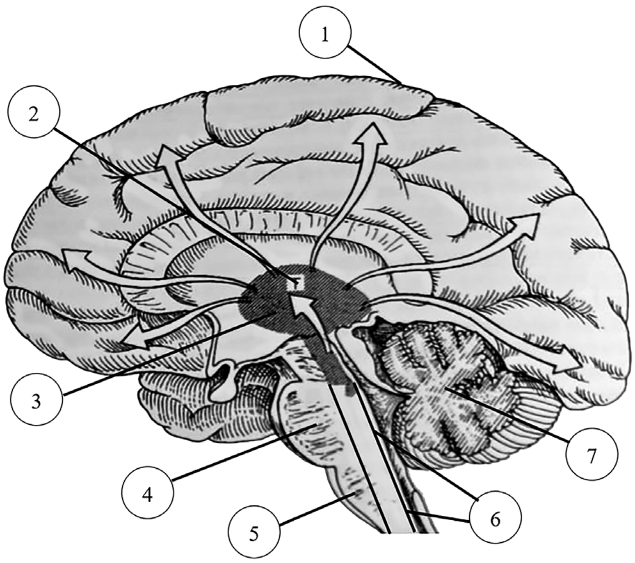

Fig. 1. The first functional block of the brain: 1 — cerebral cortex; 2 — visual tubercle; 3 — hypothalamus; 4 — brainstem; 5 — medulla oblongata; 6 — ascending brainstem RF; 7 — cerebellum

Рис. 1. Первый функциональный блок мозга: 1 — кора головного мозга; 2 — зрительный бугор; 3 — гипоталамус; 4 — мост; 5 — продолговатый мозг; 6 — восходящая РФ ствола мозга; 7 — мозжечок

The second key structure of Unit I of the brain, responsible for maintaining brain energy status, tone and activation of the cortex, is neural apparatus of the hypothalamus, which regulates the body's metabolic processes.

The third energy source is associated with thalamic system, which controls the entry of polymodal information into the brain. Firstly, sensory streams of verbal and non-verbal information support activation processes and tone of the cortex. Secondly, the thalamus is morphofunctionally closely connected with the Peipets' limbic circle, through which energy impulses associated with the cerebral cortex circulate [19, 25].

Perception of any information causes a reaction in the form of an orienting reflex. According to I.P. Pavlov, it is the most important factor of cognitive activity, closely connected with the work of both the RF and thalamic system of the brain. A significant source of activation and maintenance of tone of the cerebral cortex is also the verbal thinking activity of a person, his mental plans and understanding of perspective, which are formed in the process of purposeful cognitive activity.

In this way, normally all levels of the first functional block of the brain and all its energy sources are closely interconnected and work in interaction with the higher areas of the cortex. They not only tone the cortex, but also experience modulating influences from cortical regions of the brain, thus ensuring an adequate level of cognitive functioning.

Cognitive resource is considered in psychophysiology as a general factor of successful solution of cognitive tasks. It ensures the perception of verbal and non-verbal verbal imaginative information, analysis and correlation of perceived information with that stored in long-term memory and decision-making [6, 8, 9, 20]. According to Hans Eysenck's activation theory, the level of tone and activation of the brain is the central explanatory point of the influence of individual differences on the efficiency of cognitive activity [4, 25]. The Yerkes-Dodson law establishes an inverted U-shaped relationship between the success of completing a cognitive task and level of tone and activation of the brain. Optimal condition for cognitive success is a certain average level of tone and activation of the cerebral cortex, which was confirmed in our previous studies of efficiency of perception of non-verbal auditory information [7].

According to G. Eysenck, with insufficient activation of the cerebral cortex, the number of errors in subjects when presented with cognitive tasks increases by 3 times compared to patients with an optimal level of tone and activation [4].

It is known that the world around us, as we know it, is based on our cognitive structures. They are nonspecific, but ordered representations of previous experience. Cognitive structures formed during individual development support the processes of cognitive self-regulation and internal mechanisms of self-control. The process of cognitive self-regulation involves the development and improvement of cognitive structures and concepts, which are the product of learning. The functional role of cognitive self-regulation system lies in its ability to ensure purposeful activity in the direction that we consider correct in specific conditions. That is, we behave as our cognitive structures prescribe. At the same time, cognitive skills of a mentally healthy person give us opportunity to manage our own behavior and ensure a variety of interpersonal interactions and correction of ineffective cognitive schemas [5].

In schizophrenia and other forms of psychopathology, as a result of disorganization of physiological mechanisms of neurocognitive self-control, the ability for cognitive self-regulation is reduced. The cognitive system formed during the development of the schizophrenic process becomes invariant, often acts automatically. It is not very dynamic and is unable to perceive experience and adapt to changing circumstances. The ability to adhere to standards of behavior is lost, patient's actions are subordinated, rather, to external stimuli than to the mechanisms of cognitive self-regulation [12].

AIM

The aim of the study was to conduct an EEG assessment of functional state of the main structures of brain's energy block and to substantiate the pathogenetic significance of disturbances in neurodynamic components of activity in the development of cognitive deficit in psychopathology.

MATERIALS AND METHODS

A total of 78 people were examined, including 40 patients suffering from chronic paranoid schizophrenia associated with neurocognitive deficit and 38 healthy subjects. The average age of the main group was 37.7±3.3 years, average duration of disease was 13.4 years. Women accounted for 55%, men — 45%. The control group consisted of 38 healthy subjects, matched by age, gender ratio and social status: the average age of subjects was 38.6±3.7 years, men accounted for 52.6%, women — 47.4%.

Computer-based electroencephalography was used as the main method for studying central neurodynamics and local dynamic cerebral systems. EEG was recorded using a 21-channel system "Telepat-1" of national production with a sampling frequency of 400 Hz. EEG was recorded monopolarly according to the international system "10%–20%" from the frontal (F3–F4), central (C3–C4), parietal (P3–P4), occipital (O1–O2), anterior temporal (F7–F8), middle temporal (T3–T4) and posterior temporal (T5–T6) cortical regions. Combined ear clips served as the reference electrode.

In the post-real period, visual and spectral analysis of artifact-free EEG sections was performed, duration of which was established experimentally. A detailed analysis of alpha-frequency range parameters as one of the basic brain regulatory systems was carried out taking into account exceptional role of alpha rhythm in information and analytical activities of the brain. Attention was also paid to the fact of its close morphofunctional connection with fronto-thalamic system, which is the key structure of Unit I of the brain. Both nonspecific physical parameters of alpha wave process (index, frequency and amplitude) and physiological features of alpha oscillations (regularity, autorhythmicity (modulations) and stability of alpha rhythm) were analyzed.

Functional state of the RF was determined by parameters of latent periods of synchronization (normally 0.4–1.0 s), desynchronization (normally 0.01–0.03) and depth of desynchronization (normally 5–6 times) in the "open eyes — close eyes" test.

Tone of cerebral cortex was determined by ratio of frequency indices of alpha and delta rhythms. Normally, values of cerebral cortex tone vary in the range of 12–15. The paroxysmal index was estimated by the number of flashes in background EEG. More than two flashes in a minute segment of EEG recording are usually considered a sign of an increase in the degree of paroxysmal activity or lowering seizure threshold of the brain. Functional stability of brain oscillatory activity was evaluated by the degree of stability of background frequency of alpha rhythm. In this case, alpha frequency fluctuations exceeding 0.5 Hz are regarded as a sign of instability of brain's oscillatory activity [15, 16, 21, 22]. The WIN-EEG software, version 1.3, developed at the Institute of Human Brain of the Russian Academy of Sciences, was used to process EEG data. Statistical analysis of all data obtained was performed using the STATISTICA package, version 6.0. The reliability of results was assessed using Student's t-test.

RESULTS

Functional state of key vertically oriented structures of Unit I was assessed differentially taking into account their physiological role in maintaining cortex tone and wakefulness level. Comparative assessment of neurodynamics of the brain in main and control groups was carried out on the basis of computer-based EEG as a systemic method of studying the brain. The results of EEG study of functional state of non-specific systems, cortex tone and seizure threshold of the brain are presented in Table 1.

In subjects of the main sample, the latent period of desynchronization exceeded normative values by 2.3 times (p <0.05), and latent period of synchronization was higher than normative values by 1.6 times (p <0.05). At the same time, depth of synchronization in patients with schizophrenia was 1.22 times lower than normal. The totality of obtained data indicates a violation of functional state of ascending activating and ascending inhibitory systems of the brainstem.

Based on average normative values of the alpha index in healthy subjects of 50–60% and normative values of the delta index of 4–5%, value of the coefficient of tone and activation of cerebral cortex is normally 12.2. In our studies, average values of the coefficient of tone and activation of the cerebral cortex in subjects of the control group were 12.5, which corresponds to physiological norm. In subjects of the main group, values of the coefficient of tone of the cerebral cortex were 4.5, which is significantly lower than normative values by 2.3 times (p <0.001). A decrease in basic values of tone of the cerebral cortex creates the prerequisites for disorganization of neurophysiological mechanisms of information and analytical activity of the brain.

Functional state of ponto-hypothalamic region of the brain was assessed by the number of flashes recorded in background EEG. Normally, number of flashes on electroencephalogram does not exceed 2 per 1 minute of recording. In patients with psychopathology, the average number of flashes was 5.1 per minute, which exceeded normal values of the control group by 2.5 times (p <0.04). This indicated a tendency toward a moderate but reliable increase in the degree of paroxysmal activity of the brain.

A detailed analysis of alpha-frequency range parameters as one of the basic brain regulatory systems was carried out taking into account exceptional role of alpha rhythm in information and analytical activities of the brain. Attention was also paid to the fact of its close morphofunctional connection with fronto-thalamic system, which is the key structure of Unit I of the brain.

Both nonspecific physical parameters of alpha wave process (index, frequency and amplitude) and physiological features of alpha oscillations (regularity, autorhythmicity (modulations) and stability of alpha rhythm) were analyzed.

The functional status of thalamic system of the brain was determined based on analysis of the main parameters of the alpha-frequency regulatory system of the brain: the alpha index (%), average frequency (Hz) and amplitude (μV) of alpha rhythm, width of alpha range (Hz), depth of EEG desynchronization, regularity, modulations and stability of alpha rhythm.

Comparative analysis of parameters of alpha rhythm, presented in Table 2, reflects functional state of key cognitive areas of the brain in norm and in pathology.

In individuals with psychopathology all parameters of alpha activity are significantly changed. Zonal decrease in frequency of alpha rhythm below 9.15 indirectly demonstrates disintegration of neurofunctional structures that play a key role in the functioning of the brain. Fluctuations in frequency of basic alpha rhythm exceeding 0.5 Hz indicate instability of oscillatory activity that ensures the most important regulatory processes in the brain.

At the same time, EEG showed a 2.5-fold increase (p <0.04) in the number of flashes, which indicates an upward trend in the degree of paroxysmal activity of the brain in schizophrenia.

Table 1

Comparative analysis of key parameters of neurodynamics in persons of the main and control groups

Таблица 1

Сравнительный анализ ключевых параметров нейродинамики у лиц основной и контрольной групп

Показатели нейродинамики / Indicators of neurodynamics	Нормативные значения / Normative values	Основная группа / The main group	Контрольная группа / The control group
ЛП десинхронизации / LP desynchronization	0,01–0,03 с	0,07±0,002	0,02±0,012
ЛП синхронизации / LP synchronization	0,4–1,0 с	1,61±0,009	0,75±0,03
Коэффициент глубины десинхронизации / Depth factor desynchronization	5–6-кратное снижение / 5–6-times reducing	3–4-кратное снижение / 3-4-times reducing	5–6-кратное снижение / 5–6- times reducing
Коэффициент тонуса и активации коры мозга / The coefficient of tone and activation of the cerebral cortex	12,2	4,50±2,58	12,50±2,15
Вспышки / Flashes	Не более 2 с / No more 2 sec	5,1±0,85	1,8±0,25

Table 2

Comparative analysis of background parameters of the EEG alpha rhythm in individuals of the main and control groups

Таблица 2

Сравнительный анализ фоновых параметров ЭЭГ альфа-ритма у лиц основной и контрольной групп

Параметры α-ритма / α-rhythm parameters	Основная группа / The main group	Контрольная группа / The control group
Индекс, % / Index, %	38,6±6,6	65,7
Частота, Гц / Frequency, Hz	8,8	10,1
Ширина альфа-диапазона, Гц / The width of the alpha range, Hz	7,2–12,1	8–13
Амплитуда, мкВ / Amplitude, uV	49,8	62,2
Регулярность, Гц / Regularity, Hz	1,9	0,47
Модуляции / Modulations	– –	+++
Стабильность / Stability	– –	+++

DISCUSSION

In modern neuropsychology, the strategy for studying mental resources of a person is based on understanding the brain as a global neurodynamic system consisting of many neural networks whose operating modes are modulated by structures of Unit I. Anatomically, neural networks consist of many neurons of different brain modules. In addition, they interact in such a way that as a result of their functioning, an optimal cognitive reserve is created. It, in turn, ensures targeted cognitive and behavioral activity of the individual. That is why neurodynamic system is the basis for studying disorders of mental processes, mechanisms of development of cognitive deficit, negative and positive symptoms. All this is observed within the framework of formation of schizophrenic process and other psychopathological conditions [20].

According to the two-component model, total EEG is considered as the result of interaction of synchronizing and desynchronizing systems of the brain. Electroencephalogram reflects the activity of neurons of the cortex, which are under the constant influence of these regulatory systems of the brain.

Functional state of the cerebral cortex is determined by the balance of reciprocally interacting desynchronizing and synchronizing subcortical structures. The speed of interaction of activating and inhibitory effects of the RF on cortical horizontally oriented structures of the brain (Unit II and III), determined by latent periods of synchronization and desynchronization of alpha rhythm, was significantly reduced. When performing the test of opening and closing eyes, a reliable increase in latent periods was revealed. This, combined with incomplete suppression of alpha rhythm in patients with schizophrenia, indicates a violation of functional balance of desynchronizing (activating) and synchronizing (inhibitory) systems of the brainstem. A decrease in functional state of these basic modulating systems creates prerequisites for a slowdown in the speed of mental processes.

In 10 subjects of the main sample (25%), EEG showed dysrhythmia patterns, which were characterized by a non-dominant combination of waves of different frequency ranges. Dysrhythmia patterns are caused by a simultaneous increase in activity of synchronizing and desynchronizing systems. Such neurodynamic states are usually manifested by a pronounced cognitive decline.

Average values of the alpha index in control group subjects were within the range of normal values — 65.7%. In main sample subjects, average values of the alpha-index did not exceed 38.6%, which is 1.7 times lower than in the group of healthy subjects.

A decrease in representation of dominant alpha rhythm in EEG as a functional core of oscillatory activity of the brain can be rightfully interpreted as a factor that negatively affects cognitive functions. Any morphological or functional disorders in the brain lead primarily to a decrease in the alpha index, usually below 50%, or its complete reduction.

It is known that frequency of alpha rhythm is a neurophysiological condition and prerequisite for the effectiveness of cognitive activity. At the same time, its slowdown is due to disorganization of thalamic system of the brain and disruption of corticothalamic interactions.

Indicators of width of alpha range and variability of its amplitude are markers of neurodynamic plasticity, and therefore, the effectiveness of cognitive activity. In the group of patients suffering from schizophrenia, these indicators differ significantly from normative values towards slowing down and a left-sided frequency shift of alpha rhythm.

Modulations of alpha rhythm are the most important qualitative criterion of electroencephalograms related to organized alpha type. The presence of modulations in relative resting state indicates the optimal interaction of three regulatory systems of the brain: activating desynchronizing system of the brainstem, synchronizing inhibitory system of the thalamus and lower parts of the pons, as well as system of neocortical control of desynchronization and synchronization processes [14].

This EEG parameter subtly reflects the dynamics of ensemble organization of cortical neural activity, volume and "lifetime" of the neuronal ensemble, which is an important prerequisite for normal cognitive functioning of the brain. In EEG studies we conducted, all subjects in the main sample either had no alpha rhythm modulations at all, or they were intermittent and fragmentary.

Consequently, the decrease in frequency, regularity, absence of modulations, disruption of synchronization-desynchronization processes of alpha rhythm indicates disorganization of alpha regulatory system of the brain. This system is closely connected with the first functional block of the brain. The multi-vector disorganization of alpha rhythm that we have identified is of unconditional importance in mechanisms of development of cognitive decline in schizophrenia, as well as in other psychopathological conditions.

An increase in the number of flashes on EEG by 2.5 times above normal values indicates dysfunction of the brainstem-thalamic regions of Unit I. According to modern concepts, the neurodynamic structure that causes flashes is formed as a result of a decrease in functional state of posterior hypothalamus and brainstem structures and hyperactivation of nonspecific and specific nuclei of the thalamus [6, 25].

In this way, the results of studies we have presented show that patients suffering from schizophrenia have a functional decline in key areas of the first block of the brain, which provide activation-energy functions in brain activity. Structures of Unit I determine the function of attention, individual perceptual capabilities, memory and access to cognitive resources through the regulation of tone and activation of the cerebral cortex. Thus, they determine the efficiency of cognitive functioning. Therefore, disorganization of these brain regions creates the preconditions for a decline in cognitive resources.

Experience with patients of neuropsychiatric spectrum shows that they are characterized by intellectual passivity, inability to "mental stress", lack of motives and goals in behavior, "atony" of psyche, complacency, aspontaneity, attention disorder. These qualities combine with the manifestation of inertia, tendency to stereotypes, fantasizing and reasoning. Along with this, patients suffering from schizophrenia clearly demonstrate oddities of thought and behavior, inadequacy of speech and actions.

Pathophysiology of these psychopathological phenomena remains insufficiently studied. The results of our studies allow us to conclude that indicated disorders are largely determined by the primary defect of subcortical systems that form energy basis of mental activity. In terms of neuropsychology, the set of these signs characterizes a neurocognitive deficit associated with functional decline in energy block of the brain and decrease in the level of wakefulness.

CONCLUSION

Our studies have revealed previously unknown information about the significance of disturbances in neurodynamic components of activity in the development of cognitive deficit in paranoid schizophrenia, which have not only theoretical but also practical importance. It has been established that psychopathology involves multilevel disorganization of Unit I, which provides the entire spectrum of basic neurodynamic processes. A decrease in activation-energy and other neurodynamic components of brain function creates prerequisites for impaired concentration, perception of information, memory loss, and slowed mental processing speed. Disorganization of these components of cognitive reserve inevitably leads to the formation of profound cognitive deficits.

FINDINGS

1. Reliable signs of disorganization of nonspecific brain systems were revealed: the latent period of desynchronization increased by 2.33 times; latent period of transition to synchronization register increased by 2.14 times, and depth factor desynchronization decreased by 1.22 times, which indicates a significant violation of activation processes of the cerebral cortex.

2. The indicators of tone and energy of the cerebral cortex in the main sample were 2.8 times lower than normative values, which is an objective sign of a decrease in wakefulness level.

3. In patients with psychopathology, a moderate but reliable tendency to increase paroxysmal activity was revealed. The number of EEG flashes exceeded normal values by 2.5 times, which indicates a decrease in functional state of the posterior hypothalamus and lower brainstem during activation of nonspecific and specific nuclei of the thalamus.

Thus, EEG study of the main neurodynamic components of brain activity that determine the cognitive resource and mental performance of an individual may be very useful in objectifying functional cognitive disorders. It can also be important in choosing pathogenetic treatment of psychopathological disorders.

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

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