Neuropsychological Trends

25
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Richard H. Morley - Paul B. Jantz - Reiko Graham
The Salience Network structures as a mediator of violence and perceptions of hostility 7

Sara Invitto - Carola Capone - Graziano Gigante - Giulia Piraino Bianca Sisinni
The effect of acoustic feedback in an auditory Posner paradigm: delay effect and bias in ERP 21

Seyedeh Maryam Moshirian Farahi Mohammad Javad Asghari Ebrahimabad - Ali Gorji - Imanollah Bigdeli - Seyed Mohammad Mahdi Moshirian Farahi
Cortical brain activities related to neuroticism and extraversion in adolescence 39

Laura Angioletti - Michela Balconi
What is the role of metacognition in Parkinson's Disease patients with Pathological Gambling? 61

Ymie J. Van Der Zee - Peter L.J. Stiers - Lieven Lagae Johan J.M. Pel - Heleen M. Evenhuis
Chronological age versus developmental age in evaluating patients' performances on motion perception tests 73

Irene Venturella - Davide Crivelli - Marina Fossati - Francesca Fiorillo - Michela Balconi
Fronto-parietal network in response to pleasant and unpleasant somatic stimuli in DoC patients: a pilot study 95

Cortical brain activities related to neuroticism and extraversion in adolescence

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Abstract

The purpose of the study was to examine gender differences in brain activity related to personality traits in adolescence. 50 adolescents (M_{age}=14.20, SD 1.97; 50% boys) were recruited. To assess personality traits, the BFQ-C was used and for recording cortical brain activity, EEG was applied. Stepwise regression showed that beta band in the frontal region, theta band in the parietal region and beta band in the central region can predict neuroticism. General Liner Model showed that gender is a factor that can interact with parietal in theta band for predicting. Other results showed that extraversion is predicted by theta frontal and theta temporal regions. Moreover, GLM showed that gender is a factor that can interact to frontal in theta and temporal in beta activities for predicting extraversion. To sum up, the outcomes of this present study provided a novel framework for identifying neurodevelopmental correlates of personality traits for further research.

Keywords: neuroticism; extraversion; cortical brain activities; EEG; adolescence

1. Introduction

It is believed that the most significant structural changes in the healthy human brain take place in the perinatal period, but there is sufficient document indicating that adolescence is specified by notable neurodevelopment. Studies about brain maturation during adolescence and early adulthood are of paramount importance, considering the existence of a peak period of neural reorganization that is involved both in normal variation and the beginning of chief mental illnesses like anxiety (Whitford et al., 2007). Moreover, as a developmental period, adolescence is accompanied by mood instability, which involves greater engagement in hazardous behaviors and continuous negative and variable mood states (Meng et al., 2016). One of the most important variables related to adolescence behaviors is personality (Borghuis et al., 2017).

Two personality traits that seem to enhance vulnerability to anxiety signs and mood instability are neuroticism and extraversion (DeYoung & Gray, 2009). Individuals with high neuroticism are emotionally unstable and experience negative emotions such as fear and anxiety. Neuroticism has been regarded as a predisposition to all types of psychopathology, including the anxiety disorders (Moshirian Farahi et al., 2019; Revelle, 2016). Extraversion relegates to the orientation to be concerned with or attainment gratification from the external environment. Individuals with high extraversion are commonly assertive, enthusiastic, lively and sociable. There are pieces of evidence that indicate low levels of extraversion are closely associated with anxiety problems and avoidance behaviors (Vreeke & Muris, 2012).

Greater attention should be paid to the biological systems associated with the structural traits and their development. Personality neuroscience is founded upon the assumption that all rational differences between individuals in terms of cognition, thought, motivation, and emotion (i.e., personality) must involve consistent patterns in brain functioning. According to this perspective, the brain is seen as the proximal source of all personality traits, and greater distal impact in the genome and environment can have a sway on the personality only by affecting the brain (DeYoung & Gray, 2009; DeYoung et al., 2010). For example, extraversion is associated with volume of medial orbitofrontal cortex (DeYoung et al., 2010), amygdala, the nucleus accumbens, orbitofrontal cortex (Depue & Collins, 1999), and it reflects dopaminergic system (Allen & DeYoung, 2017). Also, neuroticism is associated with volume of brain regions, including the amygdala, medial prefrontal cortex (PFC), anterior and mid-cingulate cortex, and hippocampus (DeYoung et al., 2010; Heatherton, Macrae, & Kelley, 2004). Furthermore, the neurotransmitters serotonin and noradrenaline contributors to neuroticism (Allen & DeYoung, 2017). The biological bases of personality may be divergent in childhood, adolescence, and adulthood. Though there is evidence about personality in adulthood, there is little information about childhood and adolescence.

There are recognized theories in personality neuroscience using the electroencephalogram (EEG), such as Eysenck (1987), Gray (1970) and Gale (1981). Eysenck (1987) and Gray (1970) were among the first advocates of the assumption that personality traits provide deeper insights about individual differences with regard to brain functioning. Eysenck argues that extraversion is linked to the reticulo-cortical circuit and neuroticism is associated with the reticulo-limbic circuit. The threshold for cortical arousal in extraverts is higher than introverts, and therefore they prefer more fascinating activities and experiences to reach their desired arousal level. Eysenck conjectured that neuroticism could be described in terms of activation thresholds in the visceral brain or sympathetic nervous system (the limbic system) (Jaušovec & Jaušovec, 2007). Individuals who score higher in neuroticism possess elevated activation levels and lower thresholds in subcortical structures such as the amygdala, septum, and hypothalamus (Revelle, 2016). To investigate Eysenck's arousal hypothesis, cortical arousal was measured using EEG alpha activity. According to recent studies, extraverts show greater alpha activity than introverts and those high on neuroticism (Johannisson, 2016). Gale , Edwards, Morris, Moore and Forrester (2001), demonstrated that introverts have higher cortical arousal than extroverts and neuroticism was associated with alpha band activity differences among larger left against right hemisphere. Another study found that extraverts are more probably to have larger peak amplitudes in frontal alpha frequency. However, there were no associations between extraversion and alpha frequency band in posterior regions and no alpha frequency activity differences in neuroticism (Tran, Craig, & McIsaac, 2001).

According to Gray's theory, the behavioral inhibition system and behavioral activation system (BIS /BAS) are identified as neurological systems. The BIS shows greater sensitivity to signals of punishment and avoidance behavior that is frustrating and non-reward, whilst BAS displays greater sensitivity to signals of reward and is more adaptable to approach behavior (Glen, 2011). These two brain systems underlie the personality dimensions of impulsiveness (neuroticism-extraversion) and anxiety (neuroticism-introversion). A study has shown that measuring BIS and BAS sensitivity taps the same latent constructs as measures of neuroticism and extraversion (DeYoung & Gray, 2009). Knyazev, Slobodskaya, and Wilson (2002) found BAS is positively related to delta, theta and negatively to alpha power, whereas the BIS shows an opposite pattern of correlations. Therefore, lower arousal is observed in subjects high on extraversion and BAS, and higher arousal in subjects high on neuroticism and BIS.

According to Gale and colleagues (2001), several studies have supported the hypothesis that introverts are higher in cortical arousal than extraverts, even though a number of studies have not found these links (Jaušovec & Jaušovec, 2007). Given this information, researchers have studied the relationship between personality and alpha band activity. Moreover, there is evidence to suggest that delta and theta activity is linked with activity from the brainstem and limbic systems, respectively. Both these structures play a serious role in sustaining arousal. Also, low consistent and significant associations were observed between theta and delta activity across cortical regions for extraversion. There were few associations between personality dimensions and alpha and beta frequency activity; this was only seen in males. Fewer relationships between faster frequency bands such as alpha and personality traits may be owing to the methodological problem of using fixed alpha bands (Tran et al., 2006).

Suetsugi and colleagues (2000) reported that the frontal midline theta activity may be closely associated with improvement in the anxiety symptoms. In other research, the recording of resting brain activity using EEG had been widely used to probe neuroticism, to which theta band was found to be negatively related to the eyes-open condition. Alpha band asymmetry in the frontal regions was related to neuroticism with higher left hemisphere activation and smaller right versus left hemisphere differences (Rashid et al., 2011). In the research of Korjus and colleagues (2015), 309 subjects were assessed by EEG, the findings showed that the big five dimensions cannot be predicted by the resting state EEG data.

We had multiple reasons for conducting this study. Firstly, there are conflicting findings on the relationship between personality factors and brain functions. Secondly, since there is evidence that women show different patterns of brain activation than men, it was expected that females would show a higher level of alpha power (less brain activity) than males (Langrova, Kremláček, Kuba, Kubova, & Szanyi, 2012). Thirdly, females were found to have higher levels of neuroticism than males (Hidalgo-Muñoz et al., 2013); thus, according to the second and third reasons, it was expected that gender differences in the functioning of the brain may predict personality traits. Fourthly, previous studies have not considered all regions of the cortex. Fifthly, there is no study to date on adolescence in terms of the links between personality traits and brain activity. Therefore, we aimed to investigate gender-specific differences in brain activity related to personality types in adolescence.

2. Method

2.1 Participants

The research was a correlational study. Fifty right-handed adolescents (25 female and 25 male) were selected from schools in Mashhad. The age range of participants was from 11 to 18 years with a mean of 14.20 years (SD = 1.97). All participants gave informed consent, and all were free of specific psychological and neurological diseases.

2.2 Instruments

2.2.1 The Big Five Questionnaire for Children (BFQ-C)

The BFQ-C (Barbaranelli, Caprara, Rabasca, & Pastorelli, 2003) is a 65-item questionnaire assessing the five factors of personality in children and adolescents. The first, Extraversion, measures characteristics such as enthusiasm, activity, self-confidence, and assertiveness. Agreeableness reflects sensitivity and concern for others and their needs, whereas Conscientiousness measures orderliness, the fulfilling of commitments, precision, and dependability. Neuroticism appertains to experience feelings of discontent, anxiety, anger, and depression. Finally, Openness is interested in intellectual functioning, imagination, creativity, and social and cultural interest. Rating of the questionnaire is according to a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always). Individual item scores are combined to yield a total score for each of the five factors. Clear support has been found for the psychometric qualities of the BFQ-C in children and adolescents from various countries, such as Iran. Cronbach's alpha coefficients ranged from 0.82 to 0.95 (Barbaranelli, Fida, Paciello, Giunta & Caprara, 2008; Del Barrio, Carrasco, & Holgado, 2006; Olivier & Herve, 2015).

2.3 EEG recording

In order to record brain activity, an EEG (Mitsar Co. Ltd., Saint Petersburg, Russia) was used. The device includes 19 main electrodes (Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, P3, P4, Pz, T3, T4, T7, T8, O1, O2; see Figure 1), two reference electrodes (A1 and A2) and a ground electrode (Fpz), according to the 10-20 system of electrode placement (Figure 1). The data were collected using a sampling rate of 250 Hz and filtered in WINEEG software with a frequency band of 0.1 to 30 Hz. Linked Ear references were used with all EEG. The electrolytic gel was used and each site softly abraded until impedances were below 10 kΩ. Eyes-closed and eyes-open conditions were used for recording signals that were 3 minutes each in duration. During the eyes-closed condition, we instructed the participants to place their hands on their knees, half-open their mouths, and avoid blinking or opening the eyes. The eyes-open condition had similar instructions except that we requested them to additionally fixate their eyes on a central point.

After recording the signals, the data were saved in EDF+ format in WINEEG and opened in Neuroguide software. A 4-second, artifact-free epoch (50% overlapping) of 250 samples were extracted through Neuroguide software and submitted to the Fast Fourier Transform (FFT; the resolution was 1.8 Hz), and then the artifacts were rejected by automatic rejection method. As regard to the aims of the study, the frequency bands were for delta (1–3.5 Hz), theta (4–7.5 Hz), alpha (8–12.5 Hz) and beta activity (13–25 Hz) and we used absolute power (μV2). The mean of absolute power for each band was computed in five regions (frontal, central, parietal, temporal and occipital). In addition to quantitative data, topographic data was extracted by WINEEG after rejecting artifacts.

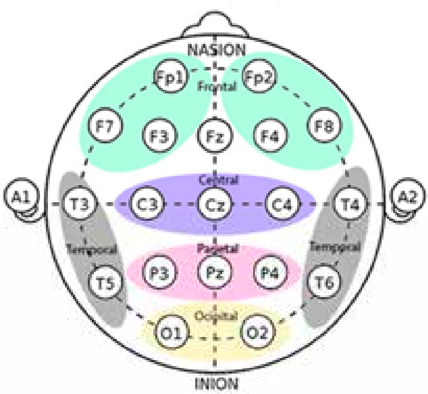

Figure 1. Cerebral areas for EEG band power

2.4 Procedure

Participants completed the consent form. In day one of procedure, prior to entering the Polyclinics of Clinical Psychology (QEEG) laboratory, researchers advised participants about the experimental conditions. After that, participants entered the lab. Initial recording was done with eyes open and eyes closed in a relaxed state. In day two of procedure, participants completed the BFQ-C (See Figure 2). Before analyzing data, outliers (disturbances) were checked and removed.

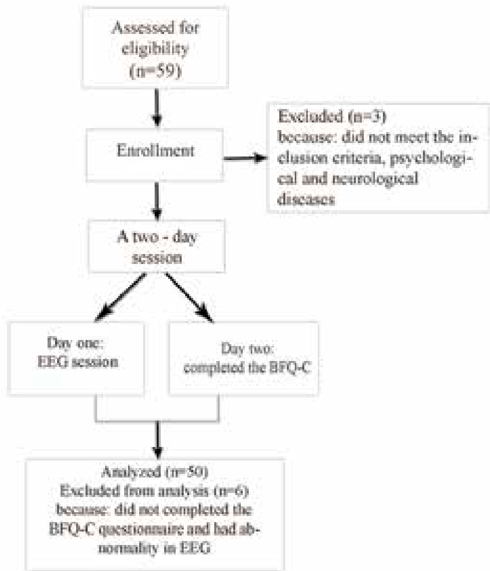

Figure 1. The flowchart of the research's procedure

2.5 Statistical analysis

After collecting the information, the data were entered in SPSS 22 (SPSS Inc., Chicago, Illinois, USA). In order to analyze the data, we used a descriptive statistic and inferential statistic includes: Pearson correlation, Stepwise Regression, General Linear Model and a Bonferroni post hoc test. Also, for analyzing topographic data, a repeated measure ANOVA and the Least Significant Difference (LSD) were used.

3. Results

The mean and standard deviations of neuroticism and extraversion for all participants were 37.24 (9.34) and 34.92 (9.34) respectively. For predicting neuroticism and extraversion factors, the frontal, central, parietal, temporal and occipital regions were computed in absolute power delta, theta, alpha and beta bands. The mean and SD of the frontal, central, parietal, temporal and occipital regions in delta band were 34.32 (17.81), 34.32 (17.81), 39.88 (19.84), 25.89 (14.94) and 39.30 (19.33) respectively and were 20.41 (8.71), 29.48 (16.03), 33.55 (21.91), 18.36 (12.75) and 29.61 (18.28) for frontal, central, parietal, temporal and occipital regions in theta band, in order. The means and SD of the frontal, central, parietal, temporal and occipital regions in alpha band were 24.56 (11.06), 41.99 (20.32), 85.83 (52.97), 39.66 (20.28) and 130.56 (78.39), respectively. Also, the mean (SD) of the frontal, central, parietal, temporal and occipital regions in beta band were 10.65 (4.31), 14.11 (4.98), 18.37 (6.55), 11.86 (4.11) and 21.51 (7.30), respectively. In terms of reliability of the EEG, the mean and SD of the spite test was 0.96 (0.02).

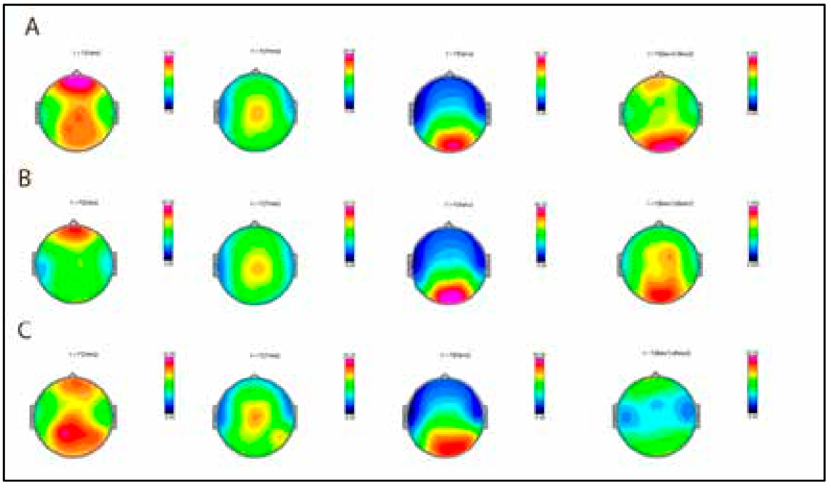

Figure 3. Eyes-closed condition topographies: (A) Delta, theta, alpha, and beta respectively from left to right for all participants. (B) Delta, theta, alpha, and beta respectively from left to right in male participants. (C) Delta, theta, alpha, and beta respectively from left to right in female participants

As seen in Figure 3, in order to analyze the topographic data, repeated-measure ANOVA and LSD were applied. Greenhouse-Geisser Epsilon was .10 (F = 76.888, P = 0.0001, effect size = 0.61: overall, and F = 0.183, P = 0.838, Effect size = 0.004: for gender differences). In terms of the total participants, the results showed that delta increased in the parietal and occipital regions compared to the frontal region (mean difference = 5.56, 4.97, $p < 0.05$), and has an increase in the frontal region than in the temporal region (mean difference = 8.42, $p < 0.05$). The delta increased in the parietal region compared to the temporal region (mean difference= 13.99, $P<0.05$), also, the central region had an increase than the temporal region (mean difference= 8.42, $P<0.05$), while the occipital had a decrease that the central region (mean difference = -5.20, $P<0.05$). Finally, the delta band had an increase in the occipital region compared to the temporal region (mean difference= 13.40, $P<0.05$).

The theta band was greater in the central, parietal and occipital regions than in the frontal region (mean difference = 9.07; 13.14; 9.20, $p < 0.05$). Moreover, results showed that theta increases in the parietal region compared to occipital, central, and temporal regions (mean differences= 3.94, 4.06, 15.88, $P<0.05$). The theta increased in the central region compared to the temporal region (mean difference= 11.12, $P<0.05$). Finally, the results showed that the theta has an increase in the occipital region than in the temporal region (mean difference= 11.44, $P<0.05$).

Also, the alpha band was larger in the parietal, central, occipital and temporal regions than in the frontal region (mean difference = 61.26; 17.42; 106.00; 15.09, $p < 0.05$). Furthermore, the results showed that the alpha band was larger in parietal region than in central and temporal regions (mean differences= 43.84, 46.16, $P<0.05$) while the parietal region has a decrease than the occipital region (mean difference= -44.73, $P<0.05$). Also, the alpha band had an increase in the occipital region than in the temporal region (mean difference= 90.90, $P<0.05$) whereas in the central region had a decrease than in the occipital region (mean difference= -88.57, $P<0.05$).

With respect to the beta band, it was more prominent in the parietal, central, temporal and occipital regions than the frontal region (mean difference = 7.71; 3.45; 1.21; 10.85, $p < 0.05$). In addition, when comparing parietal region with central, occipital and temporal activities, LSD showed that there are significantly differences between the parietal region with the central region (mean difference = 4.25), the occipital region (mean difference = -3.14), and the temporal region (mean difference = 6.50) Also, LSD showed significant increases in the occipital region compared to the temporal region in the beta band (mean difference = 9.64, $P < 0.05$). Moreover, the results showed that there is a decrease in the central region than in the occipital region (mean difference= -7.40, $P<0.05$). Finally, we found that there is an enhancement in the occipital region than in the temporal region (mean difference= 9.64, $P<0.05$).

By considering bands' oscillations, repeated-measure ANOVA and LSD showed that the alpha band increases more than the other bands in the eyes-closed condition ($P < 0.05$). In fact, the mean for alpha was significantly greater than for other bands ($P <$

0.05, see Figure 4). The Greenhouse-Geisser Epsilon was 0.51 ($F = 85.746$, $P < 0.05$, effect size=0.642). Whereas, there was no difference among boys and girls ($F= 0.222$, $P>0.05$).

In terms of correlations between the activity of the different frequency bands and neuroticism and extraversion scores, Pearson correlation showed that there is no significant correlation between neuroticism and frequency bands, while there is significant and positive correlation between extraversion, delta, beta, alpha, and beta bands ($P < 0.01$). However, we analyzed specific regions of each bands to express a clear view of links between cortical activities, neuroticism and extraversion.

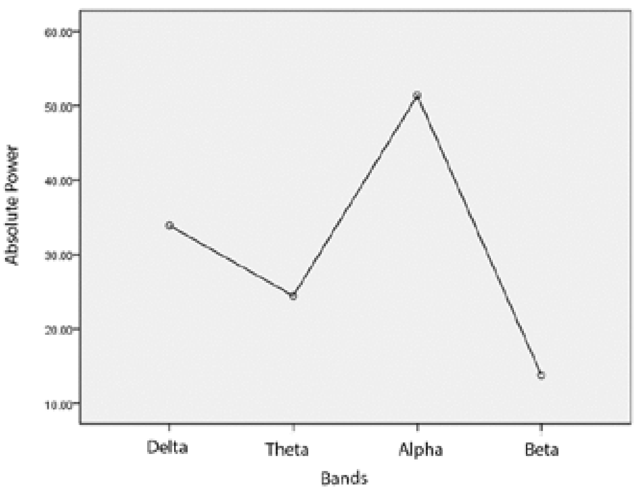

Figure 4. EEG oscillations of bands in total participants

Table 1. Stepwise Regression for Predicting Neuroticism

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig
1	332a	110	.092	8.905	.110	5.954	1	48	018
2	485b	235	.202	8.344	.125	7.680	1	47	008
3	559c	312	.268	7.997	.077	5.127	1	46	028

a *Predictors: (Constant), beta frontal*

b *Predictors: (Constant), beta frontal, theta parietal*

c *Predictors: (Constant), theta parietal, beta central*

As seen in Table 1, we first computed twenty predictors for neuroticism, then, based on stepwise regression, three models were extracted (beta frontal, beta frontal and theta parietal, theta parietal and beta central) and other regions were excluded from the analysis.

Table 1 contains information about the stepwise regression for predicting neuroticism. As regard to the multicollinearity assumption, the results showed that Variance Inflation Factor (VIF) is below 10; therefore, the multicollinearity assumption is met. In regard to the models, frontal in beta band could predict 0.092 percent of neuroticism ($P < 0.05$, F = 5.954). Also, frontal in beta band and parietal in theta band could predict 0.202 percent of neuroticism ($P < 0.05$, F = 7.680). Finally, parietal in theta band and central in beta could predict 0.268 percent of neuroticism ($P < 0.05$, F = 5.127). The beta of the first model for frontal in beta band was 0.332 ($P < 0.05$), the betas of the second model for frontal in beta and parietal in theta band were 0.371 and -0.356 ($P < 0.05$), and the beta of the third model for parietal in theta and central in beta were - 0.547 and 0.539 respectively ($P < 0.05$).

Table 2 contains the results for stepwise regression for predicting extraversion. In terms of the multicollinearity assumption, the results showed that VIF is below 10; therefore, the multicollinearity assumption is met. Considering the model extracted, the frontal region in theta band could significantly predict 0.426 percent of extraversion (F = 37.300, $P < 0.05$). Additionally, frontal in theta band with temporal in theta band could predict 0.479 percent of extraversion (F = 5.910, $P < 0.05$). The beta of the first model for frontal in theta band was 0.661 ($P < 0.05$), and the betas of the second model for frontal in theta and temporal in theta band were 0.883 and -0.334 ($P < 0.05$).

In order to examine physiological brain activity and gender interactions in personality traits, a general linear model was applied. Table 3 shows data from the general linear model for predicting neuroticism. The only significant interaction was gender with theta- parietal (F = 7.365, *P < 0.05*). However, the Bonferroni test showed that these interactions are not significant (*P = 0.259*).

The data for the general linear model for predicting extraversion is shown in Table 4. The interactions of gender with theta- temporal and gender with theta-frontal were significant (F = 3.304, *P < 0.05* and F = 21.265, *P < 0.05*) respectively. Yet, the Bonferroni test showed that these interactions are not significant (*P = 0.174*).

Table 2. Stepwise Regression for Predicting Extraversion

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig
1	.661a	.437	.426	7.079	.437	37.300	1	48	.0001
2	.707b	.500	.479	6.743	.063	5.910	1	47	.019

a *Predictors: (Constant), theta frontal*

b *Predictors: (Constant), theta frontal, theta temporal*

Table 3. Central-beta, Frontal-beta, Parietal-theta and Gender Interactions to Predict Neuroticism

Source	Average squares	df	F	Sig	Effect size
Beta-central* gender	196.305	2	3.123	0.054	0.127
Beta-frontal* gender	7.332	2	0.117	0.890	0.005
Theta-parietal* gender	462.884	2	7.365	0.002	0.255

Adjusted R square: .28

Predictor variables: Beta-central gender, beta- frontal* gender, theta- parietal* gender*

Dependent Variable: Neuroticism

Table 4. Frontal-theta, Temporal-theta and Gender Interactions to Predict Extraversion

Source	Average squares	df	F	Sig	Effect size
Theta-temporal* gender	147.660	2	3.304	0.046	0.128
Theta-frontal* gender	950.363	2	21.265	0.0001	0.486

Adjusted R square: .48

Predictor variables: Beta-temporal gender, Theta-frontal* gender*

Dependent variable: Extraversion

4. Discussion

The aim of this study was to examine the relationships between absolute power and neuroticism and extraversion factors in the adolescent. First, we investigated topographic data. The results revealed that the mean of alpha (M_{alpha}=51.36, SD=24.21) increased compared to other bands (M_{delta}=33.90, SD=15.66; M_{theta}=24.45, SD=12.70; M_{beta}=13.82, SD=3.86), but no gender differences were observed. This finding is consistent with Barry, Clarke, Johnstone, and Brown (2009), who reported significant differences between bands between eyes-open and eyes-closed conditions. In fact, when changing from eyes closed to eyes open, alpha increases. Alpha reduction across the cerebral cortex is identified as arousal and perceiving visual information, known as the thalamocortical system (Barry et al., 2009; Klimesch et al., 2001). The thalamus receives visual information from the optic nerve and then relays the information to the cerebral cortex (Yuan et al., 2016; Zhang, Snyder, Shimony, Fox, & Raichle, 2010). Previous studies have been conducted with adults, while this study was done using an adolescent sample. We also computed twenty predictors for neuroticism and extraversion. The results are discussed below.

4.1 Cortical Brain Activity and Neuroticism

Stepwise regression results showed that the beta band in the frontal region (Fp1, Fp2, F3, F4, F7, F8, Fz), theta band in parietal region (P3, P4, Pz) and beta band in central region (C3, C4, Cz) can predict neuroticism. According to GLM results, gender is a factor that can interact with parietal in theta activity band for predicting neuroticism but not with other regions and bands. However, given the pairwise compression test, this interaction was not significant between males and females.

Some previous studies have reported that neuroticism is associated with the relationship between delta and alpha band in the cortex (Robinson, 2000). Shamidtke and Heller (2004) showed that alpha activity, especially in the posterior region of the parietal lobe, is associated with neuroticism. In fact, the number of neurons that discharge synchronously in integrated cortico-cortical and thalamo-cortical systems is reflected by alpha power (Hindriks & van Putten, 2013). Whereas previous studies have proposed that neuroticism cannot predict resting-state EEG; for instance, Korjus and colleagues (2015) showed that there is no relationship between personality dimensions and power of resting state EEG. Moreover, Karamacoska, Barry, Steiner, Coleman, and Wilson (2018) showed that there is no significant relationship between neuroticism and EEG activity. However, the present study cannot support previous research.

Many assumptive functions have been inferred for the beta wave, such as inhibition of motor planning and movement, coordination in the cortex, and decision making signaling. Beta waves are well-known as the basal ganglia oscillations synchronous with oscillations in the motor cortical regions and reflected in the scalp-recorded Rolandic beta rhythms. The Rolandic beta rhythms are observed as a spontaneous activity during eyes-open and eyes-closed conditions in healthy subjects over the sensorimotor area, such as the central region (Kropotov, 2016). The beta band activity in the frontal region of the brain becomes visible to be linked to the preservation of cognitive states. As a result, it is assumed that excessive improvement of beta-band activity may lead to the abnormal perseverance of the existing state and a worsening of flexible cognitive and behavioral control. In the literature, high absolute beta-power has been reported in patients with panic and anxiety disorder (De Carvalho et al., 2015; Gordeev, 2008; Pavlenko, Chernyi, & Goubkina, 2009).

If beta-band activation indicates or supports a low possibility of change in the sensorimotor set, then it could be posted that pathological deterioration of beta-band activation or coherence should lead to abnormal inhibition of cognitive and behavioral changes. It has been shown that beta-band activation is associated with psychopathological conditions that involve a marked dominance of endogenous top-down processing, such as periods of compulsive thought (as in obsessive-compulsive disorder). Disability behavioral inhibition should be linked to high beta-band activation (Engel & Fries, 2010). Also, the eminence of beta band activity is linked to high arousal, an inability to relax, anxiety and stress, while its suppression can lead to attentional deficits, depression, and poor cognition. In optimal conditions, beta waves help with conscious focus, memory, and problem solving. In other words, high beta waves are associated with significant stress, anxiety, paranoia, high energy, and high arousal (Abhang, Gawali, & Mehrotra, 2016).

Hofman and Schutter (2012) reported that right-dominant frontal beta activity is positively associated with aggressive tendencies and reduced behavioral inhibition. Knyazev, Slobodskaya, and Wilson (2002) showed that neuroticism is positively related to the relative spectral power of high-frequency EEG bands, such as beta in frontal cortical areas. Stepwise regression analysis reveals that the significant predictor of neuroticism was the relative spectral power of the theta band in P4. According to the stepwise multiple regression analysis, behavioral inhibition system (BIS) variability could be predicted by the relative spectral power of the beta band in the frontal region. Additionally, it has previously been established that an over-active BIS is associated with emotional problems and anxiety (DeYoung & Gray, 2009; Knyazev et al., 2002). Therefore, according to Grey's theory, BIS is related to neuroticism.

Most of the earlier studies in adults have suggested that alpha in the frontal area plays a role in the behavioral inhibition system, high cortical arousal, anxiety and neurotic symptom (Gale et al., 2001; Tran et al., 2001), while the present study's findings are inconsistent with those studies. However, in some recent studies, beta band in the frontal and central areas play a key role in the behavioral inhibition system and neurological symptoms (Hofman & Schutter, 2012), which was also found in this research.

Furthermore, the results of the stepwise regression analysis showed that the neuroticism trait can be predicted by theta-parietal lobe. It has been postulated that low-frequency fluctuations of theta range are linked to emotional and motivational processes. Further, there are shreds of evidence of abnormal theta in the parietal lobe during tasks that require cognitive flexibility and attentional control in patients with post-traumatic stress disorder (PTSD). The results reveal that connectivity of right parietal cortex in the theta band is vital to the supply of information essential for cognitive flexibility and that improved theta synchronization has a more general role in depressive, attentional, and anxiety-related sequelae observed in PTSD populations (Dunkley et al., 2015; Verduijn, Vincken, Meesters, & Engelhard, 2015).

Individuals with high levels of neuroticism are prone to emotional responses to stress that foster avoidant or defensive behavior, including anxiety, depression, anger, irritability, and panic. Moreover, according to McNaughton and Gray's theory (2000), neuroticism reflects the joint sensitivity of a behavioral inhibition system (BIS) and is related to cognitive deficits such as decreased inhibition and attentional bias to negative stimuli. Thus, based on the results of this study, it seems that beta in the frontal and central regions and theta-parietal predict neuroticism (Wright & Hardie, 2012).

4.2 Cortical Brain Activity and Extraversion

Other results of this study showed that extraversion is predicted by theta frontal (Fp1, Fp2, F3, F4, F7, F8, Fz) and theta temporal (T3, T4, T7, T8) in both genders. Moreover, according to GLM results, gender is a factor that can interact with theta in frontal and theta in temporal activities for predicting extraversion. However, given the pairwise compression test, these interactions were not significant between males and females.

Previous research has found that extraversion scores were associated with the power of delta and theta. In other words, high delta and theta bands are related to behavioral activation system (BAS) scores (Knyazev et al., 2002). Wacker and Gatt (2010) reported the association between extraversion and theta Pz–Fz in a large, heterogeneous sample including both genders in the rest state. Knyazev, Bocharov, and Pylkova (2012) showed that theta activity in the frontal area is associated with extraversion. Some research using the resting EEG has found that posterior versus anterior theta activity is associated with an agency, reflecting the dopaminergic core and reward of extraversion in male participants (Chavanon, Wacker, & Stemmler, 2011). Other studies have found a positive association between extraversion and alpha activity in frontal area (Fink & Neubauer, 2008; Tran et al., 2001). Therefore, our findings supported some previous studies and conflict with others. In regard to the theta role in frontal and temporal, since anterior frontal and midline theta are associated with positive emotions, E factor is related to an increased activity in frontal in theta band. In fact, frontal theta oscillations play a major role in predicting emotion regulation (Ertl, Hildebrandt, Ourina, Leicht, & Mulert, 2013).

Moreover, theta band associated with BAS has been hypothesized as neural motivational systems that govern reward sensitivity (Scholten, van Honk, Aleman, & Kahn, 2006). The model of extraversion proposed by Depue and Collins (1999) is the most exhaustive and promising model and connects it to the brain system that regulates reward sensitivity and associated positive emotions. This model is mainly consistent with Gray's theory of BAS, which is growingly connected to extraversion (Smillie, Pickering, & Jackson, 2006). In this reward circuitry, the dopaminergic component may have a particularly strong effect on the aspect of extraversion related to drive and assertiveness, while the affiliative aspect of extraversion may be linked to endogenous opioid systems associated with positive emotions derived from achievement or consumption of reward, which is integral to social bonding. Several neuroimaging studies have shown that brain activity in reaction to positive or rewarding stimuli or at resting state is positively correlated to extraversion, especially in brain regions that both McNaughton and Gray (2000) and Depue and Collins (1999) recognize as critical in the circuitry of reward and approach behavior, these regions include the amygdala, medial orbitofrontal cortex, nucleus accumbens and striatum (DeYoung & Gray, 2009; DeYoung et al., 2010).

5. Conclusion

In the present study, we showed that neuroticism is associated with parietal and frontal in absolute power of alpha and delta frequency bands. Extraversion is associated with absolute power of theta band in frontal and temporal regions in adolescence.

Although this study examined the relationships between personality traits and cortical activity in delta, theta, alpha and beta frequency bands in adolescents, it should be suggested, in order to better understand the biological foundations of personality traits in adolescence. Also, other EEG indicators, such as asymmetry, coherence, relative power and power ratio ought to be considered in personality traits in adolescence. Moreover, it is novel to conduct a cross-sectional study in order to compare age-related changes of neuropsychological bases of personality from childhood to adulthood. To sum up, the outcomes of this present study provided a novel framework for identifying neurodevelopmental correlates of personality traits for further research.

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