

**STRESS-DEPENDENT MODULATION OF THE ASSOCIATION BETWEEN  
ELECTROENCEPHALOGRAPHIC ALPHA ACTIVITY AND VISUAL MEMORY  
PERFORMANCE IN STUDENTS FROM A FRONTLINE REGION**

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Full-scale war creates conditions of prolonged and unpredictable stress that may affect cognitive functions and the neurophysiological mechanisms underlying them. One important neurophysiological marker of cognitive processes is alpha activity in the EEG, which is associated with attention and memory. However, the extent to which chronic stress modifies the relationship between brain alpha activity and cognitive performance remains poorly understood, particularly among individuals living in frontline regions.

The aim of the study was to determine whether perceived stress modifies the relationship between EEG alpha activity and short-term visual memory performance in students from a frontline region, and to assess the effect of auditory alpha stimulation on this relationship.

A longitudinal study was conducted involving 86 students (44 women and 42 men), selected from 1200 participants who underwent baseline screening in 2024, and divided into groups with decreased and stable moderate levels of perceived stress. Visual memory was assessed using the WOM-REST test (CogniFit), while alpha activity was quantified using EEG power spectral density (PSD). Statistical analysis included paired *t*-tests and regression analysis.

Regression analysis revealed stable positive associations between alpha-band EEG PSD and task accuracy, predominantly localized in posterior parieto-occipital cortical regions, with a tendency toward right-hemisphere lateralization in men. After auditory alpha stimulation, these associations became stronger, and in some subgroups their spatial distribution changed. In women with stable moderate stress levels, additional involvement of central recording sites and a more symmetrical distribution of associations in occipital regions were observed. In men, these associations remained more localized in the right parieto-occipital region, whereas in the subgroup with decreased stress levels, additional associations appeared in the right frontal electrode after stimulation.

The obtained results indicate that auditory stimulation in the alpha range modifies the spatial organization of the relationship between brain alpha activity and visual memory performance. The pattern of these changes depends on the level of stress and participant sex. The findings also suggest that moderate stress may increase neural network sensitivity to rhythmic sensory stimulation.

**Key words:** chronic stress, EEG alpha oscillations, power spectral density, visual memory.

**Connection of the publication with planned research work.**

This work is part of the research project “Physiological and biochemical changes resulting from prolonged stress: adaptation and risk factors” (state registration number 0125U002225).

**Introduction.**

Contemporary neurobiological models consider chronic stress as a persistent functional brain state that develops under conditions of prolonged uncertainty and limited control over the situation. According to the concept of allostatic load proposed by McEwen, chronic stress is accompanied not only by hormonal changes but also by a reorganization of large-scale brain networks [1]. It has been shown that stress alters the oscillatory characteristics of brain activity, which may reflect a shift in the balance between excitation and inhibition in neural networks and be manifested in the EEG spectrum [2]. Meta-analyses also indicate that EEG oscillatory characteristics are sensitive markers of the neurophysiological effects of stress and reflect changes in the functional organization of brain activity [2].

Previous studies suggest that psychological stress may affect executive functions, particularly working memory [3]. When stress is prolonged, especially under conditions of uncertainty, cognitive performance often becomes more variable, and the retention of visual information becomes less stable [3]. Experimental stud-

ies have also demonstrated that acute stress may shift the balance toward hippocampus-dependent memory processing and away from more automated striatal responses, thereby reducing the flexibility of cognitive control [4].

Models of neural entrainment emphasize the distinction between evoked responses and true phase synchronization [5]. Rhythmic auditory stimulation has been shown to modulate local brain activity and functional brain networks [6]. Therefore, rhythmic stimulation is considered not only a method of modulating local bioelectrical activity but also a potential tool for network-level neuromodulation [7].

However, the effectiveness of rhythmic stimulation largely depends on the brain's initial functional state [8]. In some cases, electrophysiological “entrainment” of neural rhythms may occur without pronounced improvements in behavioral performance, as changes in alpha-band power do not always lead to measurable cognitive effects. This suggests that the outcomes of rhythmic stimulation depend on both the individual sensitivity of neural networks and stimulus parameters, particularly the degree of correspondence between the external rhythm and the individual alpha frequency [8].

Recent studies indicate that living under wartime conditions is associated with sleep disturbances, increased anxiety, and cognitive difficulties even in non-clinical populations [9–11]. Studies of brain net-

work dynamics show that prolonged exposure to threat is accompanied by changes in functional connectivity. In particular, weakening of hippocampal-prefrontal circuits and increased dominance of limbic systems have been reported [12]. Such changes in the organization of brain networks may influence mechanisms of cognitive control and information processing.

Overall, contemporary research highlights several key points. Chronic stress is associated with changes in oscillatory brain activity [1–2], and alpha rhythms can be modulated by auditory stimulation [5–6]. At the same time, relatively few studies have examined the relationship between alpha dynamics and behavioral performance under conditions of allostatic load [3]. There is a particular lack of studies conducted in real wartime contexts [9–12]. Moreover, the mechanisms through which chronic stress may modulate the relationship between oscillatory brain activity and cognitive performance remain insufficiently understood.

#### **The aim of the study.**

To investigate whether perceived stress modifies the relationship between EEG alpha-band power spectral density and short-term visual memory performance in students from a frontline region, and to examine the effect of auditory alpha-band stimulation on this association.

#### **Object and research methods.**

The study was conducted in accordance with the Declaration of Helsinki (1964, revised in 2013) and the Convention on Human Rights and Biomedicine (Oviedo, 1997). The study protocol was approved by the Bioethics Committee of Oles Honchar Dnipro National University (Protocol No. 1, October 17, 2023). All participants provided written informed consent prior to participation.

The study employed a within-subject repeated-measures experimental design. The experimental protocol consisted of three sequential stages: a short-term visual memory task with simultaneous EEG recording (2 min), a 10-minute period of auditory stimulation with 8-Hz amplitude modulation during rest, and repetition of the cognitive task with EEG recording.

This design allowed assessment of short-term modulation of EEG alpha activity following rhythmic auditory stimulation. Each participant served as an internal control, which reduced the influence of interindividual variability in cognitive and neurophysiological parameters. Short-term visual memory was assessed using the WOM-REST Recognition Test (CogniFit, USA). The platform automatically generates new stimuli and varies their presentation order, which reduces potential practice effects.

Participant selection was based on a 2024 screening, as described earlier [13]. During this stage, 1200 students living in frontline regions of Ukraine completed the Perceived Stress Scale (PSS–10) questionnaire.

In the present study, a subsample of students with moderate baseline perceived stress in 2024 was included in the analysis. The study had a longitudinal design and included a repeated assessment of the same participants one year later (2024–2025). The participant inclusion scheme is presented in **figure 1**.

The final sample consisted of 86 students (44 women and 42 men) aged 20–24 years, who had complete datasets for both cognitive testing and EEG recordings in both study years (2024–2025).

Based on changes in PSS–10 scores between 2024 and 2025, participants were divided into two subgroups.

The first subgroup included participants whose perceived stress decreased in 2025 (transition from moderate to low stress levels).

The second subgroup included individuals whose stress level remained within the moderate range.

The study included healthy right-handed participants without neurological or psychiatric disorders, not taking psychotropic medications, and with normal or corrected-to-normal vision.

Cognitive status was assessed using the Mini-Mental State Examination (MMSE) and the CogniFit Memory Test. Emotional state was evaluated using the Positive and Negative Affect Schedule (PANAS), and psychological resilience was assessed using the Connor–Davidson Resilience Scale.

Female participants were tested during the follicular phase of the menstrual cycle (days 5–10).

EEG signals were recorded using the Neurocom system (KhAI-Medika, Ukraine) in a sound- and electrically shielded chamber. Ag/AgCl electrodes were placed according to the international 10–20 EEG system.

The following electrodes were used for analysis: Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, Fz, Cz, and Pz. This electrode set covers frontal, central, parietal, and occipital cortical regions of the brain involved in visual information processing and working memory.

Electrode impedance was maintained below 5 k $\Omega$ , and the sampling rate was 500 Hz.

The EEG signal was filtered in the 0.3–45 Hz frequency range. Artifacts were automatically removed, followed by a subsequent visual inspection. Recordings were segmented into non-overlapping 10-second epochs.

Power spectral density (PSD) in the alpha band (8–13 Hz) was calculated using the Fast Fourier Transform (FFT) method. EEG and cognitive data were analyzed by a researcher blinded to participant subgroup allocation.

Auditory stimulation was delivered using an amplitude-modulated audio signal (envelope modulation) at a modulation frequency of 8 Hz (alpha range), presented via stereo headphones for 10 minutes. The sound level was adjusted to a comfortable level for each participant and kept constant throughout the experiment.

Statistical analyses were performed using RStudio (version 2023.12.1). Between-year differences in short-term memory performance were evaluated using the paired t-test. Before analysis, the normality of the data distribution and homogeneity of variances were verified.

Quantitative data are presented as mean  $\pm$  standard deviation ( $M \pm SD$ ). Effect size was additionally calculated using Cohen's  $d$ .

To analyze the relationship between PSD values and task accuracy, linear regression models were used. The level of statistical significance was set at  $p < 0.05$ . Bonferroni correction was applied to control for Type I error in multiple comparisons.

#### **Research results and their discussion.**

In the follow-up phase of the 2025 longitudinal study, 86 students (44 women and 42 men) participated. All participants had complete datasets for both cognitive testing and EEG recordings at both time points (2024–2025). The participant selection scheme is presented in **figure 1**.

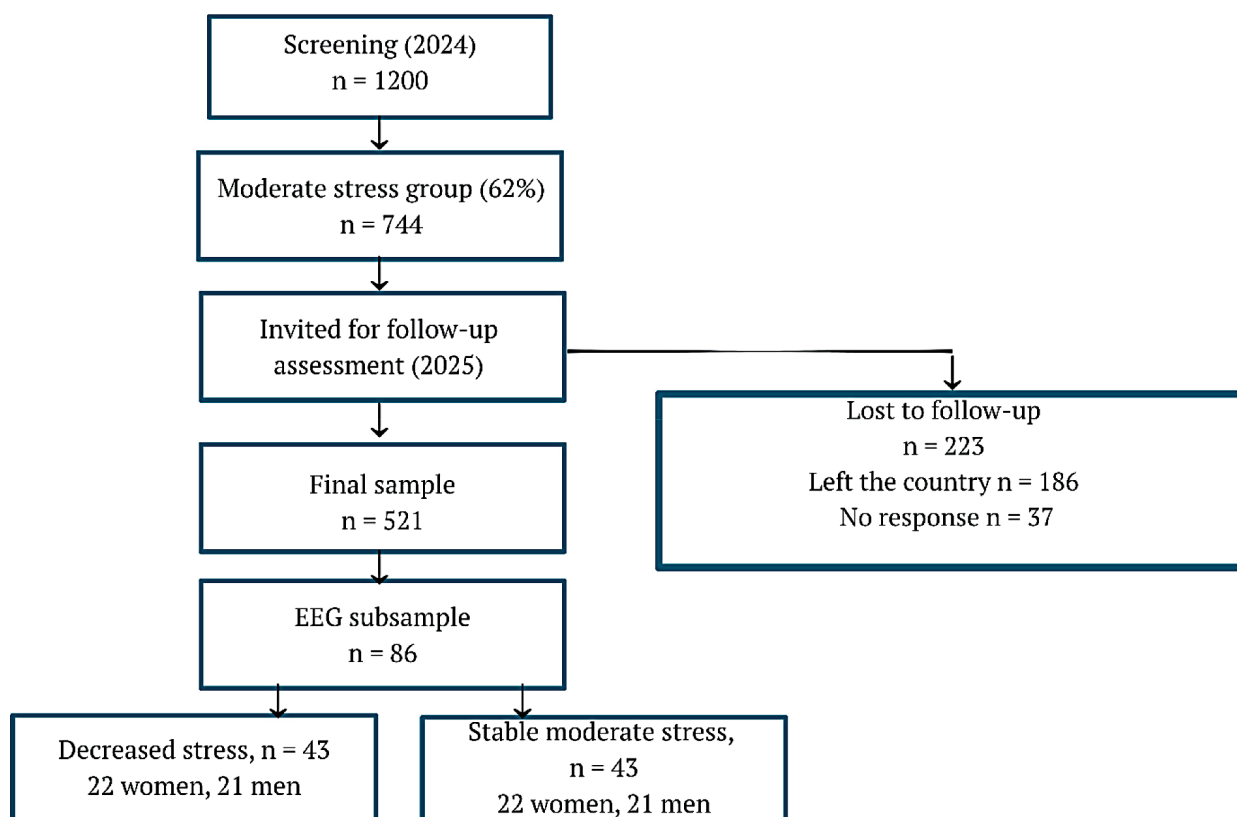


Figure 1 – Participant selection and allocation scheme in the longitudinal study (2024–2025).

Analysis of Perceived Stress Scale (PSS–10) scores showed that most participants decreased their perceived stress levels over the course of the year. In the overall screening sample, approximately 80% of students demonstrated a decrease in perceived stress levels, whereas about 20% maintained moderate levels. For the present analysis, comparable subgroups were formed based on these patterns of change.

According to these changes, participants were divided into two groups: a decreased-stress group and a stable moderate-stress group. Within each subgroup, the sample sizes and sex distributions were comparable (22 women and 21 men), reducing the likelihood of sex-related confounding in the subsequent analysis of cognitive and neurophysiological parameters.

The between-year analysis showed that the dynamics of short-term visual memory performance depended on the pattern of changes in perceived stress levels. In the subgroups with consistently moderate stress levels, task accuracy in 2025 was significantly higher than in 2024 in both men ( $t=3.64$ ,  $p=0.001$ ,  $d=1.12$ ) and women ( $t=2.09$ ,  $p=0.042$ ,  $d=0.63$ ). In the groups with decreased stress levels, no statistically significant between-year changes were observed.

After auditory alpha-band stimulation, an increase in task accuracy was observed in all subgroups (table 1). In groups with decreased stress levels, the improvement was moderate, whereas in subgroups with

consistently moderate stress levels, the stimulation effect was more pronounced.

Overall, auditory alpha stimulation was associated with improved short-term visual memory performance in all groups, with the largest effect observed in participants with consistently moderate perceived stress levels. This pattern is consistent with the hypothesis that neural network sensitivity to rhythmic sensory stimulation may depend on stress level.

Regression analysis revealed statistically significant positive associations between EEG alpha-band power spectral density (PSD) and accuracy in the visual memory task. The analysis was performed for 13 EEG channels, but only statistically significant associations are presented in the table. The spatial distribution of these relationships differed depending on participant sex, perceived stress level, and experimental condition (before and after auditory alpha stimulation) (table 2, figure 2).

In men with decreased stress levels, positive associations between alpha-band EEG PSD and task accuracy before stimulation were primarily observed in parietal-

Table 1 – Accuracy of short-term visual memory task performance before and after auditory alpha-band stimulation

Group	2024	2025 (pre)	2025 (post)	t (pre-post)	p	d
Men (decreased stress)	77.0±6.6	80.3±4.8	83.9±4.9	4.21	4.3×10 <sup>-4</sup>	0.74
Women (decreased stress)	82.0±9.0	83.7±6.5	87.2±5.8	3.18	4.51×10 <sup>-3</sup>	0.58
Men (stable moderate stress)	59.8±8.8	69.5±8.5	78.0±8.7	4.86	9.5×10 <sup>-5</sup>	0.98
Women (stable moderate stress)	69.0±14.0	76.9±11.0	86.1±10.5	3.92	7.9×10 <sup>-4</sup>	0.83

Notes: The decreased-stress group included participants whose perceived stress level decreased from moderate (2024) to low (2025); M – mean value; SD – standard deviation; 2025 before – values before stimulation; 2025 after – values after 10 minutes of auditory alpha-band stimulation; t – paired Student’s t-test value (before–after stimulation); d – effect size (Cohen’s d); n=21–22 per subgroup; total sample size N=86.

**Table 2 – Regression analysis of the relationship between EEG alpha-band power spectral density (PSD) and visual memory task accuracy in men (n=21) and women (n=22), depending on perceived stress level and experimental condition before and after auditory alpha stimulation**

Group	Condition	EEG channel	Standardized coefficient (β)	95% CI	Statistical significance, p	Correlation coefficient, r	R <sup>2</sup>
Men (decreased stress)	Before stimulation	Pz	0.31	[0.18; 0.39]	<b>1.0 × 10<sup>-2</sup></b>	0.36	0.13
		P4	0.41	[0.31; 0.49]	<b>1.76 × 10<sup>-3</sup></b>	0.49	0.24
		O2	0.43	[0.33; 0.55]	<b>1.83 × 10<sup>-3</sup></b>	0.50	0.25
	After stimulation	F4	0.42	[0.33; 0.50]	3.4 × 10 <sup>-2</sup>	0.45	0.20
		P4	0.65	[0.51; 0.72]	<b>2.5 × 10<sup>-4</sup></b>	0.67	0.45
		O2	0.70	[0.54; 0.88]	<b>3.2 × 10<sup>-4</sup></b>	0.68	0.46
Men (stable moderate stress)	Before stimulation	Pz	0.45	[0.30; 0.51]	<b>1.2 × 10<sup>-2</sup></b>	0.47	0.22
		P4	0.63	[0.51; 0.70]	<b>1.51 × 10<sup>-4</sup></b>	0.59	0.35
		O2	0.65	[0.52; 0.72]	<b>1.42 × 10<sup>-4</sup></b>	0.59	0.35
	After stimulation	P4	0.71	[0.62; 0.88]	<b>1.65 × 10<sup>-4</sup></b>	0.65	0.42
		O2	0.73	[0.55; 0.79]	<b>1.45 × 10<sup>-4</sup></b>	0.69	0.48
Women (decreased stress)	Before stimulation	Pz	0.29	[0.15; 0.41]	4.5 × 10 <sup>-2</sup>	0.32	0.10
		O1	0.41	[0.33; 0.52]	<b>1.64 × 10<sup>-3</sup></b>	0.50	0.25
		O2	0.42	[0.30; 0.51]	<b>1.77 × 10<sup>-3</sup></b>	0.50	0.25
	After stimulation	Pz	0.55	[0.45; 0.60]	<b>1.50 × 10<sup>-4</sup></b>	0.59	0.35
		Cz	0.60	[0.54; 0.77]	<b>1.48 × 10<sup>-4</sup></b>	0.59	0.35
		O1	0.34	[0.25; 0.42]	4.3 × 10 <sup>-2</sup>	0.37	0.14
		O2	0.35	[0.25; 0.44]	4.3 × 10 <sup>-2</sup>	0.39	0.15
Women (stable moderate stress)	Before stimulation	Cz	0.30	[0.19; 0.47]	3.3 × 10 <sup>-2</sup>	0.39	0.15
		Pz	0.35	[0.28; 0.41]	3.6 × 10 <sup>-2</sup>	0.45	0.20
	After stimulation	Pz	0.40	[0.32; 0.51]	<b>1.62 × 10<sup>-3</sup></b>	0.45	0.20
		P3	0.62	[0.49; 0.76]	<b>1.42 × 10<sup>-4</sup></b>	0.55	0.30
		P4	0.65	[0.52; 0.72]	<b>1.54 × 10<sup>-4</sup></b>	0.57	0.32
		O1	0.66	[0.50; 0.73]	<b>1.55 × 10<sup>-4</sup></b>	0.61	0.37
		O2	0.67	[0.60; 0.74]	<b>1.58 × 10<sup>-4</sup></b>	0.62	0.38

**Notes:** Bonferroni correction was applied separately within each combination of group and experimental condition for all tested EEG channels (adjusted significance threshold:  $\alpha=0.05/k$ , where k is the number of tested channels in the corresponding analysis set). Results that remain statistically significant after correction are shown in bold.

occipital electrodes (Pz, P4, O2). After auditory stimulation, these associations persisted in posterior regions and were also observed at the frontal electrode F4. In men with consistently moderate stress levels, significant associations before stimulation were also observed in the parietal-occipital region (Pz, P4, O2). After stimulation, they remained predominantly localized in posterior cortical regions, particularly in electrodes P4 and O2.

In women with decreased stress levels, associations between alpha-band EEG PSD and task accuracy before stimulation were predominantly localized in the occipital region (O1, O2), whereas the effect in the medial parietal electrode Pz was less pronounced. After stimulation, the spatial pattern changed: in addition to parietal-occipital electrodes, significant associations were also observed in the central electrode Cz.

In women with consistently moderate stress levels, significant associations were observed before stimulation in the central-parietal region (Cz, Pz). After stimulation, the spatial distribution of the effect expanded, involving lateral parietal and occipital electrodes (P3, P4, O1, O2).

Overall, the results demonstrate that the positive relationship between alpha-band EEG PSD and visual memory task performance is consistently observed in posterior cortical regions, particularly in the parietal-occipital area. The strength and topography of these associations vary depending on perceived stress level and experimental condition (before vs. after stimulation). The most stable effects were observed in right parietal-

occipital electrodes, particularly in the subgroups with moderate stress levels after auditory alpha stimulation.

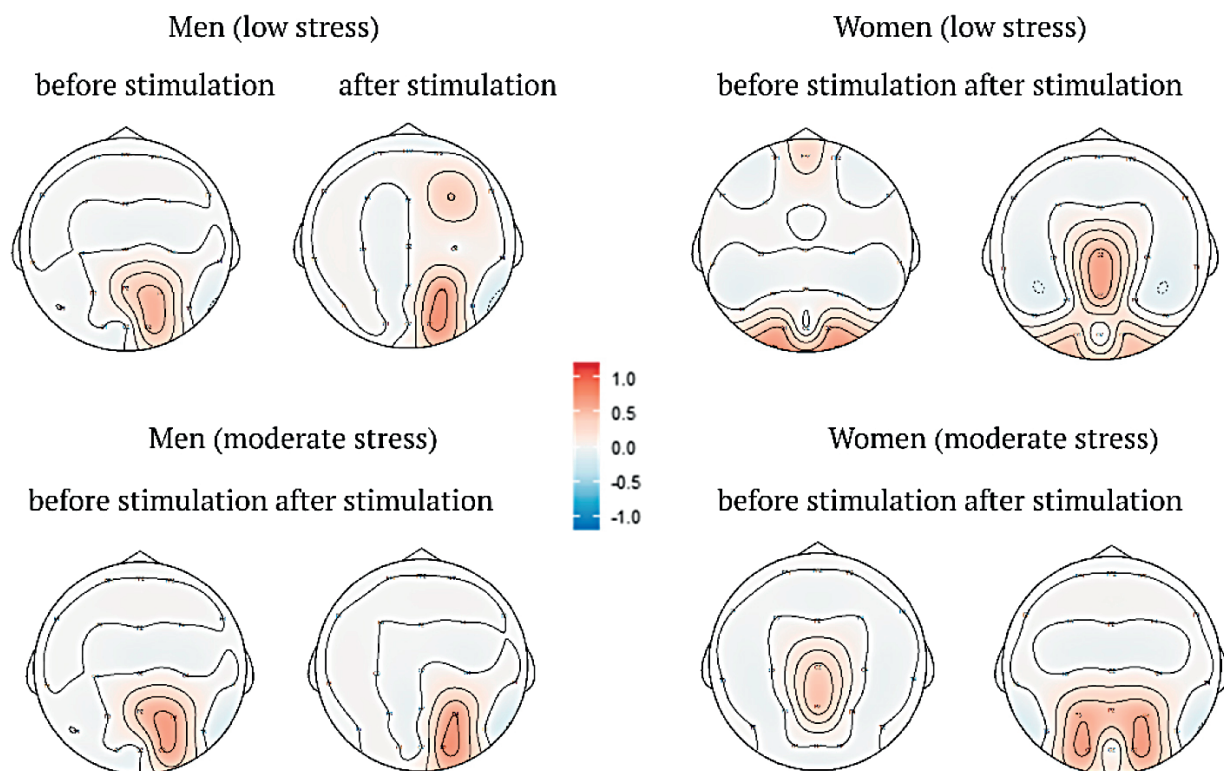
Regression analysis was performed separately for each group and time point; direct comparison of regression coefficients between conditions would require additional testing of interaction effects.

Topographic maps (**figure 2**) show that the relationship between EEG alpha-band power spectral density (PSD) and visual memory task accuracy is primarily formed in posterior cortical regions. In most subgroups, the strongest correlations are localized in the parietal-occipital region, as shown in the pre-stimulation maps.

In men with decreased perceived stress, the posterior correlation pattern remained after stimulation, although an additional small region appeared in the right frontal area. In women of this group, correlations before stimulation were concentrated mainly in the occipital region, whereas after stimulation they shifted toward more medial central-parietal areas.

In the subgroups with consistently moderate perceived stress, posterior cortical regions also dominated before stimulation. After stimulation, the spatial distribution of associations broadened, particularly in women, with lateral parietal and occipital regions also involved, along with the central-parietal zones.

Taken together, the regression results and topographic maps indicate that the association between alpha-band EEG PSD and visual memory accuracy was most consistently expressed in parietal-occipital regions. Auditory alpha-band stimulation was accompa-



**Figure 2 – Topographic maps of correlations between EEG alpha-band power spectral density and visual memory task accuracy before and after auditory stimulation, stratified by sex and perceived stress level.**

**Notes:** Color indicates the value of the correlation coefficient ( $r$ );  $n=21-22$  per subgroup; total  $N=86$ .

nied by stronger or more spatially extended associations in several subgroups, particularly in participants with consistently moderate perceived stress. These findings suggest that the level of perceived stress may influence not only cognitive performance itself but also the spatial organization of EEG–behavior relationships.

After auditory alpha stimulation, task accuracy increased in all subgroups. Regression analysis and topographic mapping revealed stable positive associations between alpha–band PSD and task performance, predominantly localized in parietal–occipital electrodes. After stimulation, these associations became stronger or spatially more extensive in some subgroups

**Conclusions.**

Participants with consistently moderate perceived stress levels demonstrated a more pronounced between-year improvement in short-term visual memory performance than participants whose perceived stress decreased from moderate to low levels.

Auditory alpha–band stimulation was associated with increased accuracy in the visual memory task across all subgroups, with the most pronounced effect observed in participants with consistently moderate stress levels.

Stable positive associations were found between EEG alpha–band power spectral density and task accuracy,

predominantly localized in posterior parietal–occipital cortical regions, reflecting the involvement of cortical networks involved in visual memory processing.

After stimulation, these associations became stronger, and in some subgroups their spatial distribution changed: in women with moderate stress levels, broader involvement of centro-parietal and occipital electrodes was observed, whereas in men the effects remained more localized in the right parietal–occipital region.

The obtained results indicate that stress level modifies the relationship between brain alpha activity and visual memory performance. The most pronounced effects were observed in participants with consistently moderate perceived stress levels. These findings allow us to hypothesize a potential “window of sensitivity” of neural networks to rhythmic sensory modulation under conditions of moderate stress.

**Prospects for further research.**

Further studies may focus on identifying the conditions under which rhythmic sensory stimulation most effectively modulates cognitive functions. Of particular interest is testing the hypothesis of a potential “window of sensitivity” of neural networks to oscillatory modulation across different levels of stress.

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### СТРЕС–ЗАЛЕЖНА МОДУЛЯЦІЯ ВЗАЄМОЗВ'ЯЗКУ МІЖ АЛЬФА–АКТИВНІСТЮ ЕЛЕКТРОЕНЦЕФАЛОГРАМИ ТА ЕФЕКТИВНІСТЮ ЗОРОВОЇ ПАМ'ЯТІ У СТУДЕНТІВ ПРИФРОНТОВОГО РЕГІОНУ

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**Резюме.** Тривале життя в умовах невизначеності та загрози, характерних для прифронтових регіонів під час війни, супроводжується хронічним стресом, який може змінювати функціональний стан мозку та ефективність когнітивних процесів, зокрема уваги й зорової пам'яті. Одним із нейрофізіологічних механізмів, що беруть участь у регуляції цих процесів, є альфа-активність електроенцефалограми (ЕЕГ), пов'язана з контролем кортикальної збудливості, сенсорною обробкою інформації та координацією функціональних мереж мозку під час виконання когнітивних завдань. В умовах тривалого стресового навантаження ці механізми можуть перебудовуватися. Водночас залишається недостатньо з'ясованим, чи змінює рівень сприйманого стресу взаємозв'язок між альфа–осциляціями мозку та ефективністю когнітивної діяльності, а також наскільки цей зв'язок є чутливим до зовнішньої ритмічної стимуляції.

Метою дослідження було оцінити роль рівня сприйманого стресу у модифікації взаємозв'язку між спектральною щільністю потужності ЕЕГ в  $\alpha$ -діапазоні та ефективністю короткочасної зорової пам'яті у студентів прифронтового регіону, а також визначити вплив аудіальної  $\alpha$ -стимуляції на цей зв'язок.

Лонгітюдне дослідження (2024–2025 рр.) охопило 86 студентів (44 жінки та 42 чоловіки), відібраних із 1200 учасників базового скринінгу за шкалою сприйманого стресу PSS–10. Залежно від динаміки рівня стресу учасників було розподілено на групи зі зниженням та зі стабільно помірним рівнем сприйманого стресу. Короткочасну зорову пам'ять оцінювали за допомогою тесту WOM–REST (CogniFit), а альфа–активність – за спектральною щільністю потужності ЕЕГ у 13 відведеннях. Для статистичного аналізу застосовували парний  $t$ -критерій, регресійний аналіз та топографічне картування кореляцій.

Найбільш виражене міжрічне покращення показників зорової пам'яті спостерігалось у підгрупах зі стабільно помірним рівнем стресу. Аудіальна  $\alpha$ -стимуляція супроводжувалася підвищенням точності виконання завдання у всіх підгрупах, причому найбільш помітний ефект також реєструвався саме за помірною рівня стресу. Регресійний аналіз показав стійкі позитивні асоціації між  $\alpha$ -ЩЦП ЕЕГ та точністю виконання завдання, які переважно локалізувалися у паріетально–окципітальних відведеннях. Після стимуляції ці зв'язки ставали більш вираженими або поширювалися на додаткові ділянки кори.

Результати дослідження свідчать, що рівень сприйманого стресу модифікує взаємозв'язок між альфа–активністю мозку та ефективністю зорової пам'яті. Найбільш виражений ефект звукової  $\alpha$ -стимуляції спостерігався у учасників зі стабільно помірним рівнем стресу, що може відображати наявність специфічного «вікна чутливості» нейронних мереж до ритмічної сенсорної модуляції.

**Ключові слова:** хронічний стрес, альфа-активність ЕЕГ, спектральна щільність потужності, зорова пам'ять.

### STRESS-DEPENDENT MODULATION OF THE ASSOCIATION BETWEEN ELECTROENCEPHALOGRAPHIC ALPHA ACTIVITY AND VISUAL MEMORY PERFORMANCE IN STUDENTS FROM A FRONTLINE REGION

Shkabara A. V., Ushakova G. O., Severynovska O. V.

**Abstract.** Prolonged exposure to conditions of uncertainty and threat, typical of frontline regions during wartime, is accompanied by chronic stress that may affect brain functional state and cognitive performance, particularly attention and visual memory. One of the neurophysiological mechanisms involved in the regulation of these processes is alpha-band electroencephalographic (EEG) activity, which is associated with the control of cortical excitability, sensory information processing, and the coordination of functional brain networks during cognitive task performance. Under conditions of prolonged stress exposure, these mechanisms may undergo functional reorganization. However, it remains insufficiently understood whether the level of perceived stress modifies the relationship between brain alpha oscillations and cognitive performance, and to what extent this relationship is sensitive to external rhythmic stimulation.

The aim of this study was to evaluate the role of perceived stress level in modifying the relationship between EEG alpha-band power spectral density (PSD) and short-term visual memory performance in students from a frontline region, and to examine the effect of auditory alpha-band stimulation on this relationship.

A longitudinal study (2024–2025) included 86 students (44 women and 42 men), selected from 1200 participants in the baseline screening, who completed the Perceived Stress Scale (PSS–10). Depending on stress levels, participants were divided into groups with decreased perceived stress and consistently moderate perceived stress. Short-term visual memory was assessed using the WOM–REST test (CogniFit), and alpha activity was quantified using EEG power spectral density across 13 channels. Statistical analysis included paired t–tests, regression analysis, and topographic correlation mapping.

The most pronounced between-year improvement in visual memory performance was observed in subgroups with consistently moderate stress levels. Auditory alpha stimulation was associated with increased task accuracy in all subgroups, with the most pronounced effect also observed under moderate stress conditions. Regression analysis revealed stable positive associations between alpha-band EEG PSD and task accuracy, predominantly localized in parietal–occipital electrodes. After stimulation, these associations became stronger or extended to additional cortical regions.

The findings suggest that perceived stress level modulates the relationship between brain alpha activity and visual memory performance. The most pronounced response to auditory alpha stimulation was observed in participants with consistently moderate stress levels, suggesting a specific “window of sensitivity” in neural networks to rhythmic sensory modulation.

**Key words:** chronic stress, EEG alpha oscillations, power spectral density, visual memory.

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The authors declare no conflict of interest

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**A** – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article.

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