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MOBILE EEG SYSTEMS FOR ALPHA NEUROFEEDBACK AND ANXIETY CONTROL

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The present research is devoted to the study of the relationship between the oscillations of the electroencephalography (EEG) bands and the level of anxiety among sixteen youth athletes aged 17–21 using a mobile EEG system. The study explores the oscillations of brain waves in eyes-open and eyes-closed conditions at rest. The EEG was recorded using a wireless EEG Headset System with dry non-contact EEG sensor electrodes designed by NeuroSky, a ThinkGear module, and a MindCap XL headband. The results of the study demonstrated statistically significant differences between eyes-open vs. eyes-closed conditions in the alpha band in the prefrontal cortex ($p \leq 0.006$). While the correlation between the alpha band and the state of anxiety in the prefrontal cortex demonstrated a statistically significant linear relationship with the negative slope in the eyes-closed condition ($p \leq 0.029$). The data derived from single-channel wireless system equipment demonstrated results that are close to those recorded by conventional lab-based equipment. The different nature of the interrelation between the EEG alpha band oscillations in the prefrontal cortex, depending on the position of the eyes and the level of anxiety of youth athletes, can reflect its relationship to the "inner" world of the individual and is a plausible neurobiological index of anxiety. These findings encourage the application of the portable EEG system for the research of brain functions. Even more, that device may be used for alpha neurofeedback for anxiety in closed-eye conditions.

Keywords: mobile EEG system, non-contact sensors, alpha band, anxiety.

Neurofeedback technologies developed in the 20th century proved to be a simple but effective way to regulate physiological characteristics such as heart rate, vascular tone, and brain electrical activity [11]. Brain-computer interface (BCI) technology for neurofeedback includes prosthetics and control systems [21] for medical diagnostics [10]. Training brain wave activity can facilitate entry into a state of alertness or relaxation [25]. In addition, neurofeedback is effectively used for training healthy [14] or paralyzed [4] users of BCI systems. The study of the EEG band's characteristics that correlate with the parameters of neurofeedback has particular interest.

Anxiety and behavior. Anxiety is a feeling of excitement and restlessness in response to certain stimuli, which may be of a

psychological or environmental nature. Anxiety occurs in response to dangerous or threatening stimuli and is a triple reaction of the body: cognitive, physiological, and behavioral [9]. Various forms of anxiety include negative thinking, excessive worry, restlessness, fear, and over-emotional reactions [12]. People with high points of anxiety predominately have increased points of trait anxiety, but in estimative states, the state of anxiety increases too. Anxiety is a psychophysiological difficulty [30]. In connection with this, systemic interdisciplinary research analyzes the process of emergence and consolidation of anxiety as the result of the complex interaction of different levels of factors: biological, physiological, psychophysiological, personal, social, and so on.

Prefrontal cortex. The prefrontal cortex (PFC) of the human brain is associated with various aspects of behavior and Personality Traits [28]. Thus, these frontal areas of the cortex are involved primarily in the planning of behavior, including social adaptation [3]. In several of the case studies presented above, some psychological characteristics can reflect features of spontaneous interactions of neural oscillations and transpose the organization of the functional activity of the prefrontal cortex. While investigating and analyzing the influence of delta and theta rhythms in components of event-related potentials, influencing levels of both extraversion and neuroticism (anxiety) on the specific character of the interrelationship between both arousal and inhibition in cortical and subcortical brain structures [26] was made available.

In summary, many studies indicate a deep interest in finding relationships between anxiety and the mechanisms of changes in the functional activity of the brain.

The study's hypothesis and aim. We assumed that qEEG data generated by a single-channel wireless EEG system is stable and associated with the psychophysiological basis of the youth athletes. Thus, we studied possible EEG oscillations in the prefrontal cortex at rest and their interrelationship with anxiety.

MATERIALS AND METHODS

Participants. The EEG records were carried out on sixteen youth athletes aged 17 to 21 (M = 18.29, SD = 1.21). The present results were achieved through the recording of two electrodes in positions Fp1–Fp2 of the NeuroSky Think Gear (USA) single-channel wireless EEG system. This system includes the scalp ring «MindCap XL» by Titan Commerce (Germany), accustomed for application in neuro-bio-managing in sports studies and other purposes (Fig. 1).

Figure 1. MindCap XL and ThinkGear module.

The MindCap XL with NeuroSky ThinkGear is a specially tailored band with a mounting system at the sides and front for sensors and a Bluetooth radio. The ear electrode on the lobe of the left ear was used as an indifferent point. This device uploads EEG data via Bluetooth to the researcher's computer. [27]. When checking brain waves based on the international 10–20 system [18], we can use electrodes at Fp1-Fp2 positions on the prefrontal cortex [5] since the prefrontal cortex is associated with properties of behavior and personality traits [15]. Using the NeuroSky single-channel EEG device, the overall level of mental attention in soccer players was accurately measured, and eye blinking did not significantly affect the measurement [10].

Anxiety test. To assess the competitive anxiety of athletes, the Sport Competition Anxiety Test (SCAT) was used. The SCAT [22] is a 15-item list designed to measure anxiety. Evidence of the test's convergent validity comes from studies that show that it is correlated with various general anxiety inventories [20].

Data Collection. Registration of potentials of the prefrontal cortex realized through unipolar output with two (pair) dry electrodes [23] at the International 10–20 system of electrodes placement referring to as frontal-polar: Fp1-Fp2 and hardware-assisted single-channel wireless system NeuroSky ThinkGear. These sensors are a significant technological breakthrough in that they are the only non-contact EEG sensors [13] ever developed [17]. In addition, amplified 8000x to enhance the faint EEG signals were conclusively sampled at 512 Hz. A standard fast Fourier transform (FFT) was performed on the filtered signal, and furthermore, the signal was double-checked for noise and artifacts in the frequency domain, again using NeuroSky's own algorithms. Other procedures and statistical analyses were demonstrated in previous studies [15, 29].

RESULTS

Spearman's rho was used to analyze the correlation between EEG rhythms and SCAT data according to a non-normal distribution by Shapiro-Wilk's test ($p<0.01$) among some rhythms in EO and EC conditions. Thus, the Spearman correlation analysis showed a significant linear relationship with a negative slope between the EC condition of the alpha band and SCAT ($R = -0.55$, $p\leq0.029$). Together, the correlation between the EO condition for the alpha band ($R = -0.31$, $p>0.225$) and all other bands and SCAT would not be considered statistically significant. The results are provided in Table 1.

Table 1. Spearman's rho between the EEG rhythms and SCAT.

Eyes-open (EO) condition					**Eyes-closed (EC) condition**				
Rhythm	Mean	SD	*R*	*P*	Rhythm	Mean	SD	*R*	*P*
Delta	51.27	47.56	0.48	>0.056	Delta	45.79	45.11	-0.32	>0.222
Theta	53.89	37.60	-0.26	>0.314	Theta	60.44	33.91	-0.42	>0.099
Alpha	58.90	29.34	-0.31	>0.225	Alpha	118.99	97.84	-0.55	**≤0.029**
Beta	98.29	34.01	0.06	>0.799	Beta	86.09	34.55	-0.22	>0.400
Gamma	32.55	7.43	-0.12	>0.604	Gamma	35.07	15.77	-0.31	>0.200

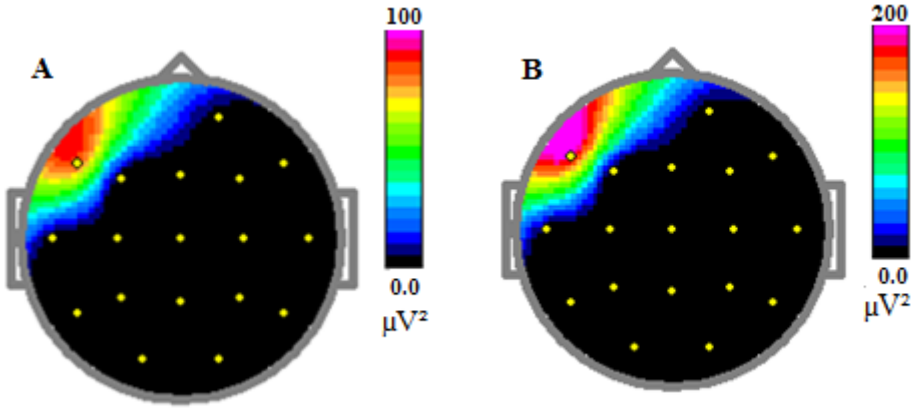

Figure 2. Grand averaged topographic scalp maps depicting differences between EO (A) and EC (B) conditions to EEG alpha band.

Differences in band characteristics between EO and EC. Due to the lack of a normal distribution, the non-parametric Wilcoxon signed-rank test was used to test the significance in this case. Thus, the result of the study reveals statistically significant differences ($p\leq0.006$) between the EO and EC conditions in the alpha band at rest (see Fig. 2 and Tab. 2).

Table 2. Wilcoxon test to EEG bands between EO and EC.

Rhythm	Mean **(EO)**	SD **(EO)**	Mean **(EC)**	SD **(EC)**	*Z*	*P*
Delta	51.27	47.56	45.79	45.11	-0.5688	>0.568
Theta	53.89	37.60	60.44	33.91	-0.7756	>0.435
Alpha	58.90	29.34	118.99	97.84	-2.7406	≤**0.006**
Beta	98.29	34.01	86.09	34.55	-1.7064	>0.087
Gamma	32.55	7.43	35.07	15.77	-0.2585	>0.794

DISCUSSION

NeuroSky ThinkGear test reliability. The qEEG data is frequently used in summarizing the assessment of the functional status of the brain [20]. The current study extends that work by demonstrating convergent results in the youth athlete population. The ThinkGear system was sensible to index variability and produced resting state power spectrum values by EC versus EO compatible with previous EEG reports using traditional lab-based systems. Finally, the stability of qEEG received from the ThinkGear system is an eventual sensible biological marker [23]. As the results of our study showed, these differences are statistically significant. At the time when the eyes opened, the power of the alpha oscillations decreased, whereas faster oscillations with a smaller amplitude occurred. The transition between these two eye states (closed versus open) may provide an interesting index of alpha rhythm reactivity and may help to report to the medical staff about the global resting state activity of the process in the human brain. It can be interpreted as a factor expressed in a significant difference between the values obtained using NeuroSky Think Gear in the position of open and closed eyes. The data derived from single-channel wireless system equipment demonstrated results that are close to those recorded by traditional lab-based systems [31]. Therefore, the ThinkGear chip can detect differences in such a characteristic. In addition, in the state of EO, the functional systems of the brain are reconstructed into the perception of information as "exteroceptive", in contrast to the state of EC, when attention is focused on working with "interoceptive" information already in the brain. Therefore, the result suggests that the topological organization by the spectral power of the brain dynamically switches corresponding to the information processing modes as we open or close our eyes.

The data on alpha oscillations and anxiety. Simplified EEG devices will be able to be widely used for health care, which includes levels of anxiety. The current study demonstrated a statistically significant interrelationship between the EC alpha band and the anxiety of youth athlete participants. According to several findings, the activity of the alpha rhythm in high-anxiety subjects is smaller, while the powers of the slow (delta) and fast/high-frequency (beta) waves are higher than those in individuals characterized by low anxiety. In this instance, the power of the alpha rhythm negatively interrelates with the indices of various types of anxiety [8]. Thus, our result is in line with the conventional approach of the anxiety and alpha relationship theory and refutes Knyazev's claims [19], requiring that alpha rhythm in healthy subjects at rest conditions is positively correlated with personal and situational anxiety. Knyazev connected their results with "evolutionism".

Finally, this study reported the effectiveness of one of the available wireless EEG devices for neurofeedback for anxiety, which had a statistically significant interrelationship with the EC condition of the alpha rhythm. Therefore, EC condition data from the alpha band from a single-channel EEG device is used to control the level of anxiety. Furthermore, this study could be used as additional information about a direct

relationship between alpha oscillations and neurofeedback. This has been borne out by many studies, including the study on the prefrontal cortex [24]. However, a single channel of data does not offer the possibility of asymmetry methods [6], and future research has evidence of inconsistencies in frontal asymmetry studies [7].

CONCLUSION

Consequently, our result suggests portable devices may provide a viable alternative to conventional stationary EEG recording systems for assessing changes in EEG oscillations and their further application to the study of brain functions for health care and other purposes. These findings support using single-channel qEEG data in behavior research and expand existing data on depressive disorder [1, 2]. Furthermore, the high intensity of alpha rhythm in youth athletes with closed eyes is inversely proportional to the level of anxiety. At the same time, the different nature of the interrelation between the alpha activities of the EEG of the prefrontal cortex, depending on the position of the eyes (closed or open), and anxiety may reflect its relationship to the "inner" world of a person. The NeuroSky ThinkGear module and MindCap XL may be regarded as neurofeedback purposes [16] for anxiety and alpha band with EC condition.

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МОБИЛЬНЫЕ ЭЭГ СИСТЕМЫ ДЛЯ АЛЬФА НЕЙРОБИОУПРАВЛЕНИЯ И КОНТРОЛЯ ТРЕВОЖНОСТИ

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Данное исследование посвящено изучению взаимосвязи электроэнцефалографических (ЭЭГ) осцилляций с уровнем тревожности шестнадцати юношей-спортсменов 17–21 года с использованием мобильной ЭЭГ системы. В исследовании изучались осцилляции головного мозга в условиях физиологического покоя с открытыми и закрытыми глазами. ЭЭГ регистрировалась при помощи беспроводной системы с сухими бесконтактными сенсорными электродами, разработанными NeuroSky, а также модулем ThinkGear и обручем MindCap XL. Выявлено статистически значимое различие между положением с открытыми и закрытыми глазами в альфа-диапазоне префронтальной коры головного мозга ($p \leq 0{,}006$). Наряду с этим, корреляция между альфа-диапазоном и тревожностью в префронтальной коре выявила статистически значимую отрицательную связь в положении с закрытыми глазами ($p \leq 0{,}029$). Данные, выявленные с одноканальной беспроводной ЭЭГ-системы, продемонстрировали результаты схожие с данными регистрируемые посредством стационарного лабораторного ЭЭГ оборудования. Различный характер взаимосвязи осцилляций альфа-диапазона в зависимости от положения глаз с уровнем тревожности юношей-спортсменов может отражать ее связь с «внутренним» миром личности и позиционироваться в качестве нейробиологического индекса тревожности. Данные результаты подтверждают применение портативных ЭЭГ-систем для изучения функций мозга. Более того, подобные устройства могут использоваться и для альфа нейробиоуправления состояния тревоги в положении с закрытыми глазами.

Ключевые слова: мобильная ЭЭГ-система, бесконтактные сенсоры, альфа-диапазон, тревожность.

ALFA NEYROGERİ ƏLAQƏ VƏ HƏYƏCANI İDARƏ ETMƏK ÜÇÜN MOBİL EEQ SİSTEMLƏRİ

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Tədqiqat mobil EEQ sistemindən istifadə edərək 17-21 yaşlı on altı gənc idmançıda elektroensefaloqrafik (EEQ) salınımlar və həyəcan səviyyəsi arasındakı əlaqənin öyrənilməsinə həsr edilmişdir. Tədqiqat açıq və qapalı gözlərlə fizioloji istirahət şəraitində beyin salınımlarını öyrəndi. EEQ NeuroSky tərəfindən hazırlanmış quru kontaktsız sensor elektrodları olan simsiz sistemdən, həmçinin ThinkGear modulundan və MindCap XL baş bandından istifadə etməklə qeydə alınıb. Prefrontal korteksin alfa diapazonunda açıq və qapalı gözlərlə mövqe arasında statistik əhəmiyyətli fərq aşkar edilmişdir ($p \leq 0.006$). Bununla yanaşı, prefrontal korteksdə alfa diapazonu ilə həyəcan arasındakı əlaqə, qapalı gözlərlə vəziyyətdə statistik əhəmiyyətli mənfi əlaqəni ortaya qoydu ($p \leq 0.029$). Tək kanallı simsiz EEQ sistemindən aşkar edilən məlumatlar stasionar laboratoriya EEQ avadanlığı ilə qeydə alınan nəticələrə oxşar nəticələr göstərdi. Gənc idmançılarda gözlərin mövqeyindən və həyəcan səviyyəsindən asılı olaraq alfa diapazonunun salınımları arasındakı əlaqənin fərqli təbiəti onun şəxsiyyətin "daxili" dünyası ilə əlaqəsini əks etdirə bilər və həyəcanın neyrobioloji göstəricisi kimi yerləşdirilə bilər. Bu nəticələr beyin funksiyalarını öyrənmək üçün portativ EEQ sistemlərinin istifadəsini təsdiqləyir. Bundan əlavə, bu cür cihazlar qapalı göz vəziyyətində həyəcanın alfa neyrogeri əlaqə üçün də istifadə edilə bilər.

Açar sözlər: mobil EEQ sistemi, təmassız sensorlar, alfa diapazonu, həyəcan.

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