BOOK CHAPTER

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# Brain and Behaviour: Quantitative Analysis among Youth Men using Mobile EEG System

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**Abstract:** The present article explores the relationship between the EEG rhythms' oscillations and the personality traits in a group of young males (soccer players and sport students). EEG was recorded by a single-channel wireless EEG system in the prefrontal cortex. Personality traits were identified in accordance with Eysenck's personality questionnaire. The regression model was used to analyse the EEG rhythms as possible predictors for Eysenck's personality traits. The findings of the study highlighted two slow rhythms that can be considered as predictors for personality traits, specifically: delta wave – for extraversion with negative slope, which could be related to mood, and theta wave – for neuroticism with negative slope, which could be related to inhibition. Those EEG patterns could condition preference for certain behavioural strategies in accordance with type of temperament. In addition, for two EEG high-frequency rhythms, association was revealed with personality traits: for beta rhythm as a hypothetical predictor for neuroticism, and for gamma rhythm – for lie. The statistically significant relationship between the slow bands with neuroticism and extraversion indicate to influences of the emotion-generating and reticular brain structures. In conclusion, the prefrontal cortex's background EEG activity can reflect preference of certain behavioural strategies, which are formed in accordance with individual type of temperament. This implies that study further examined probability association between the higher frequency bands (beta and gamma) and personality traits, which would be achieved in future researches. In addition, the data derived from a single-channel wireless system equipment demonstrated results, which is close to EEG recorded by conventional lab-based equipment.

**Keywords:** Mobile EEG System, EEG patterns, EEG rhythms, EEG

## Introduction

It is a generally accepted idea that the basis of temperament is the same as the basis for the individual characteristics of conditioned behavior, in particular, the features of the nervous system. I.P.Pavlov gave scientific explanation of temperament. It was shown that the same reasons underlie both the basis of temperament and individual peculiarities of conditioned activity, particularly, peculiarities of the central nervous system. Moreover, Pavlov-derived classification of indicators of the personality temperament is based on examinations of extroversion – introversion scales. Combinations of three main peculiarities of nervous system (strength, tranquility and flexibility) composes different types of nervous system or types of higher nervous activity (HNA) [1]. Basing on the data on the physiology of HNA, H.Eysenck [2,3] hypothesizes that the strong and weak types, according to Pavlov, are very close to the extraverted and introverted types of personality. The nature of extraversion and introversion is based on the innate properties of the central nervous system (CNS), which ensures the equilibrium of the processes of excitation and inhibition [4]. Moreover, the main reason for the differences between the extraversion and introversion properties of the nervous system, according to Eysenck, are the degree of excitation of the cerebral cortex - an indicator that has, as a rule, hereditary and not acquired origin [5,6].

### Prefrontal cortex

Prefrontal cortex (PFC) of the human brain is associated with various aspects of behaviour and Personality Traits [7,8]. Thus, these frontal areas of the cortex are involved primarily in planning of behaviour, including social adaptation [9]. Taken together, several researches demonstrated that PFC recruits cortical inhibitory circuits [10-12]. Several of the case studies presented above some psychological characteristics can reflect features of spontaneous interactions of neural oscillations and transpose organization of the functional activity of the cortex, in particular PFC. In is enough just to naming a few, extraversion and neuroticism are associated with cortical arousal [13,14]. Therewith, while investigated and analysed of influence delta and theta rhythms in components of event related potentials made available influencing levels of both extraversion and neuroticism on specific character of interrelationship both arousal and inhibition in cortical and subcortical brain structures [15,16].

### Study aims and hypotheses

We predicted the quantitative electroencephalography (qEEG) data [17] would be associated with psychophysiological basis of subject. Therefore, the aim of current study investigated spossible to identify the predictor(s) for Personality Traits by Eysenck through particularity of EEG oscillations in the PFC.

## Materials and Methods

### Participants

The studies were conducted on twenty-five soccer players and sport university students of ages between 17–21 years (M = 18.50, SD = 1.11). All students were male with normal hearing and normal vision. Furthermore, they did not have any psychiatric and neurological disorders and cardiovascular disease history.

### Questionnaire

Temperament definition was carried out to method of Eysenck's 101-item Personality Questionnaire (EPQ) [18]. The testing technique designed to revealing the following factors, characterizing structure of personality: Psychoticism, Extraversion, and Neuroticism. In addition, we added in analysing and the lie scale, which included in the EPQ. Since this may be of interest because lie scale scores are, open to more than one interpretation. Translation and adaptation of the Questionnaire had been carried out in the Department of Psychology at State University.

### *Study Design and Data Reduction*

Registration of potentials of the prefrontal cortex was realized through unipolar output with two electrodes at the International 10–20 system of electrodes placement refer to frontal-polar: $Fp_1$-$Fp_2$ and hardware-assisted of single channel wireless system «NeuroSky ThinkGear» manufactured in the USA. This system includes scalp ring «MindCap XL» manufactured in Germany accustomed for application in neuro-bio-managing in sport and other researches (Figure 1). These sensors are a significant technological breakthrough in that they are the non-contact EEG sensors [19,20]. In addition, on the forehead signals of EEG from the brain and signals of EOG (electrooculography) from eye blinks and front muscles may detected too. Furthermore, several studies in the last years demonstrated significant results to use NeuroSky devise in various researches [21-24]. Thus, NeuroSky ThinkGear consists of proprietary firmware within a single channel [25,26], dry electrodes device. Herewith amplified 8000x to enhance the faint EEG signals and a standard fast Fourier transform (FFT) is performed on the filtered signal, and in fine, the signal is double-check for noise and artefacts in the frequency domain, again using NeuroSky's owner algorithms.

**Figure 1. MindCap XL and ThinkGear module.**

Spectral analysis of EEG was conducted by separating the following ranges: delta – 1-3 Hz; theta – 4-7 Hz; alpha – 8-12 Hz; beta – 13-30 Hz; gamma – 31-50 Hz. The Hanning's window was applied (epochs were overlapped by 50%), while discretization frequency was 512 Hz. Power of a band of spectral density was expressed in $\mu V^2/Hz$. The EEG power spectrum was computed in the following derivations: Fp1 and Fp2. The data were collected in the inserted microchip and transduced over wireless communication "Bluetooth" on a computer for recording and following autonomic quantitative analysis by program software «MindRecord» (New Dimension Technology, Japan). Further, on, EEG data in untreated format were transformed into text file (ASCII) for following analysis. For analysis, 2-second portions were chosen with total length of 30-40 sec. The ear electrode on the lobe of the left ear was used as indifferent point. The electrophysiological indexes for each person were registered in the state of relaxed awareness with closed eyes for 5 min. Analysis of selected artefact-free fragments of EEG was realized with application of a program "WinEEG" (Mitsar, Russia). In this case, the epochs, containing amplitudes, exceeding 150 μV, were canceled from analysis. Along with it, eye-moving and muscular artefacts were removed with application of "Independent Component Analysis" (ICA) in the program software "WinEEG". Moreover, the epochs were checked on presence of artefacts as well visually, while the fragments, containing them, were removed from analysis.

### *Procedure*

These studies were conducted in the room of medical adviser with eyes-closed (EC) conditions with a rest. EEG was recorded unipolarly from two symmetric derivations on the right and left hemispheres for 5 minutes. The ear electrode on the left side was used as the reference. During registration, black mask, protecting from light, was put on the eyes of a tested. Each student gave verbal consent for test taking. Researcher ensured that participants were not sleeping or dozing in your EC condition. University students received course credit for participation in the study. These studies were conducted in conformity with the ethical principles of the Helsinki Declaration.

### *Statistical Analyses*

In this study, we used Shapiro–Wilk test to verify the normality of the data. As well, linear regression model was used to analysing EEG rhythms as predictor for the Personality Traits by Eysenck. The level of significance was set at $p<0.05$. Statistical analysis of collected data was performed with «SPSS v.23: An IBM Company» (USA).

## Results and Discussion

The results of the study had highlighted two predictors of the Personality Traits amongst EEG rhythms (delta and theta rhythms). Therewith, in the two rhythms had of tendency as predictors of the Personality Traits (beta and gamma rhythms). Analysis is shown in Tables 1-3 and in Figures 2, 3. On the other hand, due to the lack of normal distribution for Psychoticism scale we excluded this trait from subsequent analyses.

**Table 1. Linear regression analysis examining the association of the EEG rhythms to extraversion**

| Rhythm | Mean | SD | $F_{(1,23)}$ | $R^2$ | *t* | *P* | Shapiro-W. *(P)* |
|---|---|---|---|---|---|---|---|
| **Delta** | 48.65 | 39.24 | 8.245 | 0.264 | -2.871 | **0.009** | 0.358 |
| **Theta** | 59.61 | 35.20 | 0.284 | 0.012 | -0.533 | 0.599 | 0.406 |
| **Alpha** | 69.59 | 44.50 | 1.559 | 0.063 | -1.249 | 0.224 | 0.102 |
| **Beta** | 82.97 | 22.69 | 0.580 | 0.025 | 0.762 | 0.454 | 0.157 |
| **Gamma** | 39.21 | 21.45 | 0.061 | 0.003 | -0.248 | 0.807 | 0.217 |

**Table 2. Linear regression analysis examining the association of the EEG rhythms to neuroticism.**

| Rhythm | Mean | SD | $F_{(1,23)}$ | $R^2$ | *t* | *P* | Shapiro-W. *(P)* |
|---|---|---|---|---|---|---|---|
| **Delta** | 48.65 | 39.24 | 0.010 | 0.000 | -0.100 | 0.921 | 0.537 |
| **Theta** | 59.61 | 35.20 | 10.138 | 0.306 | -3.184 | **0.004** | 0.593 |
| **Alpha** | 69.59 | 44.50 | 0.211 | 0.009 | -0.459 | 0.651 | 0.873 |
| **Beta** | 82.97 | 22.69 | 3.845 | 0.143 | -1.961 | ***0.062*** | 0.370 |
| **Gamma** | 39.21 | 21.45 | 1.000 | 0.042 | -1.000 | 0.328 | 0.381 |

**Table 3. Linear regression analysis examining the association of the EEG rhythms to lie.**

| Rhythm | Mean | SD | $F_{(1,23)}$ | $R^2$ | *t* | *P* | Shapiro-W. *(P)* |
|---|---|---|---|---|---|---|---|
| **Delta** | 48.65 | 39.24 | 0.219 | 0.009 | -0.468 | 0.644 | 0.555 |
| **Theta** | 59.61 | 35.20 | 0.128 | 0.006 | -0.358 | 0.724 | 0.578 |
| **Alpha** | 69.59 | 44.50 | 0.815 | 0.138 | -0.903 | 0.376 | 0.877 |
| **Beta** | 82.97 | 22.69 | 0.549 | 0.023 | -0.741 | 0.466 | 0.513 |
| **Gamma** | 39.21 | 21.45 | 3.548 | 0.137 | -1.884 | ***0.072*** | 0.306 |

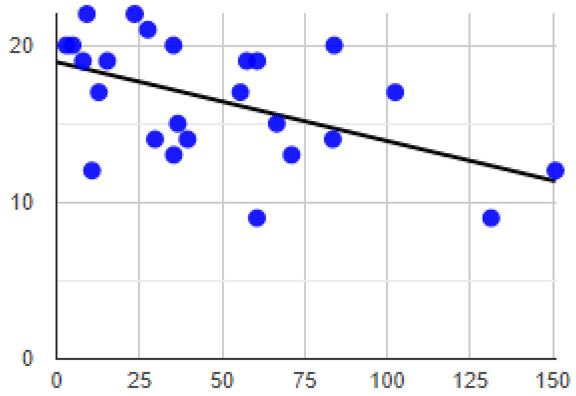


**Figure 2. The association of delta rhythm to extraversion: at abscissa (X) – power spectrum (μV²), at ordinate (Y) – level of extraversion (point).**

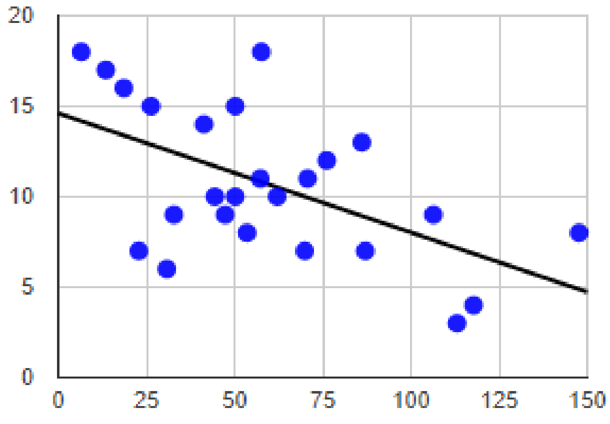


**Figure 3. The association of theta rhythm to neuroticism: at abscissa (X) – power spectrum (μV²), at ordinate (Y) – level of neuroticism (point).**

### *The Extraversion*

In the study, statistically significant association between the delta rhythm and extraversion is revealed (see Table 1 and Figure 2). Particularly, the first predictor, the delta showed the negative relationship with extraversion level ($t$ = -2.871, $R^2$ = 0.264; $p \leq$ 0.009). In our study the negative relationship with extraversion, probably determines trends of a power to the delta, which is related to increased several forms of negative mood [27]. Indeed, association extraversion with positive mood has been shown [28]. This may be related to the fact that slow oscillations, in particular delta rhythm, are associated with dopaminergic basis of extraversion [29,30]. This conclusion is confirmed by the fact that delta rhythm is implicated in reward processing [31], which is also related to dopamine [32].

### *The Neuroticism*

According to our results, the theta rhythm showed statistically significant negative relationship with neuroticism ($t$ = -3.184, $R^2$ = 0.306; $p \leq$ 0.004). The results are presented in Table 2. Neuroticism might reflect the level of anxiety of an individual, since in this context anxiety acts as a feature of temperament, in which high indicators of anxiety are always combined with relatively high rates of neuroticism and, apparently, are underlain by this innate indicator of typology of higher nervous activity [33,34]. Taken together, anxiety is associated with activation in PFC [35], including in youth population [36]. In addition, our results are consistent with the results of other researches, which revealed the high frontal theta rhythm associated with the lowest score in anxiety and neurotic scales [37,38]. Taken together, positive emotions are associated with an increase in frontal theta power. Furthermore, theta rhythm has been associated with response inhibition [39]. In addition to the above said, it was noted that the power of theta oscillations in PFC decreases during anxiety and increases during relative safety [40]. Furthermore, in most clinical therapy protocols, patients/clients are required to close their eyes while receiving relaxation or biofeedback training including theta rhythm. Indeed, our result from the regression analysis revealed that the theta rhythm predicts the anxiety (neuroticism) with eyes-closed condition in youth population (Figure 3). On the other hand, other findings with using a single dry sensor wireless mobile EEG system demonstrated that EEG power spectra in theta band decreased with an increase in motor task familiarity, which also might associated with increased neuroticism [41].

Furthermore, the beta rhythm showed negative relationship with neuroticism, but on the level of tendency ($p \leq 0.06$). This result is consistent with the data, reporting less beta power in the neurotic patients [42]. Taken together, beta rhythm suppression is associated with emotions [43]. As is well known, neuroticism and emotionality are correlated [44, 45]. In addition, our result might be interesting for future research to unravel the functional mechanism of frontal beta rhythm patterns for understanding this role in neuroticism or neurosis.

### *The Lie*

The gamma rhythm showed negative relationship with lie, but on the level of tendency ($p \leq 0.07$). The results are presented in Table 3. In addition, participants with depression, performing emotional tasks, had decreased frontal gamma rhythm [46-48]. Although our result did not reach a statistically significant level, it still gives an interesting result for future researches, especially in the prefrontal cortex for understanding a role of gamma oscillations in human behavior. On the other hand, the role of PFC to be implicated in mood and emotional regulation is well-established [49]. Taken together, the tendency to link the gamma rhythm with the scale of lies is probably, related to the fact that, as many sources report, the lie scales in various researches have a pronounced connection with depressive states [50]. Accordingly, our results indirectly support the results of the above studies, which reported that the increase in depressive states suppress the power of gamma rhythm. Thus, basing on the theory that has already been formed in recent years, we also propose that the gamma rhythm can also serve as a predictor of the lie scales. Therefore, one can conclude that the gamma power in prefrontal cortex may be a reliable marker for lie scales, because gamma oscillations in the brain cortex are much more effective than in the subcortical structures [51].

## Conclusion

Thus, the analysis of the neurophysiological EEG correlates of psychological qualities, allocated to Eysenck, indicates the specificities of neural structures in the PFC affected in various indicators of neuroticism, extraversion, and lie. Those EEG patterns, probably, determine preferentially preference to advocate policies of behaviour, established by temperament. Furthermore, statistically significant relationship between the slow bands with neuroticism and extraversion indicates that they may be influenced by emotion-generating and reticular brain structures [52] and have interrelationship with cortex in frontal lobe. In addition, to our knowledge, this is one of the first researches to using the NeuroSky Think Gear module with single-channel EEG system in studies of temperament features. It is concluded that technology developments provide an interesting a vehicle for research in Personality among athletes and non-athletes.

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