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Visual-graphic spiral pattern can reduce medical-associated stress during the geomagnetic storm

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Introduction. About 18% of all health problems in the working population are related to stress, depression and anxiety. The consequences of industrial stress exacerbated by unfavorable geomagnetic activity, can manifest itself in an increase in the psychophysiological “price” of activity, overstrain and depletion of the regulatory mechanisms of functional systems that ensure the adaptation of the body to vital factors and, ultimately, in a significant deterioration in the health of workers. Medical workers occupy a special place in the structure of professional groups of the working population, since they are at increased risk of neuro-emotional overstrain up to the development of professional burnout syndrome.

The aim of the study is to develop and test a technique that helps to reduce the level of stress and emotional load affecting the psychophysiological state of a person.

Materials and methods. The study involved 15 relatively healthy medical students aged 19 to 25 years. The algorithm of the study was as follows: the forecast of geomagnetic storms (G3-5) was tracked on the website of the Laboratory of X-ray Astronomy of the Sun (<https://tesis.lebedev.ru/>). During the storm a student was given the graphic task, in the form of synchronous outlines of stencils with two hands, before and after completing the experimental task the subject was asked to pass psychological tests: a visual-analog scale of situational emotional state according to the Dembo-Rubinstein method and the Spielberger-

Khanin scale of personal and situational anxiety (STAI). The electroencephalogram was recorded using an electroencephalograph recorder "Encephalan-EEGR-19/26".

Results. The Dembo-Rubinstein technique showed that after passing the experimental task 21% of the subjects significantly improved their emotional state according to a quantitative assessment of the visual-analog scale of situational emotional state. The level of personal anxiety also significantly decreased by 5% and the level of situational anxiety did not change, the assessment was carried out using the Spielberger-Khanin scale of personal and situational anxiety (STAI).

Limitations. The obtained results require further verification on the larger experimental groups with the involvement of medical workers of different age and specialties; lengthening the period of observation of the recorded indicators after completing of the tactile-graphical task to clarify the timing of changes in indicators of situational emotional state and personal anxiety.

Conclusions. A simple technique for reducing stress levels in medical students has proved its effectivity in changing the psychophysiological manifestation of stress, since the level of stress activity is directly related to the degree of personal anxiety. This technique can be recommended to medical workers and students as an exercise to improve cognitive activity by reducing stress and anxiety associated with the influence of geomagnetic storms, which increase sensitivity to external stress factors, on the psychophysiological state of a person.

Key words: geomagnetic storm, stress, students, electroencephalogram, spiral, Spielberger-Khanin scale.

Compliance with ethical standards. Informed consent was obtained from all individual participants involved in the study.

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Визуально-графический спиральный узор может улучшить психофизиологическое состояние во время геомагнитной бури

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Введение. Около 18% всех проблем со здоровьем работающего населения приходится на стресс, депрессию и беспокойство. Последствия производственного стресса, усугубленные неблагоприятной геомагнитной активностью, могут проявляться в повышении психофизиологической «цены» деятельности, перенапряжении и истощении регуляторных механизмов функциональных систем, обеспечивающих адаптацию организма к факторам жизнедеятельности и, в конечном итоге, в значительном ухудшении состояния здоровья работающих. Медицинские работники занимают особое место в структуре профессиональных групп трудоспособного населения, поскольку они подвергаются повышенному риску нервно-эмоционального перенапряжения в плоть до развития синдрома профессионального выгорания.

Цель исследования – разработка и апробация методики, способствующей снижению уровня стрессовой нагрузки и улучшающей психофизиологическое состояние человека. Методы. В исследовании приняли участие 15 относительно здоровых испытуемых студентов-медиков в возрасте от 19 до 25 лет. Алгоритм проведения исследования был следующим: прогноз геомагнитных бурь (G3-5) отслеживался на сайте Лаборатории рентгеновской астрономии Солнца, ФИАН (<https://tesis.lebedev.ru/>). Во время бури студенту давали тактильно-графическое задание в виде синхронных обведений трафаретов двумя руками, до и после выполнения которого испытуемому предлагалось пройти психологические тесты: визуально-аналоговая шкала ситуативного эмоционального состояния по методике Дембо-Рубинштейна и шкала личностной и ситуативной тревожности Спилбергера-Ханина (STAI). Проводилась регистрация электроэнцефалограммы при помощи электроэнцефалографа-регистратора "Энцефалан-ЭЭГР-19/26".

Результаты. Проведение количественной оценки визуально-аналоговой шкалы ситуативного эмоционального состояния по методике Дембо-Рубинштейн показало, что после прохождения экспериментального задания, у 21% испытуемых достоверно улучшилось эмоциональное состояние. Так же достоверно уменьшился уровень личностной тревожности на 5% и не изменился уровень ситуативной, оценка проводилась при помощи шкалы личностной и ситуативной тревожности Спилбергера-Ханина (STAI).

Ограничения исследования. Полученные результаты требуют верификации на более масштабных выборках с вовлечением медицинских работников разных возрастных групп и специальностей; удлинения срока наблюдения за фиксируемыми показателями после выполнения тактильно-графического задания для уточнения сроков изменения показателей ситуативного эмоционального состояния и личностной тревожности.

Заключение. Методика снижения уровня стресса у студентов медицинских вузов, которая оказалась проста в применении и эффективна в изменении психофизиологического проявления стресса, так как уровень стрессовой активности напрямую связан со степенью личностной тревожности. Данную методику можно рекомендовать

медицинским работникам и студентам, в качестве упражнения для улучшения когнитивной деятельности путем снижения напряжения и тревоги, связанных с влиянием геомагнитных бурь, увеличивающих чувствительность к внешним стрессовым факторам.

Ключевые слова: геомагнитная буря; стресс; студенты; электроэнцефалограмма; спираль; шкала Спилбергера-Ханина

Соблюдение этических стандартов: Информированное согласие было получено от всех отдельных участников, участвовавших в исследовании.

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Introduction

Stress is the process of adapting to circumstances that disrupt or threaten to imbalance the body [1]. A small stress or the optimal level of stress is necessary for a person's activity to overcome the obstacles that arise on the way to the goal achievement. This mobilizing, energizing stress makes a person active, ready for action, increasing the strength and speed of his physical and mental reactions, sharpening attention, memory, mental activity, etc. [2, 3].

The geomagnetic storms are powerful changes in the Earth's electromagnetic field, which occur due to the release of a huge number of high-speed streams during increased solar activity. Storms such as a blow of a stone on the water surface, disturb the established processes on our planet by creating temporary chaos and affecting circadian rhythms [4, 5, 6]. It was noted that geomagnetic storms can negatively affect self-motivation, reduce the learning abilities and sometimes cause depression. Thus, the main targets of solar flares are the cardiovascular and nervous systems. In healthy people effects can be manifested in time elongation of simple locomotor reaction to the velocity of the visual information processing, worsening of the attention characteristics, short and long-term memory. One of the reasons for such changes is an increase in the release of stress hormones (cortisol, adrenaline), which in turn leads to the manifestation of stressful activity and an increase in the influence of stress factors on the body [7]. This increases a person's susceptibility to stress and also been reported as suicide risk factor [8]. Nowadays informational and social stress exposure appears to be the most frequent in modern human reality.

The study of the influence of magnetic storms on living organisms possess a great importance. For the first time the hypothesis of the synchronization of biological rhythms by weak cyclic variations of geophysical fields was proposed by F. Brown (1964), who discovered the correlation of certain biological indicators of organisms placed in "permanent" conditions with the parameters of the external environment. Disturbances of electromagnetic fields in heliobiological connections are usually considered as something that brings disorganization and leads to functional disorders. It should be noted that L. Chizhevsky, the founder of heliobiology, was the first to pay attention to this problem [9]. In the process of increasing interest in phenomena occurring in the space with the development of outer space, interest in studying the relationship between solar activity and the Earth's biosphere began to increase. At present, a large amount of factual data has been accumulated on the effect of solar activity on wildlife, including humans [10]. The idea of the influence of solar activity on the body significantly affects modern human life. Television, radio, polyclinics warn the population about solar flares, geomagnetic storms they cause, and about ways to protect themselves from their effects. Numerous experiments show that there is a direct effect of short-period oscillations of the geomagnetic field on the human body. This fact is of great scientific and practical importance, since during disturbances of the Earth's magnetic field (magnetic storms), short-period oscillations of the geomagnetic field are recorded, which negatively affects the human body. At present, the term "space weather" is widely used and unites under this name a number of helio-geophysical phenomena that develop in near-Earth outer space and actively affect the Earth's biosphere. Electromagnetic

and infrasonic vibrations are often considered as a mechanism for the impact of solar and magnetic storms on a living organism, which are close in their frequencies to the natural frequency of many internal organs (0.1–10 Hz). These vibrations, emitted by the active magnetosphere and ionosphere, can resonantly affect a living organism on a cellular basis.

Some authors believe that weak magnetic storms with a 27-day cyclicity can be classified as “impulse sensors” of biorhythms, and sporadically occurring storms that are responses to solar flares, on the contrary, are “interference”, a desynchronizing factor. During electromagnetic disturbances (especially during magnetic storms), when the rhythm-setting organization of the external environment is destroyed, violations of biological rhythms are observed, which can cause a violation of the activity of the functional systems of the body [10]. The main targets affected by solar activity are the heart and the cardiovascular system [11]. The works of T.K. Breus [9] revealed the presence during geomagnetic disturbances in 85% of patients after myocardial infarction, ischemic-type heart rhythm disorders, sometimes accompanied by episodes of arrhythmia and increased blood pressure (13 patients); the presence of changes in the rheological properties of blood and capillary blood flow in 80% of patients with coronary heart disease and in 30% of healthy people during geomagnetic storms, such as a slowdown in capillary blood flow, erythrocyte aggregation, and an increase in blood viscosity (82 patients and 12 healthy people); an increase in the hormone cortisol and a decrease in the production of the hormone of the pineal gland - melatonin - in response to geomagnetic disturbances in both healthy and sick people.

In addition to the cardiovascular system, brain cells are especially sensitive to electromagnetic effects, which is manifested by an increase in the number of convulsive seizures in patients with epilepsy on days of magnetic storms. This is due to the direct, rather than reflex (as previously thought) influence of an alternating magnetic field of low frequency and intensity on the functional state of the cells of the central nervous system [12]. Though such studies especially concerning occupational medicine are very limited.

In the modern COVID-19 pandemic conditions doctors, as well as medical workers and students in general, experience a significant increase in professional workload, as well as the aggravation of contradictions between the professional and moral duty of a doctor and his ability to provide highly qualified medical care to the population [13].

The work of most doctors and volunteering medical students is characterized by a significant intellectual load, in some cases it is accompanied by great physical effort, but always places increased demands on the volume of operational and long-term memory, attention, endurance, long-term preservation of working capacity, as well as on the totality of personal qualities of a doctor that allow him to work in contact with sick people throughout his professional experience while maintaining the necessary level of professionalism and compassion [14, 15].

About 18% of all health problems of the working population are related to stress, depression and anxiety. With regard to doctors, the authors are most concerned about the widespread prevalence of chronic fatigue syndromes and professional burnout, which experts associate with the social essence of the doctor's profession, that is, the need for constant emotional impact when working with sick people [16].

It should be noted that studies on the assessment of working conditions of doctors of various specialties and their impact on health have been carried out for a long time, mainly in the 70s and 80s of the last century. However, they paid primary attention to the traditional factors of the production environment and the labor process of physical, chemical and biological nature, while the complex of psychosocial factors affecting the formation of the health of these specialists remained less studied [17]. In recent years, domestic studies devoted to the work of doctors have been isolated, and as before, they focus on traditional factors of the working environment and occupational morbidity of medical workers, while the problems of patterns of formation and prevention of stress at work remain poorly studied [18].

At the same time, it is obvious that the professional activities of doctors can not only be the cause of the formation of occupational diseases, but also play an important role in the pathogenic mechanisms of the development and progression of other pathologies, including chronic fatigue syndrome and burnout syndrome, which most authors regard as clinical signs of chronic stress at work [19, 20].

Therefore, the creation of simple affordable quick and effective antistress trainings and exercises is quite an urgent task, especially if the trainings are relatively simple and adapted to the intensive rhythm of modern life. Over the past decade numerous health psychologists have cautiously begun looking at how the art therapy might be used in a variety of ways to heal emotional stress injuries, increase understanding of oneself and others, develop a capacity for self-reflection, reduce symptoms, and alter behaviors and thinking patterns. Given the ubiquity of creative expression, as well as the relative ease of engagement, the extent to which psychological and physiological effects are sustainably health enhancing is an important area for public health investigation. Certain graphical symbols can be a refuge from the intense emotions associated with chronic stress. There are no limits to the imagination in finding creative ways of expressing grief. For example, even a molding clay can be a powerful tool to help people express these feelings through tactile involvement at a somatic level, as well as to facilitate verbal communication and cathartic release and reveal unconscious materials and symbols that cannot be expressed through words [20].

The aim of this research is to evidence the hypothesis that working with visual-graphic spiral pattern can reduce stress symptoms and improve the cerebral activity in medical students during the severe geomagnetic storm.

Materials and methods

The experiment was conducted on 15 relatively healthy students of both sexes aged 19 to 25 years living in Crimea, who had experience of working in hospitals. Written informed consent was obtained from all subjects for the participation in the study.

The research algorithm was as follows: severe geomagnetic storms were traced on the website of Laboratory of X-ray astronomy of the Sun, Lebedev Institute, Russia (<https://tesis.lebedev.ru/>).

The students were requested to use thin transparent plastic plates in the form of rectangles measuring 30 x 20 cm with slits in the form of symmetrical straight and smooth lines having a configuration of movement in a certain direction and sequence (RF Patent No. 149915 of 12/17/2014 "Harmonization of the function of both cerebral hemispheres") for the accomplishment of the experimental antistress task. In particular the subjects were asked to outline the stencil No.12, which has slots in the form of two mirror-symmetrical spirals (Figure 1) for 5 minutes.

Each participant was circling both spirals from the center to the outside simultaneously with the fingers of both hands, randomly alternating fingers, the degree of pressing and the speed of circling. Provided exercise with the involvement of two hands synchronously allows to integrate the activities of both cerebral hemispheres along with the gentle self-massage of fingertips.

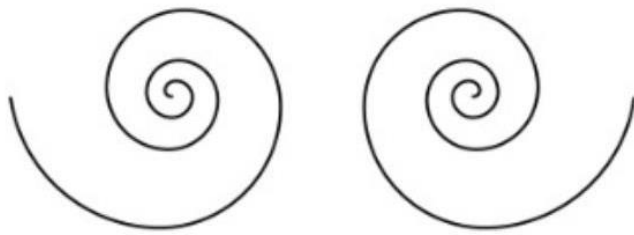


Figure 1. Antistress mirror-symmetrical spirals for simultaneous tracing with both hands.

Добавить переводы на русский язык названий и всей текстовой части рисунков (под соответствующей текстовой частью на английском, с новой строки).

Рисунок 1. Антистрессовые зеркально-симметричные спирали для синхронного обведения обеими руками.

During the storm student was given graphic task, before and after completing the experimental graphical task, the subject was asked to pass psychological tests: a visual analogue scale of the situational emotional state and the Spielberger-Khanin scale of personal and situational anxiety (STAI). The Spielberger-Khanin method consists of a questionnaire in which there are 40 statements. Positions 1 through 20 are focused on determining the level of situational anxiety. Positions numbered 21-41 will characterize personal anxiety. The State-Trait Anxiety Inventory (STAI) is a commonly used measure of trait and state anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). It can be used in clinical settings to diagnose anxiety and to distinguish it from depressive syndromes. It also is often used in research as an indicator of caregiver distress. Its form has 20 items for assessing trait anxiety and 20 for state anxiety. State anxiety items include: "I am tense; I am worried" and "I feel calm; I feel secure." Trait anxiety items include: "I worry too much over something that really doesn't matter" and "I am content; I am a steady person." All items are rated on a 4-point scale (e.g., from "Almost Never" to "Almost Always"). Higher scores indicate greater anxiety.

The electroencephalogram was recorded by the encephalograph Encephalo "Poly 6" for 1 minute before and after the experimental task in open/closed eyes state, 16 electrodes were used and placed according to the international scheme "10-20". The 10-20 system is based on the relationship between the location of the electrode and the main area of the brain, in particular the cerebral cortex. The 10-20 system is recommended by the International Federation of Electroencephalography and Clinical Neurophysiology. Each electrode position (lead) is identified by a letter (to identify the lobe of the brain) and a number (or other letter) to determine the location of the electrode within the lobe. Any electrode is located from other electrodes at a distance equal to 10 or 20% of some individually measured distances. The names of the electrodes include the first letter of the Latin name of the area on which the electrode is placed, and a number indicating the side and location of the electrode within this area.: pre-frontal (Fp), frontal (F), temporal (T), parietal (P), occipital (O), central (C), midline (Z). Odd numbers indicate the left hemisphere, even numbers indicate the right.

All quantitative data were represented as mean \pm SD. The software SPSS Statistics 22.0 (SPSS, Chicago, IL) was used to perform the statistical analysis. Wilcoxon test was applied to compare the results of psychological testing. One-way ANOVA (analysis of variance) was used to verify the differences between groups. Value of $p < 0.05$ was regarded as statistically significant.

Results

We have detected the changes influenced by the increased solar activity which affected the autonomic balance and the level of performance and reactive anxiety caused by the effects of magnetic storms on nonspecific systems and autonomic centers located in the structures of the limbic-reticular complex of the brain. The obtained data demonstrated that the subjects' emotional state significantly improved by 21% (Figure 2) from the initial value. The level of personal anxiety also significantly decreased by 5,0% (Figure 3).

The electrophysiological study showed that after completing the task the subjects showed an increase in the alpha rhythm in the occipital O2 lead, which might indicate the relaxation of the visual analyzer and the optimization of the perception mechanisms. A significant increase in the power of the theta rhythm in both hemispheres of the brain evidenced the improvement in the work of the visual analyzer associated with a decrease in the level of anxiety.

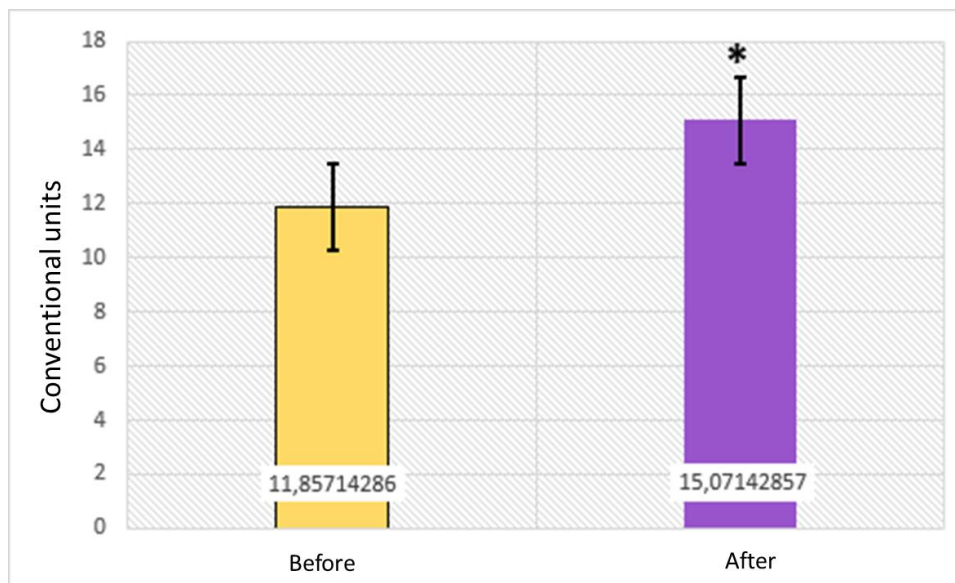


Figure 2. Comparison of changes in the general emotional state before and after the completion of the graphic task. N = 15. * $p \leq 0.05$ (Confidence level t-Wilcoxon test)

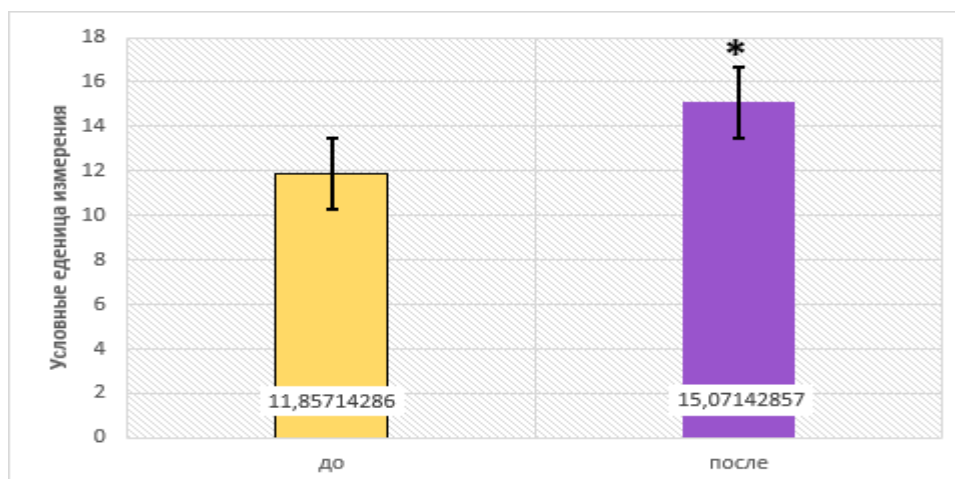


Рисунок 2. Сравнение изменения общего эмоционального состояния до и после выполнения графического задания. N = 15. Знаком «*» выделено достоверное изменение показателей $p \leq 0,05$ (t-критерий Вилкоксона)

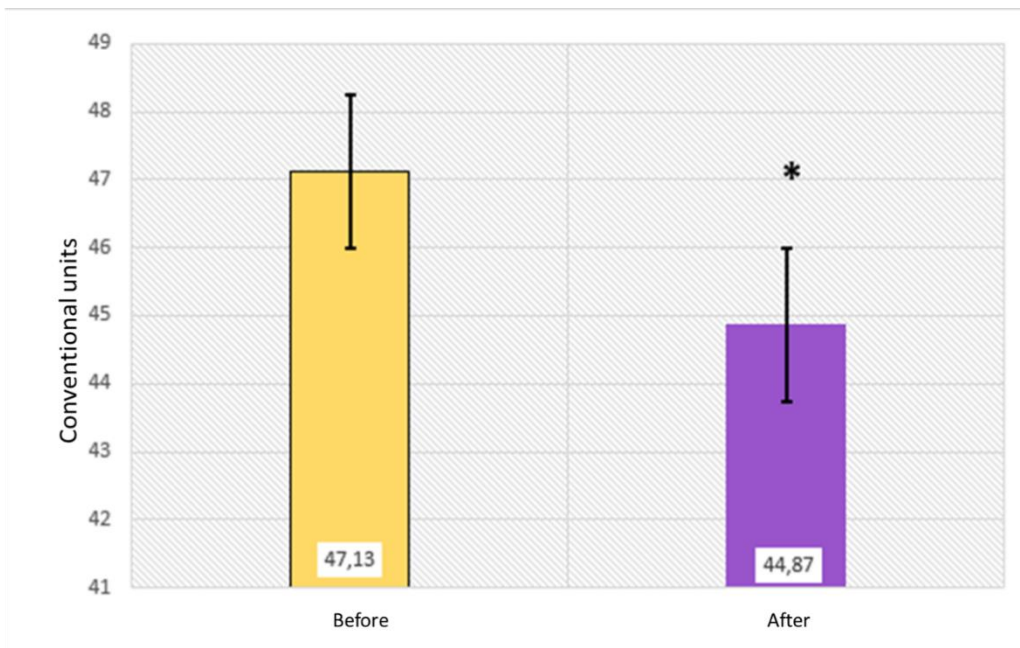


Figure 3. Comparison of changes in situational and personal anxiety, respectively, before and after the graphical task. N = 15. * $p \leq 0.05$ (Confidence level t-Wilcoxon test)

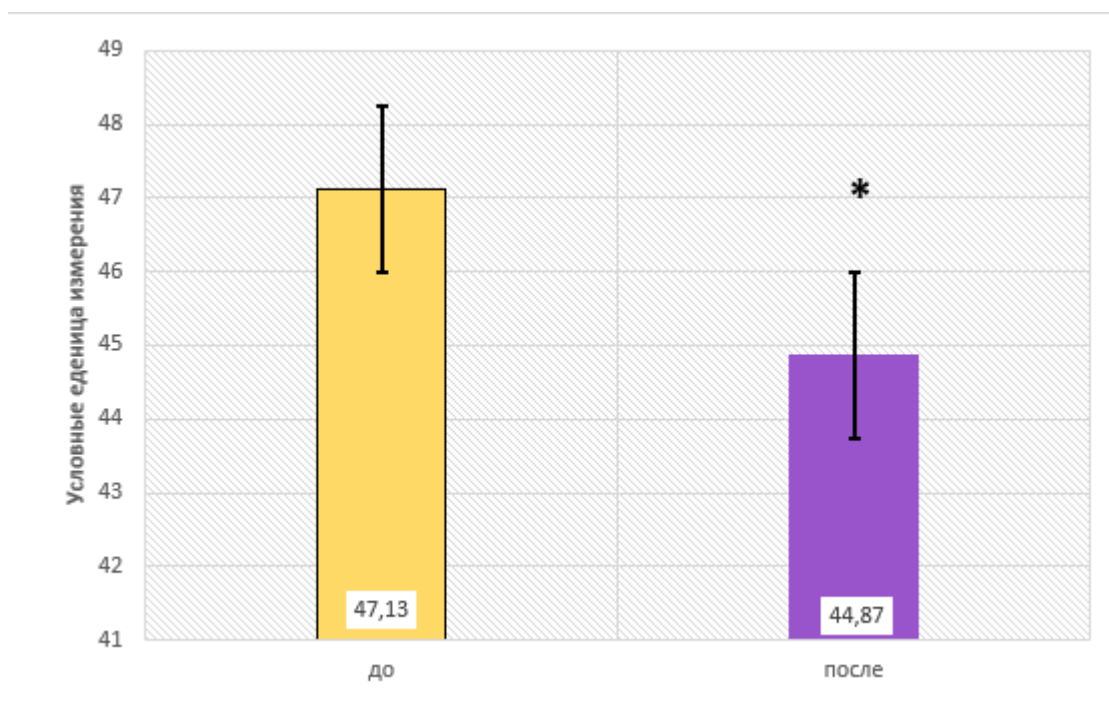


Рисунок 3. Сравнение изменения ситуативной и личностная тревожности соответственно до и после выполнения графического задания. N = 15. Знаком «*» выделены достоверное изменение показателей $p \leq 0,05$ (t-критерий Вилкоксона)

A significant increase in the power of the beta rhythm occurred in lead P4 (Table 1), this lead corresponded to the right parietal lobe of the brain.

Table 1. Comparison of changes in the power of brain rhythms before and after performing a graphic task with open eyes

Lead	Rhythms									
	Alpha		Beta		Delta		Gamma		Theta	
	before	after	before	after	before	after	before	after	before	after
P4	116,65±7,2,52	156,57±99,01	1029,26±269,62*	1111,41±269,41*	494,21±87,29	402,65±67,99	428,93±123,48	529,85±383,46	132,48±126,11	220,67±60,43
O1	134,12±2,3,55	166,03±21,22	1048,14±277,21	1134,89±266,56	312,17±78,66	439,54±96,57	429,31±120,83	530,23±380,61	132,04±18,36*	235,09±66,81*
Oz	122,67±7,2,63	161,68±22,91	1045,61±272,91	1130,73±266,33	315,83±77,25	449,03±55,03	429,74±21,80	530,75±381,67	132,06±17,82*	246,08±91,64*
O2	133,64±2,3,21*	171,37±24,74*	1050,01±273,371	1136,84±265,83	316,41±82,59	448,40±58,32	429,17±120,63	530,91±379,26	132,44±19,11**	237,95±76,95**

Note: mean ± SD, unit of measurement μV^2 . Wilcoxon t-test. * $p \leq 0,05$, ** $p \leq 0,01$

Таблица 1. Сравнение изменения мощности ритмов головного мозга до и после выполнения графического задания при открытых глазах

Отведение	Ритмы									
	Альфа		Бета		Дельта		Гамма		Тета	
	до	после	до	после	до	после	до	после	до	После
P4	116,65±7,2,52	156,57±99,01	1029,26±269,62*	1111,41±269,41*	494,21±87,29	402,65±67,99	428,93±123,48	529,85±383,46	132,48±126,11	220,67±60,43
O1	134,12±2,3,55	166,03±21,22	1048,14±277,21	1134,89±266,56	312,17±78,66	439,54±96,57	429,31±120,83	530,23±380,61	132,04±18,36*	235,09±66,81*
Oz	122,67±7,2,63	161,68±22,91	1045,61±272,91	1130,73±266,33	315,83±77,25	449,03±55,03	429,74±21,80	530,75±381,67	132,06±17,82*	246,08±91,64*
O2	133,64±2,3,21*	171,37±24,74*	1050,01±273,371	1136,84±265,83	316,41±82,59	448,40±58,32	429,17±120,63	530,91±379,26	132,44±19,11**	237,95±76,95**

Приведено среднее значение и ошибка среднего, единица измерения μV^2 . t-критерий Вилкоксона. «*» выделены достоверное изменение показателей $p \leq 0,05$. «**» выделены достоверное изменение показателей $p \leq 0,01$

At the same time in a state with closed eyes there was noted a significant increase in the alpha and decrease in the delta rhythm (Table 2).

Table 2. Comparison of changes in the power of brain rhythms before and after performing a graphic task with closed eyes

Lead	Rhythms									
	Alpha		Beta		Delta		Gamma		Theta	
	before	after	before	after	before	after	before	after	before	after
C3	97,48 ±23,6 5	125,4 2±16, 34	1066, 29±7 05,03	1365,91 ±593,8 5	118,54 ±45,6 2*	94,52 ±29,0 7*	463,14 ±175,3 7	536,55 ±425,3 8	56,55 ±36,8 3	58,51 ±22,7 3
Cz	84,94 ±19,6 3	108,2 7±59, 21	1062, 54±6 98,48	1360,24 ±589,6 3	116,41 ±35,6 9*	97,49 ±29,7 6*	462,48 ±173,3 4	536,24 ±424,6 2	61,40 ±28,0 2	62,26 ±23,5 1
C4	92,51 ±19,8 4	119,7 8±64, 38	1065, 08±7 01,93	1359,07 ±587,6 5	119,02 ±38,2 2*	94,96 ±81,0 4*	462,23 ±172,7 6	535,49 ±423,5 2	56,66 ±26,4 9	58,19 ±25,7 8
P3	252,7 1±75, 76	321,3 5±21, 76	1084, 53±7 07,06	1376,49 ±595,2 4	142,42 ±63,7 8	114,64 ±19,7 2	463,09 ±172,0 4	536,67 ±423,0 5	72,14 ±35,3 7	77,91 ±36,6 2
Pz	210,5 8±51, 25	282,9 5±21, 92	1077, 08±7 01,20	1371,23 ±597,6 3	139,23 ±57,5 6	191,19 ±18,5 9	463,14 ±172,3 1	536,91 ±423,6 4	73,53 ±46,8 4	92,35 ±41,8 2
P4	251,4 4±109 ,43	349,4 4±65, 84	1083, 82±7 11,95	1377,85 ±601,0 6	214,74 ±61,6 1	116,63 ±83,4 6	464,39 ±175,1 2	538,58 ±428,2 5	73,54 ±48,6 1	80,41 ±64,8 2
O1	314,9 3±119 ,43*	407,4 8±88, 33*	1102, 49±7 49,74	1389,35 ±367,2 1	214,74 ±35,2 9	213,43 ±52,4 4	463,81 ±169,5 6	538,14 ±1424, 15	82,27 ±59,2 8	117,13 ±87,1 7
Oz	283,5 7±92, 91*	365,9 1±59, 35*	1095, 14±7 34,29	1390,54 ±614,1 7	166,52 ±94,2 5	227,65 ±29,1 1	463,96 ±168,7 9	539,03 ±425,5 9	84,47 ±53,1 5	85,37 ±47,3 5
O2	332,6 3±140 ,89*	446,7 1±53, 08*	1094, 71±7 30,83	1392,98 ±609,2 6	169,26 ±95,2 4	134,22 ±9,94	462,83 ±165,6 9	539,38 ±127,0 5	83,64 ±48,5 5	88,79 ±51,2 6

Note: mean ± SD, unit of measurement μV^2 . Wilcoxon t-test. * $p \leq 0.05$, ** $p \leq 0.01$

Таблица 2. Сравнение изменения мощности ритмов головного мозга до и после выполнения графического задания при закрытых глазах

Отведе	Ритмы									
	Альфа		Бета		Дельта		Гамма		Тета	
	до	после	до	после	до	после	до	после	до	после
C3	97,48± 23,65	125,42 ±16,34	1066, 29±70 5,03	1365,91 ±593,85	118,54 ±45,62 *	94,52± 29,07*	463,14 ±175,3 7	536,55± 425,38	56,55 ±36,8 3	58,51± 22,73
Cz	84,94± 19,63	108,27 ±59,21	1062, 54±69 8,48	1360,24 ±589,63	116,41 ±35,69 *	97,49± 29,76*	462,48 ±173,3 4	536,24± 424,62	61,40 ±28,0 2	62,26± 23,51
C4	92,51± 19,84	119,78 ±64,38	1065, 08±70 1,93	1359,07 ±587,65	119,02 ±38,22 *	94,96± 81,04*	462,23 ±172,7 6	535,49± 423,52	56,66 ±26,4 9	58,19± 25,78
P3	252,71 ±75,76	321,35 ±21,76	1084, 53±70 7,06	1376,49 ±595,24	142,42 ±63,78	114,64 ±19,72	463,09 ±172,0 4	536,67± 423,05	72,14 ±35,3 7	77,91± 36,62
Pz	210,58 ±51,25	282,95 ±21,92	1077, 08±70 1,20	1371,23 ±597,63	139,23 ±57,56	191,19 ±18,59	463,14 ±172,3 1	536,91± 423,64	73,53 ±46,8 4	92,35± 41,82
P4	251,44 ±109,4 3	349,44 ±65,84	1083, 82±71 1,95	1377,85 ±601,06	214,74 ±61,61	116,63 ±83,46	464,39 ±175,1 2	538,58± 428,25	73,54 ±48,6 1	80,41± 64,82
O1	314,93 ±119,4 3*	407,48 ±88,33 *	1102, 49±74 9,74	1389,35 ±367,21	214,74 ±35,29	213,43 ±52,44	463,81 ±169,5 6	538,14± 1424,15	82,27 ±59,2 8	117,13 ±87,17
Oz	283,57 ±92,91 *	365,91 ±59,35 *	1095, 14±73 4,29	1390,54 ±614,17	166,52 ±94,25	227,65 ±29,11	463,96 ±168,7 9	539,03± 425,59	84,47 ±53,1 5	85,37± 47,35
O2	332,63 ±140,8 9*	446,71 ±53,08 *	1094, 71±73 0,83	1392,98 ±609,26	169,26 ±95,24	134,22 ±9,94	462,83 ±165,6 9	539,38± 127,05	83,64 ±48,5 5	88,79± 51,26

Приведено среднее значение и ошибка среднего, единица измерения мкВ². t-критерий Вилкоксона. «*» выделены достоверное изменение показателей $p \leq 0,05$.

A coherent analysis of the connection between the frequency characteristics of the analyzed leads was used to reveal the patterns of connections between processes in the brain of the subjects before and after the performance of the tactile-graphic task. The analysis took into account only those relationships that are significant at $p \leq 0.05$. As a result we have found that in the states with open or closed eyes prior to performing the experimental task, the indicators of interhemispheric connections when performing coherent analysis corresponded to the normal values.

After completing the experimental task in a situation with open eyes it can be noted that there is an active displacement of interhemispheric connections to the frontal area, connections appear that were not there before the task was completed, and connections become less pronounced in the occipital lobe (Figure 4). An increase in the number of interhemispheric connections of coherent waves of delta and gamma rhythms, with a decrease in the strength of these connections, indicates a decrease in general or personal anxiety, which was previously confirmed by the results of psychological testing. The involvement of both sides of the frontal lobe of the brain is noted in the study of theta rhythm, which may indicate the beginning of the

manifestation of a relaxed state or a state of consciousness close to a similar one during the process of creative activity.

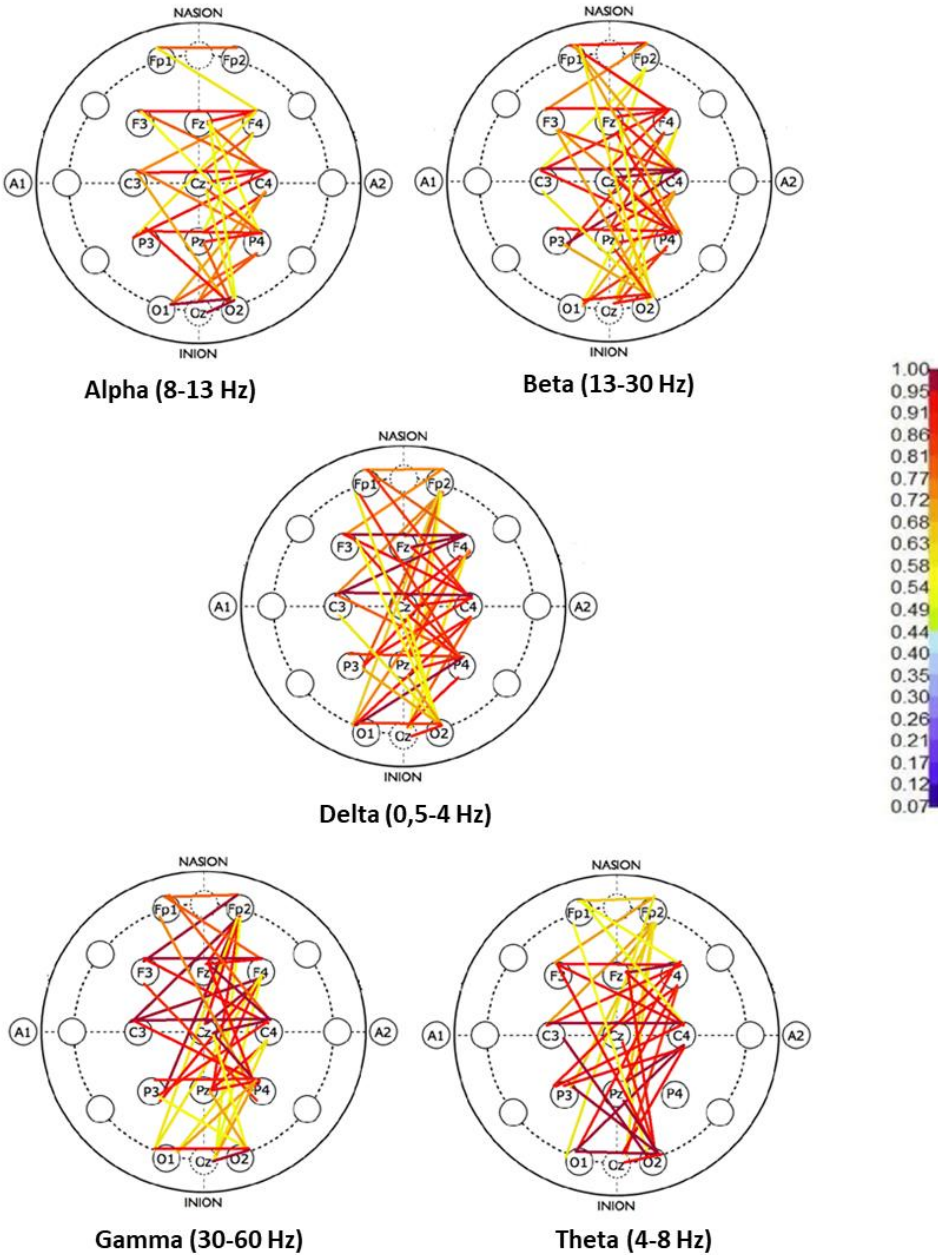


Figure 4. Coherent analysis, the relationship of frequency characteristics between the hemispheres of the brain in a situation with open eyes after completing the task. Only significant interhemispheric connections are shown at $p \leq 0.05$ (ANOVA).

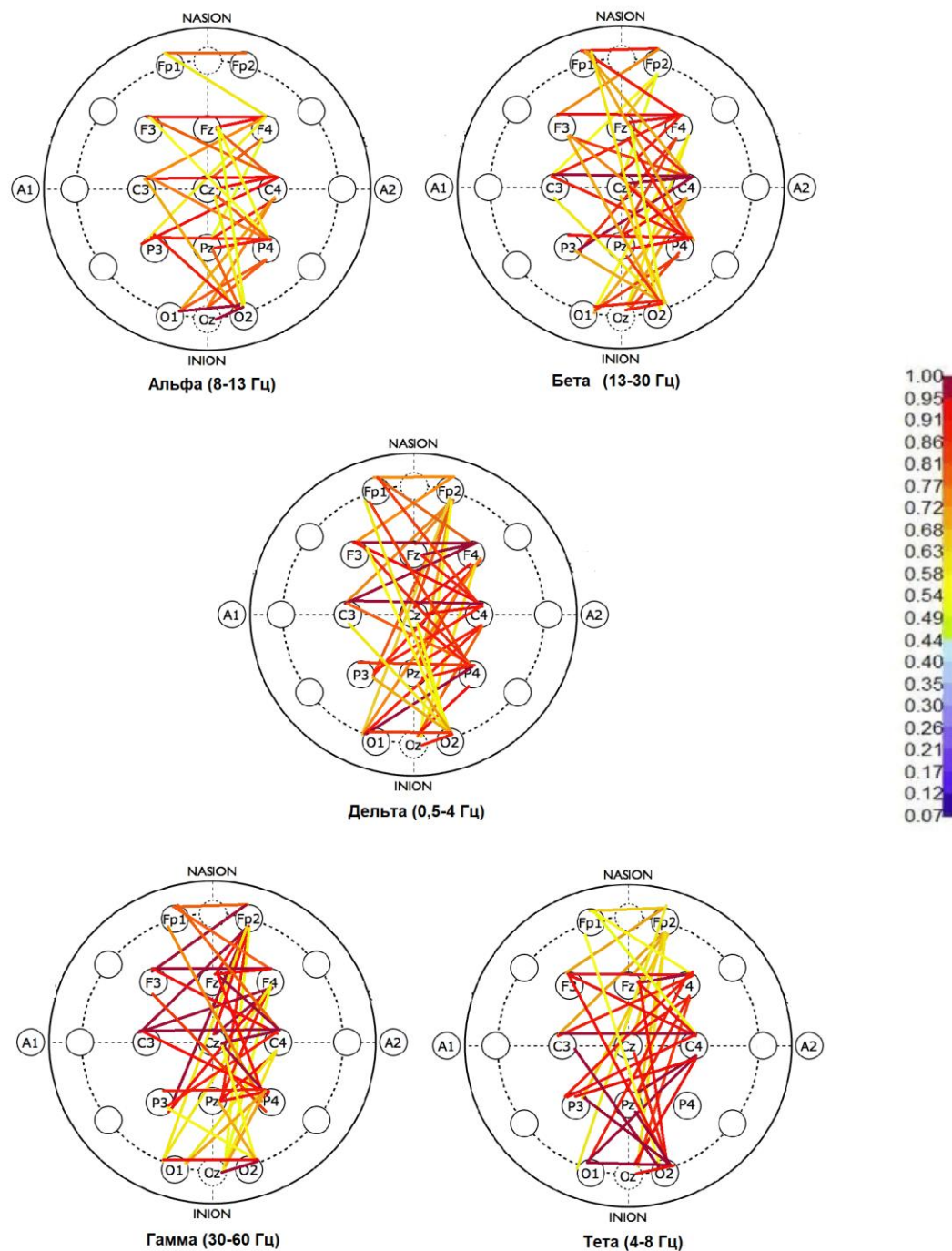


Рисунок 4. Когерентный анализ связей частотных характеристик между полушариями головного мозга в ситуации с открытыми глазами после выполнения задания. Показаны только достоверные межполушарные связи при $p \leq 0,05$ (ANOVA).

The analysis of the electroencephalogram obtained after performing a sensory-tactile task with closed eyes demonstrated an active displacement of interhemispheric connections from the frontal region to the prefrontal and post- and precentral regions of the brain (Figure 5). Such displacement can occur due to the process of visual and mental relaxation. The interhemispheric connections formed by the alpha rhythm were redistributed in such a way that the Fp 1, F 4 and P 4 connections were activated. The generation of coherent waves of the beta rhythm increased

with narrowing of the generation area with a shift in emphasis to the central region of the brain, which indicated the transition of the information processing process from a more conscious level to a subconscious level. Indicators of the gamma rhythm have not changed significantly, since closing the eyes always increases the level of situational anxiety.

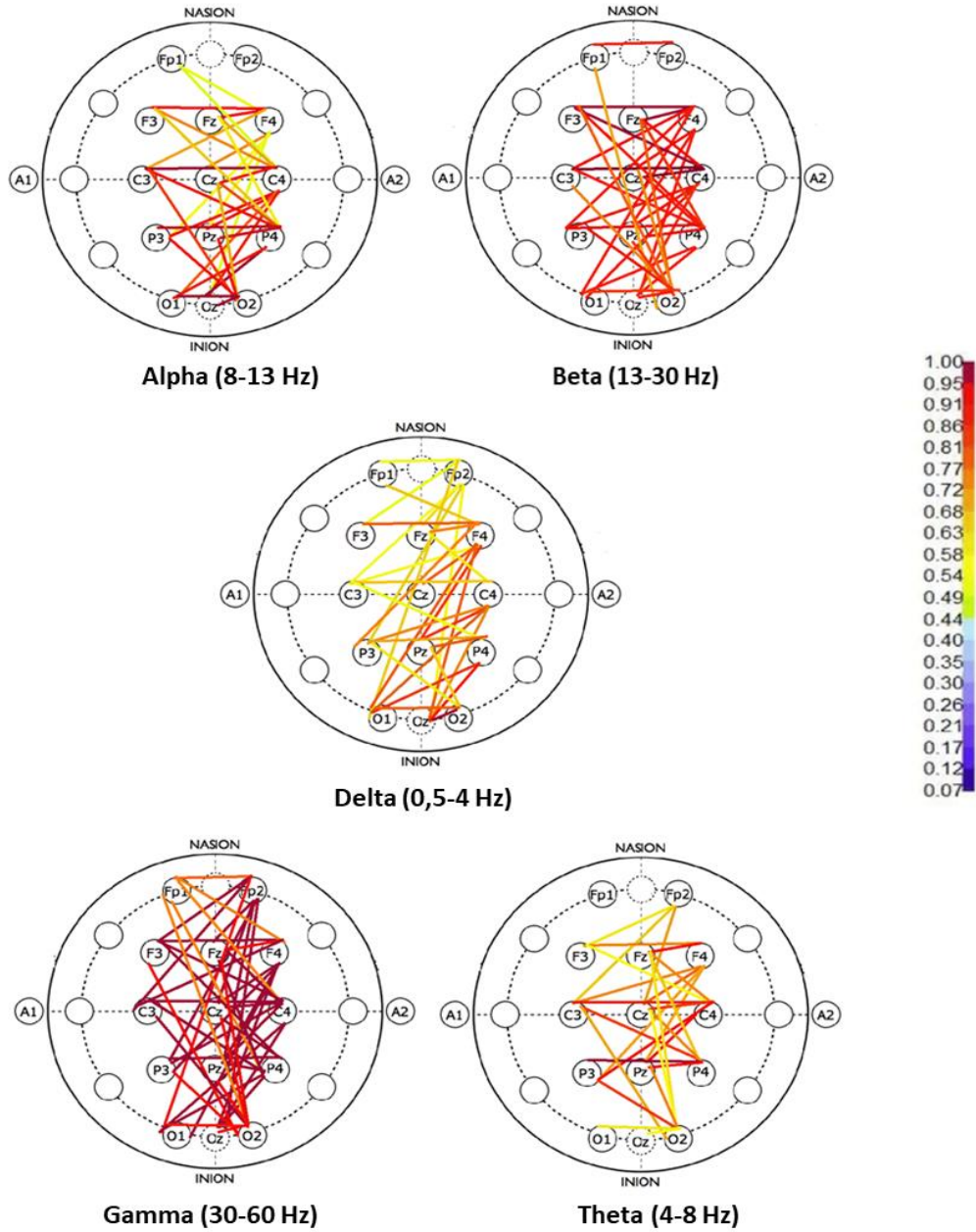


Figure 5. Coherent analysis, the relationship of frequency characteristics between the hemispheres of the brain in a situation with open eyes after completing the task. Only significant interhemispheric connections are shown at $p \leq 0.05$ (ANOVA).

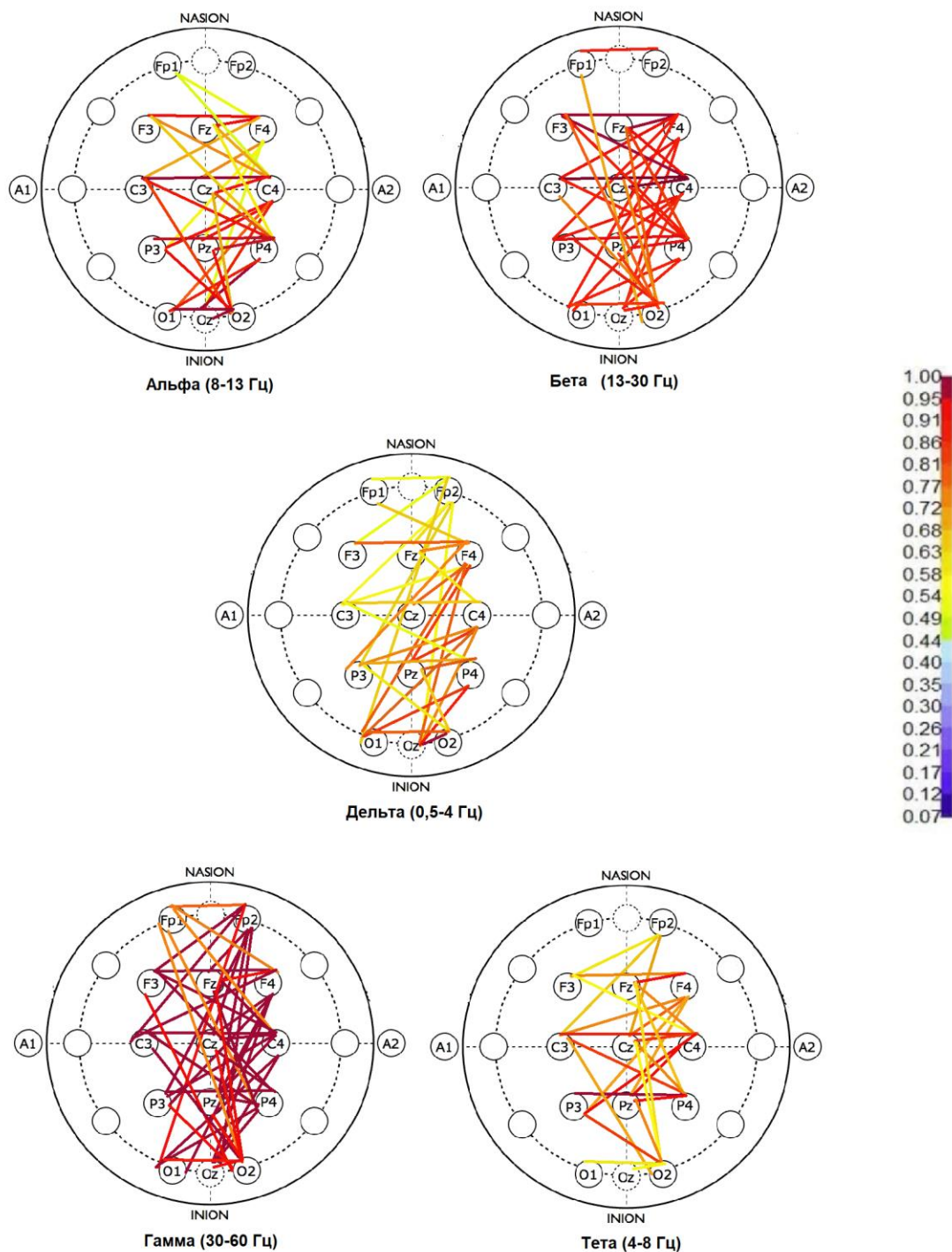


Рисунок 5. Когерентный анализ связей частотных характеристик между полушариями головного мозга в ситуации с закрытыми глазами после выполнения задания. Показаны только достоверные межполушарные связи при $p \leq 0,05$ (ANOVA).

Discussion

In past years the problem of biosphere and information stress is one of the topical issues of modern society. Our century is considered the century of the "information explosion". Medical

practice has been identified as one of the most stressful professions within the healthcare systems. The global prevalence of workplace stress among nurses was reported to be around 9%–68%, varying across different countries and specialty sectors within healthcare institutions [14, 18, 19]. Stress does not only affect the level and quality of people's vital functions, but also has a negative effect on the cognitive functioning, as a result of which cognitive abilities deteriorate [17, 18]. The stressful work environment has been reported to cause negative consequences to most healthcare institutions, with hospital managers having to deal with a high number of cases on workers absenteeism, turnover intentions, medical errors, and impaired job performances [13]. Such situations were prone to compromise the quality of health service delivery and patient satisfaction.

Factors associated with perceived psychological stress among medical workers can be exacerbated by another nonoccupational risk factors. Stress awakens negative emotions such as fear, anxiety, irritability which can be additionally exacerbated by geomagnetic storms [20, 21, 22]. It is known that the point of application of geomagnetic fields are the regulatory systems of the body, the main of which are the integrative apparatuses of the brain. Apparently, magnetic storms primarily affect the nonspecific systems of the brain, i.e. structures of the limbic-reticular complex, responsible for the "tuning" of higher mental functions, emotional reactions and autonomic regulation for the implementation of the current activity of the body. [4, 5, 6].

The neurological state of medical students before the beginning of the research observed during severe electromagnetic storm was characterized by high level of anxiety and decreased function of analyzers. This differentiation manifests itself in the stress of the brain processing information. In this case mainly the left hemisphere is involved. At the same time, the right one is idle, thereby violating the interhemispheric balance. Undoubtedly such students could demonstrate relatively poor learning abilities.

This experiment can represent the negative effect of severe geomagnetic storm on brain activity that might lead to various neuropsychiatric disturbances such as anxiety and mild depression. Due to the influence of magnetic fields on the pineal gland, it is possible that these effects are mediated through alterations in melatonin production. Phase advance in pineal circadian rhythms of melatonin synthesis may be a possible mechanism of causation, or be present as a consequence of 5-hydroxytryptamine or adrenergic system dysfunction associated with geomagnetic disturbances. Increased cell membrane permeability and calcium channel activity are suggested as possible underlying biochemical mechanisms of geomagnetic storm effects [21, 22].

It is also known that people and particularly medical workers experiencing chronic stress due to different reasons are reported to be at a higher risk of making poor decisions; display hostile attitude toward patients; make more medical errors; and have difficult relationships with co-workers. Burnout due to stress among doctors also increases risk of depression; anxiety; sleep disturbances; fatigue; alcohol and drug misuse; marital dysfunction; premature retirement and perhaps most seriously suicide. Nowadays many health care workers experiencing chronic stress are also reported to be at greater risk of making poor judgment or errors in patient care, disengaging from work, demonstrate hostility toward patients, have diminished commitment and dedication to productive, safe, and optimal patient care as well as have difficult relationships with co-workers [15]. Therefore geomagnetic storm and daily work stress can summarize their negative effects, that multiple stress situations require more detailed studies.

The electrophysiological study showed that after completing the graphical task the ECG of subjects showed an increase in the alpha and theta rhythms which may indicate the relaxation state and the significant improvement in the work of the visual analyzer associated with a decrease in the level of anxiety [23].

Application of the visual-graphic therapy does not contradict the medical view in bringing emotional, somatic, artistic, and spiritual dimensions to learning. Rather, it complements the

biomedical view by focusing on not only sickness and symptoms themselves but the holistic nature of the person. It was found by numerous studies that those patients who were engaged in art therapy demonstrated statistically significant decreases in symptoms of physical and emotional distress during treatment. In addition to the introduction of self-care through guided imagery, the art-making therapy involved the women drawing complete pictures of themselves and engaging in meditation [24]. The relaxation and symptom reduction produced by creative expression opened pathways to emotional healing as it was partially observed in our experiment.

A significant increase in the power of the beta rhythm was noted in lead P4, such kind of change can be interpreted as an intensification of the processes of spatial perception of time and the flow of a conscious thought process [25, 26]. With closed eyes there was a significant increase in the alpha and decrease in the delta rhythm, which may indicate the acceleration and facilitation of the analysis of previously obtained visual information [27, 28].

After completing the experimental task with open eyes there was traced an active displacement of interhemispheric connections to the frontal area, connections appeared that were not there before the task was completed, and in the occipital lobe the connections became less pronounced. Such changes indicate the activation of the thinking process associated with analytical activity. The interhemispheric connections formed by the alpha rhythm were redistributed in such a way that the right hemisphere became the accent hemisphere, and the connections between the occipital leads were mainly activated, which demonstrates a relaxing effect on the process of visual analysis. A new connection appeared between leads Fp 1 and F 4 probably due to the activation of the mental process of processing visual information against the background of a decrease in anxiety. The generation of coherent waves of the beta rhythm with a shift in emphasis on the frontal lobes has intensified and enlarged, which indicates an increase in the awareness of the perception of reality [26, 29].

The electroencephalograms obtained after performing a sensory-tactile task with closed eyes demonstrated an active displacement of interhemispheric connections from the frontal region to the prefrontal and post- and precentral regions of the brain. Such displacement can occur due to the process of visual and mental relaxation. The interhemispheric connections formed by the alpha rhythm were redistributed and some connections were activated. This indicated the manifestation of a relaxing effect on the more active left hemisphere (which is active, since all the subjects are right-handed), which evidenced for the decrease in cognitive load and the extinction of internal stress self-dialogue [30]. The generation of coherent waves of the beta rhythm increased with narrowing of the generation area with a shift in emphasis to the central region of the brain, which indicated the transition of the information processing process from a more conscious level to a subconscious level. This situation is typical for the relaxation process and an improvement in the rate of assimilation of information flows. A decrease in the number and strength of interhemispheric connections of coherent delta waves may indicate a decrease in the level of personal anxiety [21]. Parameters of the gamma rhythm have not changed significantly, since closing the eyes always increases the level of anxiety, this phenomenon is associated with human evolutionary development, in the absence of visual control over the situation since an individual feels more vulnerable to environmental hazards [31].

Many medical professionals are beginning to recognize the role that visual therapy play in the healing process, increasingly, artistic approaches in medicine programs are emerging worldwide. Analyses of the result indicated that the visual graphic therapy intervention enhanced experimental group participants' psychological well-being by decreasing their negative emotions and enhancing their positive emotions. It is possible to assume that future studies involving better methodology and more consistent assessment of outcomes will demonstrate the ability of visual-graphic therapy to improve psychological and physical well-being and quality of life. As can be seen from our analysis, it is likely that creative engagement

contributes to many aspects of physiological and psychological conditions typically associated with improved health status.

The experiment described in this article was carried out on a limited number of students therefore the obtained data should be verified by additional research involving the greater number of subjects.

Conclusion

Fluctuations of the Earth's geomagnetic field should be monitored in the hospitals and considered as significant nonoccupational stress factors primarily affecting the activity of the central regulatory systems of the body, which include, first of all, the higher cortical mechanisms of regulation and subcortical integrative apparatuses responsible for organizing the current activity of the body and adaptation to environmental changes, functional tension of the body's regulatory systems, reduced tolerance to mental and physical stress. Strong geomagnetic storm can negatively affect not only physical but mental state of working or studying person and require adequate management.

Observation of the certain visual-graphical patterns can be a refuge from the intensive emotions associated with routine stress and can rapidly improve the emotional state and the brain function due to graphomotor activity.

The obtained psychological testing data showed that as a result of the experimental task which was the spiral circling, the emotional state of the subjects significantly improved by 21% of the initial value. The level of personal anxiety also significantly decreased by 5%.

Electrophysiological examination also showed that the subjects' anxiety levels decreased and signs of relaxation appeared. Performing an experimental task has a relaxing effect on the subjects and reduces the level of personal anxiety.

We have evidenced the efficacy of affordable method for reducing the level of stress in medical students, which can be also applicable for the other healthcare workers and seems to be effective in changing the psychophysiological manifestation of stress, since the level of stressful activity is directly related to the degree of personal anxiety. It has been proved that the fulfillment of the experimental task reliably reduces the level of personal anxiety aggravated with the influence of geomagnetic storms.

The advantage of the proposed visual-graphical technique as the effective tool for the reduction of the routine and occupational stress is the simplicity of its application, the possibility of use in different age groups, the absence of contraindications to use and high efficiency in a short period of time (5-10 minutes per day). It can be easily implemented during the breaks in the production process and can provide significant assistance in improving labor productivity by regularly reducing the level of personal anxiety and possibly contributing to a prevention of poor quality of care delivered to patients, increased medical errors and poor retention due to chronic stress in healthcare workers.

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