Parietal EEG Theta/Beta Ratio as an Electrophysiological Marker for Extraversion-Related Differences

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Abstract

Personality traits describe the typical behavior of a person. These traits are related to cognitive processing. While extraversion represents a Behavior Activation System (BAS), neuroticism is a part of the Behavior Inhibition System (BIS). Independence of these systems allows assuming the existence of several personality types with different Extraversion and Neuroticism scores. These traits are also related to monoaminergic systems functioning, differences in EEG alpha asymmetry, and attention control during processing of emotionally laden stimuli. However, personality traits-related EEG differences are not consistent within studies. To investigate these relationships between EEG waves and personality, a study with 235 participants was conducted. After fulfilling the EPI questionnaire, resting-state EEG with closed eyes was recorded. Attention control and dominance of subcortical processes were evaluated with theta/beta ration (TBR) and the delta/beta ratio (DBR). Cluster analysis revealed the existence of two personality types with high Extraversion and low Neuroticism, and low Extraversion and high Neuroticism. These clusters had a small difference in TBR in the right parietal lobe. Spearman correlation supported this finding, revealed a connection of Extraversion with higher TBR in all areas except lateral prefrontal lobe and DBR in the parietal lobe, and left medial areas. Due to this, existence in attention control between introverts and extraverts is concluded.

Keywords: EEG Theta/Beta Ratio; Theta-Beta Ration; Extraversion; Neuroticism.

Introduction

Personality has a strong impact on behavior and cognitive functioning. Anxiety has an impact on cognitive capacity due to attentive bias and processing of unrelated to the task information, Eysenck, Derakshan, Santos & Calvo (2007). Anxiety, which is related to personality traits, has a negative impact on inhibition function, processing efficiency, and shifting function [1]. In addition to the description of relationships between cognitive functions and personality trait, an association of personality traits with brain activity was investigated.

Personality differences are studied with different neuroimaging methods. EEG allows investigation of brain activity with high temporal resolution. Analysis of different frequency band activity provides and information about the interaction of cortex and subcortical structures in affective processes [2]. The dominance of slow waves over fast waves represents a reduced cortical control and motivational imbalance [3]. Slow wave to fast wave ratios allows investigation of attentional control and anxiety.

Neurobiology of traits revealed the hierarchy of personality traits and their relation to brain functioning. According to DeYoung [4], Neuroticism and Extraversion belong to different metatraits. While Extraversion belongs to Plasticity metatrait, which represents a tendency to explore, Neuroticism is a part of Stability metatrait, which is a tendency to restrain disruptive emotions. Several studies revealed Extraversion is a part of the Behavioral Approach System and connected to the dopaminergic system and endogenous opioid systems [5]. A positive association between Extraversion and brain activity during the resting state in nucleus accumbens, medial orbitofrontal cortex, amygdala, and striatum was found [6]. Similarly, an association of Neuroticism with brain activity in anterior cingulate cortex, insula, and amygdala was reported. This trait is related to chronical stress and reduced capability to mobilize [7]. Neuroticism is related to both Behavioral Inhibition System (BIS) and Fight-Flight-Freeze System (FFFS) which are modulated by serotonin and norepinephrine

neurotransmitters. EEG and personality correlates were reported as well. Belonging of Extraversion and Neuroticism to different metatraits allows assumption of their independence and existence of several subjects' classes with various means.

Theta-beta ration (TBR) is related to both the performances of attention-demanding tasks and self-reported attentional control. TBR was inversely correlated with inhibitory control functioning measured and self-reported attention control [8]. This ratio is positively related to disadvantageous decision-making and ADHD [9]. Although these finding allowed hypothesizing that delta-beta ratio (DBR) is also related to attention control self-report, Morillas-Romero et al. [10] revealed that anxiety-related decrease in attention control occurs only during performance of emotionally laden stimuli. While anxiety is related to Neuroticism [11], the difference between groups with a significant difference in this trait could result in TBR and DBR difference as well.

Knyazev et al. [12] reported a right temporoparietal junction (RTPJ) is involved in the processing of emotional social stimuli and the generation of a behavioral response. Mediation of these processes by RTPJ was positively associated with Agreeableness. In turn, Extraversion has a moderate correlation with the Hurst exponent in posterior sub-network of DMN (DMNp) [13]. Wacker [14] revealed the connection of extraversion with cognitive control during the AX continuous performance task and frontal EEG alpha asymmetry (FAA), which were changed to the opposite by the D2 blocker. In contrast, research of FAA in adolescence revealed no connection to Extraversion or other personality traits [15]. However, machine learning algorithms fail to predict personality differences, while open and closed eyes EEG were successfully distinguished [16]. The absence of consistency in these conclusions illustrates a necessity of further investigations of this field.

Rojas et al. [17] reported that parietal electrodes of the 10/20 International system of EEG electrodes placement are related to several Yeo networks. For P4 and P3 EEG seeds, the highest Sørensen-Dice similarity coefficient was obtained for the default mode network (DMN), frontoparietal (FP), and limbic networks. In the same study, a connection of P3 and P4 electrodes to ipsilateral lateral parietal cortex (LP), medial prefrontal cortex (MPF), middle temporal gyrus and ipsilateral inferior temporal cortex (IT) was revealed. Due to this, differences in these areas can be a representation of DMN, FP, and limbic networks. These findings make a link between EEG investigations and MRT studies what contributes to the analysis of gained results.

Due to described findings, this study is aimed to test the following hypotheses:

H1: several personality types with different Extraversion and Neuroticism scores exist.

H2: these personality types are different in physiological predictors of attentive control.

Methods

Participants

Participants were 235 students of Kyiv National Taras Shevchenko University, 62 of whom were female. All of them reported the absence of brain injuries or mental disorders. Participants' mean age is 18.45 with a standard deviation of 1.95.

The study was approved by the Bioethics Commission of **Educational and Scientific Centre "Institute of Biology and Medicine",** Taras Shevchenko National University of Kyiv. Written informed consent was obtained from each subject in accordance with the World Medical Association (WMA) declaration of Helsinki (Helsinki, Finland, June 1964).Participants received additional points to their exam marks for participation in the study.

Questionnaire

Participants completed the adapted version of the Eysenck Personality Inventory (EPI). While the questionnaire was developed by Eysenck in 1963 [18], it was adapted by Shmelev A.G. in 1985. The Russian version of EPI includes 57 items. Extraversion and Neuroticism scales included 24 questions each. Nine items are aimed to evaluate sincerity (Lie Scale) [19]. Cronbach's alpha in the current sample was 0,710 for Extraversion and 0,753 for Neuroticism.

Procedure

Informed consent was obtained from participants. EPI was completed before EEG measurement of resting-state with closed eyes (3 min). R Studio was used to analyze data.

EEG Recordings

Monopolar EEG record was performed with the use of EEG 23 Ch system Neurocom (Ukraine, XAI-MEDICA). Silver/silver chloride electrodes were symmetrically locates at anterior frontal (Fp1, Fp2), frontal (F3, F4, Fz, F7, F8), central (C3, C4, Cz) parietal (P3, P4, Pz), occipital (O1, O2) and temporal (T3, T4, T5, T6) recording sites in accordance with international 10-20 scheme. The interconnected ear electrodes were used as a reference for all electrodes. The interelectrode impedance levels did not exceed 5 kΩ. The sample rate of 500 Hz was used for all channels. We estimated the spectral power density (SPD) of all frequencies from 0.2 to 35 Hz. Theta/beta ratio was calculated by dividing the theta power by the beta power, the delta/beta ratio by dividing the theta power by the delta power.

Results

Summary

Mean value of the Neuroticism scale was 12.88 with SD 4.31. Mean value of the Extraversion scale was 13.21 with SD 3.86. Theta/beta ratio (TBR) and delta/beta ratio (DBR) was calculated for participants who completed EPI. To evaluate variables distribution, the Shapiro-Wilk test was performed. For all variables, the test's significance was lower 0.01 for comparison with a normal distribution with the same mean and standard

deviation. Due to this, the hypothesis of normality was rejected. Non-parametric tests were used for further analysis.

Classification of Participants

Table 1: Descriptive Statistics of Extraversion and Neuroticism for Groups.

	Group 1		Group 2	
	M	SD	M	SD
Extraversion	10.67	2.88	16.26	2.39
Neuroticism	14.16	4.13	11.35	4.04
TBR (P4)	3.54	3.47	4.75	4.75

The PAM clustering algorithm was used to identify two clusters based on Extraversion and Neuroticism measures. The number of clusters was defined with the gap statistics method used for PAM cauterization. Gap statistic reached its maximum of 1.098 for two clusters. Due to this, participants were divided into two clusters with the PAM method. Gained cluster differed significantly in Extraversion and Neuroticism scales (Table 1). The first group was lower in Extraversion and higher in Neuroticism with significance p<0.001. Cohen's d r equivalent of the difference between two means for Extraversion was 0.72, while the one for Neuroticism was -0.33. Due to this, the effect size of the difference in Extraversion was bigger in comparison to the effect size of Neuroticism difference. There were no differences between groups in gender distribution. The group with high Neuroticism included 128 participants, while a group with high Extraversion included 108 participants. Both groups have different Extraversion and Neuroticism values from the ones in the sample.

The combination of high Extraversion and low Neuroticism without combinations without either simultaneously high or simultaneously low traits allows if these traits are opposites of one scale. If this assumption was true, Neuroticism and Extraversion be negatively correlated. To evaluate relationships between Extraversion and Neuroticism, the Spearmen correlation was performed. The correlation coefficient was low (rho = .04) and insignificant (p-value =.50). The hypothesis of relatedness of Neuroticism and Extraversion was rejected.

Between-Group Differences in EEG

No difference was found between groups in DBR. A significant difference was identified only for TBR in the P4 electrode. Cohen's d was 0.14 what can be recognized as a weak effect size. The first group's mean of TBR in P4 was 3.54 with SD 3.47, while the second's one was 4.76 with SD 4.75. To evaluate the relationships between personality traits and TBR in P4, a correlation analysis was conducted.

Correlation Between Personality Scores and DBR

Since the data were not normally distributed, Spearman correlation analysis was conducted to reveal relationships between Extraversion scales and selected slow wave – fast wave ratios. Low but significant correlation were revealed with DBR in Fp2 ($r = .158$, $p=.015$), F3 ($r = .167$, $p=.010$), C3 ($r = .132$, $p=.043$),

C4 ($r = .162$, $p=.013$), T6 ($r = .162$, $p=.013$), P3 ($r = .184$, $p=.005$), P4 ($r = .198$, $p=.002$), O1 ($r = .145$, $p=.027$), and Pz ($r = .154$, $p=.018$) (Table 2).

Table 2: DBR Spearman Correlation with Extraversion.

	r	p
Fp2	0,158	0,015
F3	0,167	0,010
C3	0,132	0,043
C4	0,162	0,013
T6	0,162	0,013
P3	0,184	0,005
P4	0,198	0,002
O1	0,145	0,027
Pz	0,154	0,018

Correlation Between Personality Scores and TBR

More theta/beta rations correlated with Extraversion: Fp1 ($r = .218$, $p=.001$), Fp2 ($r = .222$, $p=.001$), F3 ($r = .236$, $p=.000$), T3 ($r = .191$, $p=.003$), T4 ($r = .207$, $p=.001$), C3 ($r = .149$, $p=.022$), C4 ($r = .217$, $p=.001$), T5 ($r = .167$, $p=.010$), T6 ($r = .192$, $p=.003$), P3 ($r = .196$, $p=.003$), P4 ($r = .238$, $p=.000$), O1 ($r = .209$, $p=.001$), O2 ($r = .168$, $p=.010$), Fz ($r = .156$, $p=.017$), Cz ($r = .180$, $p=.006$), and Pz ($r = .206$, $p=.001$) (Table 3). Correlations are stronger and more significant. Since correlation with P4 is the strongest one, between-group difference cannot be stated as non-existing.

Table 3: TBR Spearman Correlation with Extraversion.

	r	p
Fp1	0,218	0,001
Fp2	0,222	0,001
F3	0,236	0,000
T3	0,191	0,003
T4	0,207	0,001
C3	0,149	0,022
C4	0,217	0,001
T5	0,167	0,010
T6	0,192	0,003
P3	0,196	0,003
P4	0,238	0,000
O1	0,209	0,001
O2	0,168	0,010
Fz	0,156	0,017
Cz	0,180	0,006
Pz	0,206	0,001

Discussion

The first hypothesis was accepted after data analysis. The study revealed that two classes could be distinguished in the general population based on Extraversion and Neuroticism

trains. One of these classes has a high Extraversion and low Neuroticism, another one has opposite scoring. Since Neuroticism and Extraversion are not related, there are at least two types of personality: the first with high Extraversion and low Neuroticism, the second with low Extraversion and High neuroticism. Since data were not normally distributed, the results of the cluster analysis are doubtful and require further examination.

Analysis results require rejection of the second hypothesis since no difference was found between two personality types. However, the third hypothesis cannot be rejected due to the correlation of Extraversion with TBR and DBR in many areas. Positive relationships between Extraversion and TBR in frontal lobe allows if extraverts have a lower attention control and more prone to disadvantageous decisions comparing to introverts. Positive association of Extraversion with DBR in parietal lobes predicts higher self-reported attention control. Since both central parietal and central frontal areas have differences in TBR, the difference in DMN functioning can exist. Positive correlation of Extraversion with most brain areas' TBR indicates that extraverts have higher domination of subcortical structures over the cortex. Association of DBR in the parietal lobe and left hemisphere with Extraversion can be explained by DBR relationship to testosterone/cortisol ratio [20]. However, this assumption results in a higher stress level in extraverts comparing to introverts, while previous research relates stress level to Neuroticism that did not have a correlation with DBR [21,22].

Conclusion

It is difficult to evaluate the existence of two groups with opposite Extraversion and Neuroticism measures in the general population due to the absence of normal distribution within the sample. Although extraversion related between-group difference in P4 TBR cannot be stated, correlation analysis supported its existence. There are relationships between extraversion and attention control. There are significant but small differences in brain functioning related to Extraversion that can be described as more dominant subcortical structures in extraverts comparing to introverts.

Competing Interests

The authors declare that they have no competing interests.

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