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EEG-CORRELATES OF ANXIETY OF STUDENT YOUTH IN THE REALITIES OF THE EXTREME SITUATION OF MARTIAL LAW

Relevance. *It is known that anxiety caused by an extreme situation can provoke chronic stress and the development of various somatic diseases. At the same time, there is no comprehensive information about EEG patterns in young people experiencing anxiety in the modern realities of Ukraine. The article deals with the peculiarities of the brain functioning of students with different levels of anxiety in the conditions of extreme situation of martial law. It is assumed that the level of anxiety of students while studying at a higher education institution in the extreme situation of martial law can affect the functioning of the brain. Extreme situation was understood as complicated conditions of educational activity: day and night air raids, mixed form of education, uneven workload, etc.* ***The purpose of the research*** *is to find out the peculiarities of brain functioning according to the indicators of its electrical activity in students with different levels of anxiety during an extreme situation of martial law.* ***Research methods.*** *The method of electroencephalography (EEG) was used to study background EEG patterns and record cognitive evoked brain potentials P_{300} of the auditory modality and determine the levels of reactive (RA) and personal (PA) anxiety. The study was conducted with the participation of 38 practically healthy male students aged 17-19 years. A correlation between EEG power and RA levels was found.* ***Results of the research.*** *The correlation analysis between EEG wave power and RA levels revealed the existence of a relationship between them, especially in the low-wave range, where correlations were found in four cortical loci. It was found that students with high anxiety were characterised by significantly lower reactivity of brain mechanisms compared to their peers with lower levels of anxiety. The low level of brain reactivity in students with high anxiety was observed at all stages of evoked brain activity, and their EEG was characterised by a low-amplitude pattern. The analysis of the amplitude characteristics of N_1-P_2 and P_2-N_2 revealed the existence of a significantly lower power of the interpeak intervals of the EEG in individuals with high anxiety compared to subjects with medium and low anxiety gradations. The obtained results can be useful for creating new approaches to preventing and overcoming anxiety as a consequence of the impact of an extreme martial law situation.*

Keywords: *psychophysiological functions, anxiety, electroencephalography, evoked brain activity, extreme situation, martial law.*

Introduction. Among various problems that have recently been of concern to modern scientists, the issues of social anxiety and stress management have become a priority. As a result of constant air raids, forced displacement, shelling, deaths of relatives, etc., Ukrainians' anxiety is increasing, their neurological status is deteriorating, and somatic morbidity is rising. It is known that high anxiety, which lasts for a long time, provokes the development of chronic stress, which can have serious consequences: constant fatigue, insomnia, aggressiveness, low productivity, impaired attention and memory, lability of behavioural strategies, etc. The functioning of many physiological systems is disrupted, in particular, the central nervous system (CNS), which undergoes dangerous changes [11, 26].

The need to restore impaired functions, prevent and treat neuroses and their complications, and develop depressive states makes it important to understand the mechanisms of brain functioning in stressful situations, as well as to find new algorithms to mitigate the impact of excessive anxiety on the psyche of the younger generation. According to the researchers, high anxiety and the associated increase in morbidity, loss of interest in life and learning, the threat of new unpredictable symptoms and disability are challenges that need to be addressed today [4, 6]. The authors are concerned about the danger posed by the growth of anxiety among the civilian population, in particular among students, which can have devastating consequences for the country's future [5, 12].

It has been proven that personal anxiety is a relatively stable individual characteristic that can be used to judge a person's tendency to worry, and reactive (situational) anxiety reflects emotions of tension, anxiety, worry, irritation or nervousness [6, 22]. It is known from the literature that the level of anxiety and its variations in university students have certain features that may be associated with adaptation to the educational process, balance of nervous processes, formation of attitudes towards the future field of professional activity, etc. At the same time, there is currently no comprehensive information on EEG patterns in relation to anxiety. While some authors insist on the desynchronisation of EEG rhythms and the predominance of β rhythms under these conditions, others point to the dominance of θ waves [15, 27]. Thus, the electrophysiological correlates of anxiety in stressful situations as markers of the level of physiological processes have not been studied sufficiently, which has led to the relevance of our study.

Statement of the problem and purpose of the study. One of the priorities of the national education system in the context of European integration is the formation of a professionally competent and psychologically healthy personality. The educational process of student youth in today's realities is characterised by intense mental activity, high pace of the educational process, a variety of experiences of life situations, high learning requirements, forced mixed forms of education (full-time, distance, online) against the background of the negative realities of martial law. All this can lead to increased anxiety among students, creating additional stress on the central nervous system [23].

Anxiety, as an individual trait, reflects a person's persistent tendency to experience strong feelings for insignificant reasons. The body of an anxious person functions in the mode of constant expectation of negative events, which is manifested in behavioural strategies characterised by disorders of self-preservation processes, adaptation to changing living conditions, and depletion of psychophysiological reserves [4]. It is important to remember that the material basis of a person's full life is the optimal course of certain physiological processes aimed at ensuring various functions: mental, motor, metabolic, etc.

Anxiety at the physiological level is manifested by changes in the functioning of many visceral systems (increased heart rate, blood circulation, respiration) and the central nervous system, in particular the brain. During anxiety, there is an increase in the overall excitability of the nervous system, a decrease in the thresholds of sensitivity to irritating stimuli, and a shift in the emotional background to a negative plane [6, 12].

The authors point out that the development of anxiety may be an indicator of insufficient restructuring of psychophysiological mechanisms. Increased activation of the nervous system initiates the development of inadequate behavioural strategies and causes symptoms of fear and anxiety [10, 25]. It is important to define human psychophysiological adaptation as the ability to adapt to changing conditions of existence and withstand the pressure of existing or imagined circumstances of the world around us [7, 21]. Disclosure of the manifestation of anxiety properties, scientific substantiation of the physiological basis of stimulus perception, consideration of performance, clarification of the role of the central nervous system opens up opportunities for revealing the mechanisms of body functioning, gives a chance to find ways to optimise the psycho-emotional background by reconfiguring the brain, etc.

Our working hypothesis was that the level of anxiety in students while studying at higher education institutions (HEIs) in an extreme situation of martial law as a threat to health and life itself [4] has certain characteristics that can correlate with the peculiarities of brain functioning.

The purpose of our research was to find out the peculiarities of brain functioning based on the indicators of its electrical activity in students with different levels of anxiety during an extreme martial law situation.

Organisation and methods of the study. In accordance with the aim, we studied cognitive evoked potentials (P_{300}) by electroencephalography and levels of reactive (RA) and personal (PA) anxiety by means of a questionnaire. The study was conducted with the participation of 38 practically healthy young men aged 17-19 years, 3rd year students of Bohdan Khmelnytsky National University of Cherkasy, who had no pathologies of the auditory, endocrine, nervous systems and traumatic brain injuries. The study was conducted over a 6-month period (from October 2024 to March 2025) in compliance with bioethical standards and the provisions of the Declaration of Helsinki (1975, 1996-2013) with the prior consent of the subjects after they were informed of the purpose, duration, and procedure of the study.

The EEG was recorded with a computerised encephalograph "NeuroCom" by HAI Medica in 19 leads with symmetrical electrode placement according to the international system 10-20 at rest in a shielded sound and light-insulated chamber in a sitting position. The combined ear electrode was used as a reference electrode. EEG recording during each stage of the experiment lasted 40 s. The signal analysis time was 4 s, the sampling frequency was 500 Hz, and the overlap was 50%. The frequency filters were in the range of 0.5 Hz (for low) - 45 Hz (for high). The power of brain biocurrents in the α-, β-, and θ-frequency ranges in all leads was assessed using the NeuroCom software.

The study of evoked potentials (EPs) was carried out on the same computer system. For this purpose, sound stimulation of the right and left ears was performed for 50 ms with a sequence period of 1-2 s, with an intensity of 75-85 dB in the state of closed eyes. The tone frequency of the meaningful stimulus was 2000 Hz, and that of the irrelevant stimulus was 1000 Hz. The appearance of the stimuli in the series was pseudo-random (for every 10 non-significant stimuli, 2-3 significant stimuli were generated). The analysis period was 750 ms. The subject had to pay attention to, recognise and count one of the stimuli (the significant one), which was presented less frequently. The pre-stimulus time interval (about 200 ms) was analysed. The number of averages for the salient stimuli was close to 30, the frequency band was 0.5-50 Hz. Responses to salient stimuli were assessed by verifying the P_{300} component by comparing responses to salient and non-salient stimuli. It was believed that responses to a significant stimulus contain medium-latency components, as well as the P_{300} cognitive complex itself. The latency and amplitude of the components P_1, N_1, P_2, N_2, P_3, N_3 between peak latencies P_1-N_1, N_1-P_2, P_2-N_2, N_2-P_3, and the duration of the P_{300} wave were assessed. All subjects were right-handed.

To identify the levels of reactive (RA) and personal (PA) anxiety, the subjects were offered to complete a questionnaire based on the Spielberger-Khanin questionnaire [2, 25]. The statistical processing of the results was carried out by methods of mathematical statistics using Microsoft Excel 2010 software packages. The reliability of changes and differences between comparative values was assessed by the Student's t test for difference, nonparametric Wilcoxon-Mann-Whitney U test. Differences with P values ≤ 0.05 were considered significant.

The results of the study and their discussion. It is known that anxiety is an individual quality of a personality characterised by a tendency to excessive worry, acute perception of stress factors, experiences associated with expected troubles, failures, threats, and the thought of inability to adapt to new conditions of existence. The authors agree that anxiety, as a normal emotional response to negative events, is involved in the formation of an adequate response of the body, capable of mobilising energy resources to overcome adversity [6, 10]. At the same time, a high level of anxiety or its duration can disrupt the psychophysiological status of a person and cause fatigue, the development of somatic diseases, and neurological disorders [12].

In accordance with these views, we analysed the anxiety of the students under study during our 6-month study (Table 1).

As can be seen from the table, the results of the Spielberger-Khanin test at the beginning of the study were close to high levels (in the case of both RA and PA). The PA score did not exceed 45 points, and the average RA score was not less than 36 points. Over time, in most of the subjects, the studied anxiety indicators increased, and at the 6th month of the study they acquired the status of high ($P \leq 0.05$). Thus, the increase in the level of PA was 30.6 %, while the increase in RA was 62.8 %. In addition, it should be noted that many answers in the questionnaires of the subjects contained information about an increase in the number of cases of deterioration of health, low activity, and the prevalence of bad mood, which indicated the possibility of developing fatigue and exhaustion.

Table 1.

Indicators of personal and reactive anxiety of the subjects

Investigated indicators (scores)	October 2024 X±m	March 2025 X±m	Reliability of differences
PA	41,8±3,2	54,6±3,6	$P \leq 0,05$
RA	37,7±2,6	61,4±3,2	$P \leq 0,05$

According to the data we obtained from students at the end of the study, the levels of both RA and PA were high and did not meet the generally accepted norm [1, 6]. Our results are in line with the findings of other researchers who emphasise that a significant proportion of the adult population has shown a clear trend towards increased anxiety after Russia's unprovoked full-scale invasion of Ukraine [23, 26].

This increase in anxiety was probably caused by the events of the hot phase of hostilities and the associated development of psychological discomfort. After all, from October 2024 to March 2025, according to official statistics (https://map.ukrainealarm.com), an average of 3 to 21 air alerts were announced per day in Cherkasy region, which could last from 30 minutes to 3 hours or more. The number of alerts was at least 6 every day. In October 2024 alone, there were 300 air raids in the middle of the school week (Wednesday-Thursday). But even on the weekend of this month (Sunday), the occupiers terrorised the civilian population of the region at least 99 times, creating an atmosphere of intimidation and danger of arrivals. Approximately the same situation occurred in the following months, which may have contributed to the increase in anxiety among students.

Our research revealed a high level of anxiety in 39.2% of the respondents, a medium level in 31.4%, and a low level in 28.6%, which allowed us to form three groups according to RA: with high, medium and low levels. The first group included 15 young men with a high level of RA, the second group consisted of 12 peers with an average level of RA, and the third group included 11 young men with a low level of anxiety.

It should be noted that anxiety is closely related to the functioning of the limbic system. The amygdala, as its component, regulates emotions such as aggression, fear, and anxiety. It is this brain structure that is responsible for controlling affective reactions, recognising stimuli and evaluating them. Powerful neural afferentation from the amygdala to the frontal cingulate cortex can cause fluctuations in the perception of emotional information [8, 19], and lead to the development of feelings of fear and anxiety [14]. Also, based on current views that EEG is an integrative characteristic of brain functioning that reflects the activity of many neuronal groups [13], we analysed the background electrical activity of the brain of the students under study at the initial and final stages of our study in groups allocated by RA levels. The analysis of the EEG wave power in each group at the beginning of the study showed that in the resting state with eyes closed, it was within the normal range for all subjects. At the same time, there were significant differences between the waves of the high-frequency range of individuals with different levels of RA in the

frontal-central and temporal cortex ($P \leq 0.05$) (Fig. 1). People with an average level of RA took an intermediate position.

As can be seen from the figure, opening the eyes caused a decrease in the power of α-waves (by 39.3% in subjects of the 1st, 44.7% of the 2nd and 32.4% of the 3rd group, respectively), and was also characterised by significant fluctuations in the power of β-band waves. In subjects with low RA, similar changes were recorded in the anterior and posterior cortex. It is likely that such dynamics of α- and β-wave power was associated with an increase in the afferent flow of information and an increase in energy demand [13].

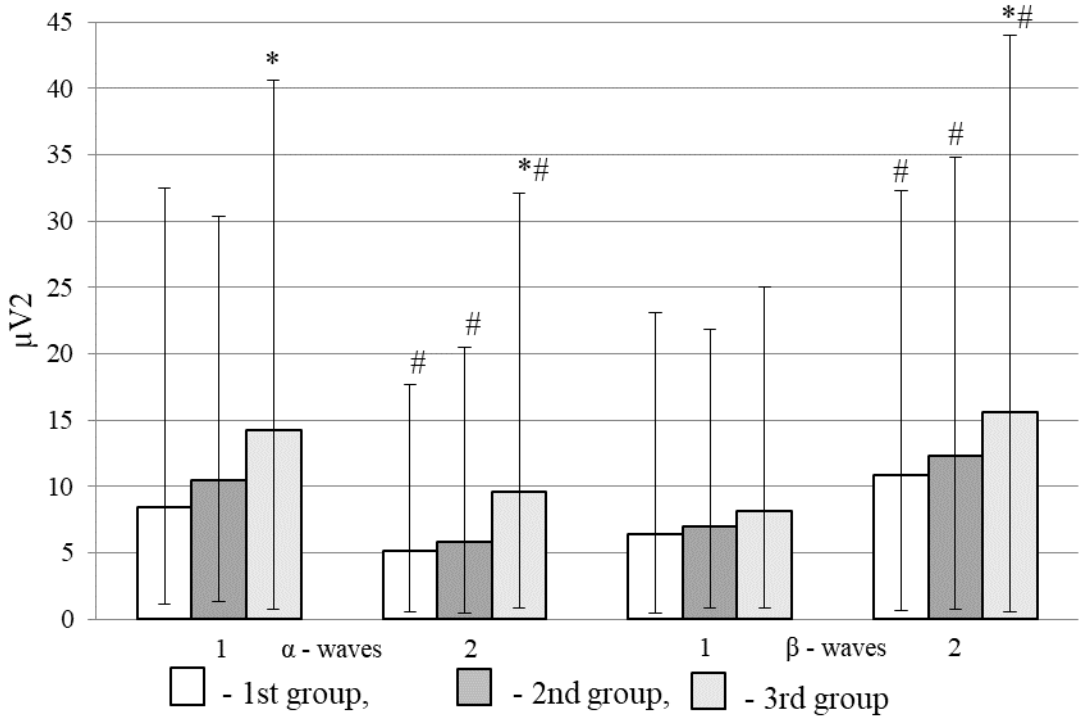

Fig. 1. Power of EEG oscillations in the α- and β-bands in the state with eyes closed (1) and with eyes open (2) in individuals with different levels of reactive anxiety; * – significance of differences $P \leq 0.05$ relative to the indicators in their group, # – $P \leq 0.05$ relative to the indicators with eyes closed in their group.

In general, a comparison of the EEG power indices of the study groups recorded at the beginning and end of the study revealed a decrease in the range of α-waves and a marked increase in θ-rhythmicity as markers of anxiety [11, 17], which was more pronounced in the first group. According to the authors, the feeling of anxiety is accompanied by the appearance of θ waves in the central cerebral cortex [15]. At the same time, it is known that the state of anxiety can be manifested by desynchronisation of the main alpha rhythm and a decrease in its amplitude [18].

Our correlation analysis between EEG wave power and RA levels revealed the existence of a relationship between them, especially in the low-wave range, where correlations were found in four cortical loci ($P \leq 0.05$-0.01) (Fig. 2). This suggests that anxiety can significantly change the functional state of the cortex and subcortical structures of the brain, as well as "reconfigure" the relationships between them. The dominance of the slow-wave range of EEG characteristics in subjects with a higher level of RA may indicate exhaustion and an increasing deficit of reserve energy capabilities of the "anxious" brain.

Thus, our results probably indicate the existence of functionally different strategies for processing auditory information and forming a brain response in subjects with different levels of

anxiety, as well as a faster rate of nerve impulse transmission and response formation in low-anxious subjects compared to those with higher RA gradations.

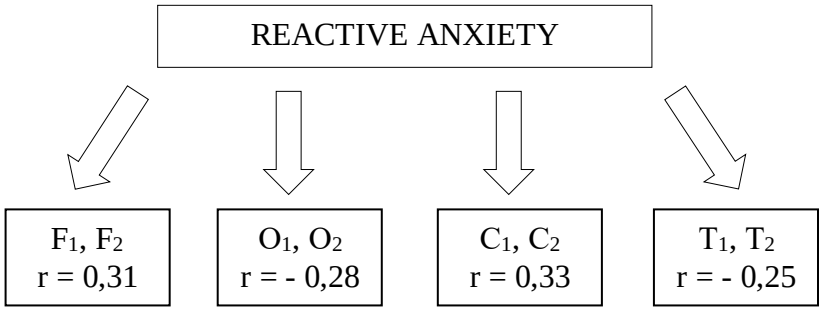

Fig. 2. Correlations between the power of the subjects' EEG waves in the θ-range.
Notes: only significant relationships are shown (p<0.05-0.001).

It is obvious that anxiety can make significant adjustments to the functioning of the cortex and subcortical structures of the brain, and affect the establishment of synaptic contacts between neurons. We assume that the dominance of the slow-wave range of EEG characteristics in individuals with high anxiety may demonstrate the limited capabilities of the brain of a person in an extreme martial law situation, which will interfere with the perception, differentiation of sound stimuli and synthesis of brain responses to stimuli.

To test this hypothesis, we analysed the dynamics of evoked brain activity as a total indicator of its bioelectrical activity, which can be used to judge in more detail the possibility of developing an adequate response under conditions of increased stress. It was found that the latent periods of some components o f auditory ERs in individuals with high RA were longer than in subjects with medium and, especially, low anxiety. While the comparison of P_1 components of individuals of different anxiety groups did not reveal any significant differences, the latency of the P_2 component was lower in medium- and low-anxious subjects of the second and third groups, respectively ($P \leq 0.05$) (Table 2).

Table 2.

Difference in the median latency periods of the components of the evoked cognitive potential P_{300} of the auditory modality in subjects with different levels of RA

Components of EPs	Differences between the indicators of individuals with different levels of RA (Δ, %)		
	high – medium	high - low	medium - low
P_1	9,75 (+)	10,53 (+)	9,89 (-)
P_2	12,8* (+)	45,6* (+)	28,1* (+)
P_3	24,9* (+)	55,6** (+)	31,4* (+)

Notes for Tables 2 and 3: * - significance of differences $P \leq 0.05$, ** - $P \leq 0.01$; "-", "+" - respectively, shorter or longer latency period relative to the comparison group.

It is accepted that the early components of the EPs, such as P_1 and P_2, reflect the unconscious perception and deployment of the initial stages of nonspecific processing of the stimulus auditory signal [11]. On this basis, our results may indicate the benefit of faster stimulus perception and higher cortical cell reactivity in subjects with lower RA at the early stages of response formation. This may also reflect the ability of a "relatively low-anxiety" brain to activate more neurons, establish synaptic connections between them more quickly and in greater numbers, intensify the processes of excitation irradiation along neural circuits, and turn on fast sensory fibres, lemniscus projection systems, and subcortical cortical structures [9, 14]. Similar results

were obtained in relation to the latency period of the P_3 component, which demonstrated a significant slowing of cerebral reactivity in response to auditory stimuli in subjects with high levels of anxiety ($P \leq 0.01$). It is known that the P_3 wave is a reflection of the analytical processes of the brain responsible for the conscious specific processing of information in the primary and secondary cortical areas of the cerebral hemispheres. Thus, the total brain response time in subjects with lower anxiety did not differ significantly from the norm, although it was slightly shorter (by 60-80 ms). In contrast, the total latency of the analysed P_{300} peaks of the subjects of the first group with a high level of RA was 2.3 times higher ($P \leq 0.05$). It should be assumed that a significantly longer latency period of the P_3 component of highly anxious subjects may indicate a smaller number of activated synaptic connections, a lower rate of nerve impulse transmission, and a slower mediator function.

According to modern views, the late components of evoked brain activity reflect the work of nonspecific nuclei of the thalamus, reticular formation, limbic and other multitasking nonspecific brain systems [16, 19, 24]. Probably, a high level of anxiety "paralysed" the perception of the stimulus, inhibiting the transmission of nerve impulses, which led to a paradoxical effect in the work of brain mechanisms, manifested by inadequately low reactivity in response to stimuli.

The analysis of the amplitude characteristics of N_1-P_2 and P_2-N_2 revealed the existence of a significantly lower power of the interpeak intervals of the EPs in individuals with high anxiety compared to subjects with medium and low anxiety gradations, whose indicators almost corresponded to the norm accepted in psychophysiology (Table 3).

Table 3.

Difference in the median amplitudes of the components of the evoked cognitive potential P_{300} of the auditory modality in individuals with different levels of RA

Components of EPs	Differences between the indicators of individuals with different levels of RA (Δ, %)		
	high – medium	high - low	medium - low
P_1	6,33 (-)	5,46 (+)	6,58 (+)
P_2	15,8* (-)	27,4* (-)	17,6* (+)
P_3	53,4* (-)	73,5** (-)	24,3* (-)

It is possible that the low power of the studied interpeak intervals of the EPs in the subjects of the first group is indicative of the suppression of brain activation capabilities by stress factors and the unfolding of adverse morphological and functional changes in the central nervous system. It should be noted that stimulation with simple single-tone auditory stimuli, to which the brain response was formed, cannot be very demanding in terms of activating neural reserves or forming synaptic connections, because in the early stages of perception, the nature of the stimulus is not yet assessed. Probably, the high level of anxiety made it impossible for the brain to respond adequately due to the dominance of inhibitory processes. At the same time, the longer latency of both the early and late components of the EPs and the low power of their amplitude in highly anxious subjects indicated a relatively slower rate of nervous processes at all stages of information processing and response formation and the exhaustion of energy reserves.

The results of the research open up new opportunities for physiological monitoring of anxiety, preventing the development of depressive states and neurological dysfunctions that may arise as a result of extreme martial law situations. They can also be useful in improving existing approaches to preserving the mental health of students.

Conclusions.

1. The reactivity of brain mechanisms in students with high anxiety compared to those with low anxiety gradations was found to be significantly lower ($P \leq 0.05$).

2. A correlation between EEG power indices and RA level was found. In the low-wave range, the correlation was found in four cortical loci ($P \leq 0.05$-0.01).
3. It was found that the EEG of subjects with high RA is characterised by a low-amplitude pattern.
4. Highly anxious individuals have a lower level of brain reactivity at all stages of evoked brain activity.
5. The obtained results may be useful for creating new approaches to preventing and overcoming anxiety as a consequence of the impact of the extreme situation of martial law.

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ЕЕГ-кореляти тривожності студентської молоді в реаліях екстремальної ситуації воєнного стану

У статті розглядаються особливості функціонування головного мозку студентів із різним рівнем тривожності в умовах екстремальної ситуації воєнного стану. Під екстремальною ситуацією розуміли ускладнені умови навчальної діяльності: денні і нічні повітряні тривоги, змішана форма навчання, нерівномірність об'ємів навчального навантаження тощо. Припускали, що рівень тривожності студентів під час навчання у вищому навчальному закладі за цих умов може впливати на мозкову діяльність.

Метою було з'ясування особливостей роботи мозку за показниками його електричної активності у студентів з різним рівнем тривожності під час екстремальної ситуації воєнного стану.

Досліджували фонові патерни ЕЕГ, реєстрували когнітивні викликані потенціали мозку P_{300} слухової модальності та визначали рівні реактивної (РТ) і особистісної (ОТ) тривожності
у 38 практично здорових студентів чоловічої статі віком 17-19 років.

Виявлено кореляцію між потужністю ЕЕГ і рівнем РТ. Між низькочастотними хвилями і рівнем РТ були встановлені кореляції у чотирьох локусах кори мозку: центральних, темпоральних, окципітальних та фронтальних.

Встановлено, що студенти з високою РТ характеризувалися значно нижчою реактивністю мозкових механізмів порівняно з однолітками, що відрізнялися нижчими її градаціями. Низький рівень мозкової реактивності у обстежуваних з високою тривожністю реєструвався на всіх етапах викликаної мозкової активності, що збільшувало час загальної відповіді мозку на подразники.

Вивчення показників потужності ЕЕГ обстежуваних з різними рівнями РТ, зафіксованих на початку і наприкінці дослідження, встановило зниження діапазону α-хвиль та помітне зростання θ-ритміки, як маркерів тривожності, що у високо-тривожних представників було більш виразним. ЕЕГ студентів з високим рівнем РТ характеризувалася низько-амплітудними патернами.

Отримані результати можуть бути корисними для створення нових підходів до запобігання та подолання тривоги як наслідку впливу екстремальної ситуації воєнного стану.

Ключові слова: *психофізіологічні функції, тривога, електроенцефалографія, викликана мозкова активність, екстремальна ситуація, воєнний стан.*

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