The Assessment of Frontal EEG Asymmetry according to Neuroticism and Extraversion Dimensions

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Abstract

Background: Nowadays, the study of neurological infrastructure of personality traits has a special place in neuropsychological research. According to Eysenck, the correlation between personality and behavior is the result of individual differences in the brain function. The purpose of the present study was to investigate the frontal EEG asymmetry according to neuroticism and extraversion dimensions.

Methods: The statistical population of the present study was all male students of Payame Noor University of Tehran, who studied in the academic year of 2017-2018. Based on the final scores of distribution in two dimensions of extraversion and neuroticism, four groups (extroverts, introverts, neuroticism and emotional stability) with 25 subjects were selected. The subjects completed the Eysenck Personality Questionnaire- Revised, Waterloo Handedness and footedness Questionnaires-Revised, and their eyedness was assessed, then the electrical activity of the subjects' brain was recorded through EEG from different points on the scalp.

Findings: The findings of the study show that there is no significant difference between the four groups in the right frontopolar (FP2), right middle frontal (F4), right lateral frontal (F8) and right frontal cortex (RF) in alpha activity. There is a significant difference between the left frontopolar (FP1), left middle frontal (F3), left lateral frontal (F7) and left frontal cortex (LF) between the four groups ($P < 0.01$); as alpha wave activity on left regions in neurotic and introverted individuals is more than emotional stable and extroverted subjects.

Based on the fact that, the result of this research is limited to studying frontal electroencephalographic asymmetry, it was limited to comparing electrical activity of the brain. It is recommended that, future research study the relationship between asymmetry of the other lobes of the brain and personality traits with tools like PET scan.

Conclusion: In general, the findings of the present study strengthen the relationship between personality dimensions and frontal EEG asymmetry.

Keywords: EEG asymmetry • Frontal lobe • Personality characteristics • Extraversion • Neuroticism

Introduction

Considering personality theory put forward in psychological sciences, it can be concluded that, researchers agreed on the existence of extraversion and neuroticism as two huge dimensions of the personality. These two dimensions are obvious in general-factor personality models [1] and multidimensional personality questionnaire like: Eysenck personality questionnaire and five-factor model [2,3]. One of the influential personality theories in which extraversion and neuroticism can be seen and it has obtained a special place in neuropsychology research is Eysenck's personality theory. In Eysenck's opinion, personality can be perfectly described by combining high and low levels of two prominent traits, extraversion-introversion and neuroticism-emotional stability [4]. Eysenck believed that, these traits have neurological foundations. From his point of view, behavior and personality correlation is the result of individual differences in the brain function. In studies, the frontal lobe is often known as a part of the brain which is also involved in personality formation process. Damage to this part of the head can lead to depersonalization [5]. Davidson et al. believed that, there exist individual differences in asymmetry of the frontal lobe activities in early life which are relatively stable over time and the role of frontal and anterior temporal asymmetries in mediating approach- and withdrawal-related emotion is considered.

In fact, Alpha symmetry in the frontal area is connected to a normal range of individual differences in emotions [6,7]. Considering this, studies conducted about the brain activity using EEG demonstrate that, asymmetry in different parts of the frontal lobe is strongly related to mental states, temper, psychopathology and reaction to emotional stimuli [8].

Based on studies showing that, asymmetry in frontal area may be related to personality, it can be considered that, extraversion, as one of the fundamental dimensions of the personality is connected to a special biological basis. Specifically, individual differences in network activities of the brain lobes are in charge of individual gestures in extraversion. Introversion is determined by high levels of activities. As a result, brain cortex activity in introverts is more than extroverts [9,10]. Studies by using electroencephalography (EEG) have illustrated that, extraversion has a positive correlation with frontal alpha activity and to explain extraversion biologically, it can be said that, the ascending reticular activating system causes cerebral cortex to be more activated. Individuals showing extraversion personality traits also have ascendant cortical arousal threshold. Extroverts show less activity versus introverts in reticular activating system which exists in frontal part of the brain and it is argued that, this chronic immobility leads to emotional behaviors and searching for an environment enriched with stimulus which is reflected in extroverts' personality traits. A study conducted by wacker on the correlation among extraversion, frontal alpha symmetry and measurement of dopamine release with positive emotions showed that, extraversion is linked to cognitive consistency and cognitive flexibility which are related to positive mood. Extraversion is also accompanied by frontal alpha symmetry and more activity in the left side of the brain and these relationships were the opposite in the group members who were given D2 blocker drugs [11]. These results support dopamine as a basis for frontal alpha symmetry, extraversion and multiple effects of positive emotions on cognitive stability and cognitive flexibility and generated to the previous studies which have put forward cognitive differences between extraversion and introversion. Moreover, these studies have indicated that, waves asymmetry in temporal and parietal areas is also accompanied by superior activity in the left hemisphere and extraversion personality traits; as asymmetry only in temporal location is accompanied by introversion personality traits. In these studies, it was illustrated that, the more activity of alpha wave in frontal, Parietal and temporal areas of the right hemisphere is related to extraversion [12].

A study showed that 50% of NSE male rats induced to Pilo lost cells from the entorhinal cortex, and 17%, of them showed mossy fiber sprouting. This work showed that functioning abnormalities of mossy cells may arise without status epilepticus and may be related to sprouting.. Other group observed SRS in NSE male rats under telemetry, 6-8 months after Pilo administration. Authors also reported commitment of hippocampus, piriform cortex and thalamus in MRI analysis, 1 year after Pilo injection [6].

Another aspect of personality which has been studied in the current research is neuroticism. Eysenck believed that, individuals who get the higher score in neuroticism have higher activation levels in their cortex and lower threshold in the subcortical structures [13]. Arousal threshold in introverted personalities is low and for this reason it seems that, they are looking for lower levels of stimulation. Low threshold for stimulation that creates a chronic irritable condition makes these individuals be in search of low stimulus environments looking for isolation and avoiding change. Individuals with high levels of neuroticism have much activity and low threshold in subcortical structures like: amygdala, prefrontal cortex, mid-cingulate cortex, medial prefrontal

cortex, hippocampus and hypothalamus. The irritability causes people with neuroticism personality trait to have more negative emotional experiences. Eysenck believed that, neuroticism accompanies more activity of the left frontal alpha. Based on the fact that, the right hemisphere supports negative emotions and the left hemisphere supports positive ones, increasing alpha waves in the left hemisphere leads to decreasing the activity in this hemisphere and consequently, results in activity dominance the right hemisphere. The difference which is seen between the left and right hemisphere activity during happiness and disgust has only been seen in the frontal and anterior temporal areas and no difference has been seen in EEG of central, parietal and occipital areas. However, EEG asymmetry in the frontal area of the brain with the dominance of alpha wave can be well seen during negative mood states and neuroticism. Regarding this, in the study carried out by Maier et al. the relationship between alpha asymmetry in frontal area and depressed mood and personality traits were examined. The results show that, individuals who got the higher score in neuroticism have more activity in the left cortical area than the right side. This result was not seen in the individuals with low score in neuroticism which stemmed from absolute activity in the left anterior temporal area in high scores in negative mood [14]. In this respect, there are other studies indicating that, right hemisphere activation is related to an increase in N1 component range and negative assessment of the emotion to all stimuli [15]. Also other research studied the effect of cortisol hormone in stressful situations on alpha asymmetry in frontal area showed that, individual differences in frontal alpha symmetry is a good predictor for the effect of the cortisol hormone on alpha asymmetry [16]. Admitting the hypothesis that, the brain areas in the right and left hemisphere have a prominent role in activation is indicative of their role in outbreak or automatic activation regulation in connection with emotional moods. It seems that, not only do these areas appear in emotional information processing harmoniously, but also they appear in emotions experience in the right hemisphere which is associated with depressive emotional states and anxiety in different forms. As the studies show, depression and low mood is accompanied by decreasing activity in the left hemisphere and increasing activity in the right hemisphere [17,18]. Also in a study conducted by Schmid et al. individuals were taught to respond to some stimuli and avoid some. The results show that, alpha activity in the left frontal area might be related to reward feedback processing which is shown by negative feedback [19]. Also other studies conducted on prisoners found a relationship between aggression and alpha asymmetry with more power in the right hemisphere [20]. Generally speaking, alpha symmetry assessment during rest is related to some personality traits in both pathological situations and individual differences in the form of personality traits. Zhao et al. created two positive emotions: amusement and compassion, and two negative emotions: aggression and fear by emotional movies to screen frontal electroencephalography (EEG) and alpha, beta and theta absolute power in central part of the brain. Results indicated that, amusement and compassion lead to alpha and theta asymmetry in FP1/FP2 and F3/F4 areas. The same result applied to aggression and fear. Theta wave could also recognize two negative emotions in central areas. However, alpha and beta waves recognized two positive emotions in central parts of the brain. Generally, these findings illustrate that asymmetry in EEG and wave's power in medial frontal areas can have the ability to recognize emotions individually [21]. It can be expected that, there exists difference in EEG pattern of the frontal area of the brain based on personality traits. The importance lies in the fact that, by the usage of the new tools like EEG, it can be more accurate to diagnose personality disorders and treat them quickly due to the fact that, it provides the possibility to diagnose more accurately and quickly even when facing ambiguity, So neurological studies are essential in this field. Additionally, although many studies have shown that, brain functional asymmetry is related to emotional and cognitive processing, based on researchers' information, its relationship with individual differences and personality traits is still unknown. Thus, researchers decided to study frontal EEG asymmetry in personality dimensions of extraversion and neuroticism based on Eysenck's personality type theory.

Materials and Methods

The statistical population of the study was all male students of Payame Noor University of Tehran, who studied in the academic year of 2017-2018. At first, 700 students were selected randomly and they answered to the revised Persian version of Eysenck personality questionnaire distributed among them. At the second stage, considering subjects dropout, putting aside incomplete questionnaires and questionnaires with lie scale score (L) above 12, 605 individuals were finally selected for final screening. At the third stage, among 605 individuals based on the end distribution of scores in two dimensions of extraversion (E) and neuroticism (N), four groups (extroverted, introverted, neurotic and emotionally stable) of 25 were selected. The considered criterion to select subjects can be seen in Table 1 based on personality dimensions and lie scale- revised Eysenck personality questionnaire on the basis of standard score (Z).

Besides the above-mentioned items, the following inclusion criteria were also examined: homogeneous right side superiority (hand, foot and eye), age between 22 to 35, not having physical illnesses, psychological disorders and epilepsy, not to drink alcohol and not to take psychotropic drugs.

Research tools

Eysenck Personality Questionnaire-Revised (EPQ-R): This questionnaire has 100 yes/no questions. 23 questions are about extraversion (E), 24 questions are about neuroticism (N), 32 questions are about psychoticism (P) and 21 questions are about lie scale (L). Eysenck et al. calculated the reliability (Cronbach's alpha coefficient) of E, N, P and L scales respectively 0.90, 0.88, 0.81 and 0.82 in men and 0.85, 0.85, 0.73 and 0.79 in women [22]. In Hasani's research, Cronbach's alpha coefficient for men (n=725) in E, N, P and L scales has been respectively calculated 0.86, 0.82, 0.78 and 0.75.

Waterloo Handedness questionnaire- Revised: This questionnaire has 39 questions. 36 questions are related to the hand activity and 3 other questions provide additional information and explanation. This questionnaire is scored in a five-point Likert scale (-2 to +2). The variations range of the total scores of the questionnaire is -72 to +72. Waterloo Handedness questionnaire has been codified by Steenhuis and Bryden [23] and its reliability and validity has been reported desirable [24]. Hassani has made some trivial changes proportional to Iranian culture after having translated it again, removed problems and available inconsistencies and has calculated Cronbach's alpha coefficient 0.92 (n=80) for right-handed men.

Waterloo Footedness Questionnaire- Revised: This questionnaire has 13 questions. 10 of which are about activities done with the foot and 3 last questions consist of supplementary details. This questionnaire is also scored in -2 to +2 range. The variations range of the questionnaire total score is from -20 to +20. Waterloo footedness questionnaire has been codified by Steenhuis and Bryden and has a desirable reliability and validity. Hassani has made some trivial changes proportional to Iranian culture after having translated it again, removed problems and available inconsistencies and has calculated Cronbach's alpha coefficient 0.94 (n=80) for right-footed men.

Eyedness determination: Distance determination from the standard stimulus has been used to determine subjects' eyedness. Firstly, they were asked to look at a fixed point placed in their 3 meter distance with two eyes open while pointing at the fixed point with their thumb accurately. When targeting and subject's focus is fixed, they are asked to keep their eyes closed respectively and report displacement rate of the fixed point. The closed eye which reported little or next to nothing displacement rate of the point is called superior eye.

Recording electrical activity of the brain

Subjects' brain electrical activity was recorded by EEG from different parts of the scalp. EEG was recorded based on international 10–20 system with 21 channels. Meanwhile, two electrodes were placed in the left ear (A1) and right (A2) and an electrode named grand electrode was placed in front of the forehead. In other words, 21 channels of the device were overall used in the current research but in results analysis, based on the purpose of the research only alpha wave activity of left frontopolar (FP1), right frontopolar (FP2), left lateral frontal (F7), left medial frontal (F3), right medial frontal (F4), right lateral frontal (F8) were worked on.

Before starting to record waves, enough Salem gel was injected in special places placed on electrodes in order to reduce electrodes impedance and record waves well. When the impedance in each electrode reaches to less than five Kilo ohms and the difference of two homogeneous electrodes reaches to less than one Kilo ohm, the condition to record EEG waves is provided. The selected montage to record brain waves has low pass equal to 1 and high pass equal to 70 Hertz with Gain 200 Microvolts. Fast Fourier transform (FFT) was used to quantify data. For this purpose, firstly, available artifacts in the waves were removed and absolute power of alpha wave with uV2 unit for the pieces without artificial waves was calculated for ten seconds. In order to normalize the obtained data, decimal logarithm of the average power of the alpha wave was calculated for each base and extracted numbers for the frontal area were considered as the reagent of the alpha absolute power in the form of main data for analysis.

Data Analysis

As previously mentioned, at first, four groups out of 700 individuals had been selected based on E and N scores. Firstly, screened individuals were invited to the next stage of the research after a phone call or meeting in person by the researchers. In this stage, subjects were assessed individually after they consented to it consciously. In this meeting, the purpose of the study was explained and their probable questions were answered by the researchers. Then they filled out Waterloo Footedness and Handedness Questionnaire-

Revised and their eyedness was assessed by distance determination from the standard stimulus. Electrodes were placed in different parts of the brain after estimating inclusion criteria and right side superiority and electrical activity in relaxing mode of the brain based on two randomly mutual balanced orders with closed and open eye (O-C-C-O-C-O-O-C, C-O-O-C-O-C-C-O) was recorded. In order to control physiological conditions, all subjects' waves were recorded between 9 to 12.

Results

In order to compare four groups of subjects in alpha wave activity of the left frontopolar (FP1), right frontopolar (FP2), left lateral frontal (F7), left medial frontal (F3), right medial frontal (F4), right lateral frontal (F8), multivariate analysis of variance was firstly used. To do multivariate analysis of variance, first, outlier data were studied based on their conversion to standard scores (Z) and Z scores out of the range of +1.5 and -1.5 were removed. In study of the brain location, Levene's tests range (F(3,96) -0.12-1.15; P>0.01(and Kolmogorov–Smirnov (0.39-1.22) is indicative of homoscedascity and normal distribution of variables and also Box's M test result (F (108, 20472.48)-1.33 P>0.01) showed that covariance matrix of the dependent variables is the same groups and multivariate analysis of variance can be used. In Table 2 the results of Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root tests can been seen.

As it can be deduced from the Table 2 data, there exists a significant difference at least in alpha activity of one of the frontal lobe. Significance of differences in previous tests does not specify which groups in which frontal lobe are different from each other. For this purpose, one way ANOVA and Bonferroni test were used and their results were mentioned in Table 3.

Based on the significance level mentioned in Table 3, It can be seen that,

alpha activity of the right frontopolar (FP2), right medial frontal (F4), right lateral frontal (F8) and the whole right frontal activation (RF), There was no significant difference among four groups but in the left frontopolar (FP1), left medial frontal (F3), left lateral frontal (F7) and the whole left frontal activation (LF), there exists a significant difference.

Table 1: Considered criterion to select subjects.

Groups	Standard scores (Z) criterion based on N, P, E dimensions and L scale	Scores range in L scale	Scores range in P dimension	Scores range in N dimension	Scores range in E dimension
Neurotic	zN>1.5 & zP< -0.5 & z L <-0.5& zE< 0.5 & zE>-0.5	Removing the scores above 4.20	Removing the scores above 4.30	Score of 89.25 or above	Removing the scores above 15.45 and below 11.05
Emotionally Stable	zN< -1.5 &zP< -0.5 & zL< -0.5 & zE<0.5 & zE> -0.5	Removing the scores above 4.08	Removing the scores above 4.10	Score of 4.55 or below	Removing the scores above 15.28 and below10/26
Extrovert	zE>1.5 & zP< -0.5 & zL< -0.5 & zN< -0.50	Removing the scores above 4.11	Removing the scores above 4.12	Removing the scores above 9.15	Score of 19.24 or above
Introvert	zE< -1.5 & zP< -0.5 & zL< -0.5 & zN<-0.5	Removing the scores above 4.06	Removing the scores above 4.12	Removing the scores above 9.15	Score of 6.80 or below

Table 2: The results of multivariate analysis of variance tests for general comparison of the groups in alpha wave activity of the frontal lobe.

Test	Measure	df hypothesis	F	Eta-squared (η2)
Pillai's Trace	1.27	24	***8.35	0.42
Wilks' Lambda	0.16	24	***9.65	0.46
Hotelling's Trace	2.92	24	***10.67	0.49
Roy's Largest Root	1.72	8	***19.54	0.63

Table 3: Mean and standard deviation of alpha activity pattern in different areas of the frontal cortex in four subject groups and one way ANOVA results and Bonferroni tests to compare four groups

Hemisphere	Location	Group	Subjects' number	Mean	Standard deviation	F (3,96)	Eta-squared (η2)	Bonferroni tests
Right	FP2	N+	25	2.07	0.24	0.46	0.03	NS
		N-	25	2.05	0.23			
		E+	25	2.06	0.22			
		E-	25	2.07	0.3			
	F2	N+	25	2.02	0.32	0.89	0.05	NS
		N-	25	2.04	0.36			
		E+	25	1.97	0.29			
		E-	25	1.92	0.25			
	F8	N+	25	2.27	0.26	0.26	0.02	NS
		N-	25	2.12	0.31			
		E+	25	2.08	0.44			
		E-	25	2.34	0.3			
	RF	N+	25	6.31	0.48	0.25	0.02	NS
		N-	25	6.16	0.5			
		E+	25	6.23	0.59			
		E-	25	6.26	0.5			
Left	FP1	N+	25	0.64	0.23	***6.85	0.17	N+< E+& N-
		N-	25	1.24	0.19			E-< E+& N-
		E+	25	1.28	0.16			
		E-	25	0.7	0.24			
	F3	N+	25	0.52	0.29	***9.42	0.31	N+< E+& N-

	N-	25	1.13	0.2			E-< E+& N-
	E+	25	1.09	0.23			
	E-	25	0.71	0.24			
F7	N+	25	0.71	0.26	***14.54	0.39	N+< E+& N-
	N-	25	1.24	0.14			E-< E+& N-
	E+	25	1.07	0.24			
	E-	25	0.65	0.36			
LF	N+	25	1.84	0.46	***24.44	0.43	N+< E+& N-
	N-	25	3.56	0.34			E-< E+& N-
	E+	25	3.38	0.36			
	E-	25	2	0.45			

*P>0.05 ** P>0.01 *** P>0.001

Discussion

The purpose of the current research is to study frontal alpha asymmetry based on extraversion and neuroticism dimensions. Personality dimensions were studied based on Eysenck's personality theory. The results indicated that, there is no significant difference in alpha activity of the whole right frontal (RF) among four groups but there is a significant difference in activation of the whole left frontal (LF) among four groups and alpha activity in this area in neurotic and introverted people is more than emotionally stable and extroverted people. The results of the current research are consistent with previous studies results. Reznik and Allen showed that, frontal asymmetry plays a prominent role in emotion and psychopathology relationship [25]. Uusberg et al. in their study results prove the fact that, neuroticism has a negative correlation with frontal electroencephalographic asymmetry which shows the fact that higher level of neuroticism is related to functional asymmetry and inhibition of two hemispheres [26]. Based on Eysenck' theory cortical-network loop shows Neurological dimensions of extraversion and introversion traits as it has less reactive activities in extroverted individuals rather than introverted ones. On the other hand, cortical visceral loop controls mental emotional responses. Irritability of this system in neurotic people is more than emotionally stable people and these individuals experience more negative emotions. It can be concluded that, neuroticism and extraversion personality traits are related to asymmetry of electrical activity of brain frontal cortex.

The results of the current study are also explicable with psychological processing related to electroencephalographic asymmetry. Based on recent model, frontal cortex function of the left hemisphere and right hemisphere is different and exclusive; as the frontal cortex of the left hemisphere supports working memory processing which is related to selective and goal directed attention and tendency to activity, the frontal cortex of the right hemisphere is related to inhibition response. Functional difference in the right and left hemisphere shows two ultimate personality components of tendency and inhabitation. As a result, frontal asymmetry is related to how to process information and formation of the subsequent behaviors [27]. The results of the current study are indicative of the activity reduction in the left hemisphere in neurotic and introverted individuals which is accompanied by disturbance in attention and functional tendencies, So that these people do not have the ability to focus on a specific goal and controlled behavior to prevent impulsiveness.

Based on Davidson' studies there is a relationship between asymmetry and emotional states [28]. On the other hand, Watson and Clark worked on the relationship between personality traits and emotional states. Therefore, it can be said that there is a relationship between asymmetry and personality traits. Based on the studies carried out by Hagemann et al. and Allen et al. extraversion is related to positive emotions and neuroticism is related to unpleasant emotions [28,29]. Some other studies illustrated that frontal electroencephalographic asymmetry is related to motivational factors and more activity in the right side is in relation with avoidance and more activity in the left side is related to arousal [29-31]. Hence, This issue is indicative of the current research results that alpha increase and decrease in the function of the left side leads to reducing positive emotions and increasing neuroticism and an increase in the activity of the right side and alpha reduction in this hemisphere leads to increasing extraversion and pleasant emotions and this proves the biological effect of the cortex activity on personality traits [32].

The other reason to explain the results of the research is the relationship between behavioral inhibition and activation, asymmetry and personality traits. Gray's theory works on the combination of extraversion and neuroticism personality traits. It is shown in many studies that limbic system (especially amygdala) plays an important role in creating emotional behaviors and a number of studies have shown that amygdala makes an anxious feeling in individuals [33]. Although EEG is created in cortex surface, it is also related to subcortical structures. Based on general principles of amygdala-cortex, amygdala receives afferents from temporal lobe and sends afferents to the frontal cortex [34]. This system recommends temporal and frontal cortices role to produce negative emotions. Electrical stimulation of the temporal and left frontal cortex makes a fear feeling in individuals which is similar to direct stimulation of amygdala and deactivating it leads to outbreak of the positive emotions. In this research cortex activity was measured by the mean range of the alpha wave. Increasing alpha activity originates from phasic depolarization of the cortex pyramidal neurons. However, decreasing alpha activity originates from continuous depolarization of the cortex pyramidal neurons [35]. The average depolarization level of the pyramidal neurons acts as activity threshold of these neurons; low level of the depolarization average of the cells which is determined by increasing activity of alpha makes it difficult to create an action potential and high level of the depolarization average which is determined by decreasing activity of alpha makes it easy to create an action potential. Thus, much activity of alpha in frontal cortex leads to decreasing activity of the pyramidal neurons and amygdala activity thresholds will be increased which leads to increasing negative emotions, fear and anxiety. Based on the fact that, decreasing activity of the left frontal lobe is related to increasing activity in amygdala and neurotic people usually experience more anxiety, obtained results of the current study is justifiable.

Conclusion

Generally, findings of the current research reinforce the relationship between personality dimensions and frontal electroencephalographic asymmetry of the brain. Based on the results of this study neural networks asymmetry is 7 in relation with personality traits and emotional information processing.

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