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Human Personality Traits Reflect in Neural Oscillations

Zeynab Hasanein[1], Atena Sajedin[1], Mohammad Bagher Menhaj[1*], Abbas Ali GholamHosseini[2]

[1] Department of Electrical Engineering, Amirkabir University of Technology, Hafez Ave., Tehran, Iran.
[2] Department of Education and Psychology, Alzahra University, DehVanak Ave.,Tehran, Iran.

ABSTRACT: Association between neural oscillation and personality has been a topic of enhancing interest of neuroscience and psychology. It is believed that human personality reflects in the brain's electrical neural oscillation. However, it's exact relations and mechanisms are not fully understood. In the present work, we analyze electroencephalograms (EEG) signals recorded from 40 healthy subjects during the performance of electronic personality traits tasks, as measured by the NEO-FFI. Subsequently, we examine how these personality traits are related to patterns of different neural oscillations. We found that a personality trait of contrasting conscientiousness is significantly associated with engagement of frontal cortex theta and gamma oscillations. Likewise, extraversion is significantly associated with activity in the temporal and parietal regions. We realized that, the personality traits were significantly and consistently associated with the frequency rhythms in different brain areas. We then investigated the correlations between personality traits and psychophysical health factors. Our data indicated that the level of fatigue and social disturbance among participants are inappropriate in relation to other psychometric properties. We found a significant correlation between neuroticism and fatigue, Depressive reactions and Physical health. This study illustrates an approach to investigating personality traits and how it is related to patterns of brain activity.

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1- INTRODUCTION

Studying a relation between human personality and neural activity is known as an interesting issue in neuroscience and psychology. Personality traits are considered as reliable behavioral tendencies. Many researches have investigated the relation of brain activity with personality especially in two dimensions of extraversion and neuroticism (Schmidtke & Heller, 2004). Generally, extraversion is described as having positive emotions like motivation, passion and commitment; with this definition introverts tend to be more quiet, conservative and reserved (Yamasue et al., 2008). Neuroticism is associated with negative affect (Balconi, Falbo, & Brambilla, 2009). An important question is that, how these personality specifications will be reflected in brain activity. Many experimental studies have examined the relation between personality traits and the brain activity (Schmidtke & Heller, 2004; Yvonne Tran et al., 2005). Hans Eysenck's theory of personality (Eysenck, 1990, 1967) hypothesized that extraversion can be expressed as cortical arousal, which is linked to the alpha oscillation (Y. Tran, Craig, & McIsaac, 2001) and is characterized by thalamocortical neurons (Knyazev & Slobodskaya, 2003).

While it is well established that extraversion/neuroticism is reflected in brain oscillations, the precise mechanisms by which these effects are implemented remain poorly understood, and previous studies have reported conflicting findings (Gale & Edwards, 1983; Y. Tran et al., 2001). Some studies have reported a significant correlation between alpha rhythms activity and extraversion (Savage, 1964; Zuckerman, 1991) while some others have indicated enhanced alpha activity in introverts (Broadhurst & Glass, 1969) or illustrated no differences between introverts and extraverts in the alpha activity (Gale, Coles, Kline, & Penfold, 1971).

Gale et al. (2001) illustrated that neuroticism was associated with smaller right versus left hemisphere differences in alpha oscillation. Tran et al. (2001) found extraversion leads to the larger peak amplitudes in frontal region alpha activity. Fink et al. found the associations between extraversion and low frequency bands (6–8 Hz) of brain activity (Fink & Neubauer, 2004). Also some studies have found associations between neuroticism with alpha oscillation activity in the frontal regions (Hagemann, Naumann, Lurken, Becker, & Maier, 1999; Minnix & Kline, 2004). Furthermore, it has been shown that enhanced activity in frontal areas of the left hemisphere is associated with the emotions like happiness or anger while the enhance in EEG brain activity in frontal areas of the right hemisphere is related with the expression of anxiety

*Corresponding author's email: Menhaj@aut.ac.ir

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and fear. Low frequency activities are associated with the activity of limbic system and brainstem and play a key role in maintaining arousal (Knyazev & Slobodskaya, 2003; Joseph, 1999).

Adding on, theta band power enhancement has been observed during pleasant stimuli with various trait anxiety levels (Aftanas, Pavlov, Reva, & Varlamov, 2003). Some other studies have shown that the complexity of the task is a key factor in the association between extraversion and neural activity (Fink & Neubauer, 2004). Also theta oscillation has been demonstrated to synchronize as a function of increased task demands (Klimesch, 1999).

The aim of our study is to explore the association between neural activity with human personality including extraversion and neuroticism. In our study, personality was measured by NEO-five-factor inventory (NEO-FFI) which considers five major domains of personality including Extraversion (excitement seeking), Neuroticism (tendency to experience negative affect), Agreeableness (helpfulness, compassion) and Conscientiousness (dependability, responsibility) and finally Openness to experience (broad-mindedness and adventurous) (Costa & McCrae, 1992). The personally traits were collected during EEG recording of 40 healthy subjects. Mean log-transformed band powers and wavelet coefficients were extracted from the EEG for each electrode site, and statistical analyses were conducted. We found that some prominent areas present an association between the neural oscillation from the posterior regions and personality traits.

2- MATERIALS AND METHODS

In this study, we investigated the relationship between personality aspects (neuroticism, extraversion, flexibility, self-fascination, accountability) of the participants and their brain activity.

2-1- Participants

Forty voluntary participants (10 women) (mean age=45.1, S.D.=4.12) were recruited from Social Security Organization of Iran. participants were from 35 to 55 years old. They had no cardiovascular, or acute cerebrovascular disease history, no history of epilepsy or seizure, nor any other mental illnesses, and they did not use psychiatric or psychedelic drugs.

2-2- Questionnaire Administration and Scoring

Participants completed the Positive and Negative Affect Schedule Questionnaire (PANAS; Watson, Clark, & Tellegen, 1988) prior to EEG recordings. The PANAS test has been used extensively both for clinical and research purposes to identify a participant's emotional state. It includes two 10-item scales that examine the person's tendency to experience positive and negative effects. PANAS is a self-assessor tool designed to measure negative (PANAS-N) and positive emotions (PANAS-P).

2-3- Personality Traits Evaluation Criteria

In our study, all participants had completed the electronic NEO-FFI personality test during EEG session recording. The NEO-FFI test includes 60 items in which participants decide whether they agree or disagree with each question through a 5-point Likert scale: Totally disagree, disagree, indifferent, agree, totally agree. Responses are aggregated to determine the score for the personality constructs: (i) Extraversion, (ii) Neuroticism, (iii) Openness, (iv) Agreeableness and (v) Conscientiousness. Experimental studies have supported the validity of NEO test with evidence for its validity and construct, consistency (0.86 - 0.95), reliability arising from (i) self, peer and spouse ratings (Costa & McCrae, 1992), (ii) longitudinal studies, (iii) cross-cultural replication, (iv) heritability studies (Jang et al., 1998). Costa and McCrae (1992) also reported the correlation between the 5 sub-scales of the short and long forms from 77% to 98%. NEO tests for the 40 participants were administered using a standardized assessment protocol in which they completed the questionnaire during the EEG session.

2-4- EEG Recording and Quantification

Resting EEG was recorded with a stretch-lycra electrode cap on the scalp (Electrocap International, Bayamed Company) from a standard International 10-20 assembly system of 32 channels referenced to linked earlobes. The letters O, P, C, T, F show the frontal, temporal, central, parietal and occipital lobes.

All electrodes were referenced to linked earlobes and the impedances were kept > 8 K. EEG signals were recorded at a sampling rate of 128 Hz, and also the gain was set at 16K, assure that waveform resolution was not lost. All participants were assessed for their EEG activity for eyes opened and alert, and during performing NEO test (Figure 1). In our study, the frequency bands were for delta (1–3.5 Hz), theta (4–7.5 Hz), alpha (8–13 Hz) and beta (14.5–30 Hz) and gamma activity (30-60 Hz). The EEG data was log transformed before statistical analysis in order to normalize the magnitude data. The brain waves were collected from 30 channels (Fp1, Fp2, F7, F3, Fz, F4, F8, Ft7, Fc3, Fcz, Fc4, Ft8, T7, C3, Cz, C4, T8, Tp7, Cp3, Cpz, Cp4, Tp8, P7, P3, Pz, P4, P8, O1, Oz, O2), which formed frontal, parietal, temporal and occipital areas. After collecting quantitative EEG data and answering the NEO questionnaires, the participants were categorized in different personality groups. The data were normalized using the logarithmic method, and were analyzed using Pearson correlation in SPSS.

3- DATA ANALYSIS

3-1- NEO-FFI

To investigate NEO-FFI personality traits in participants, different analyses consisting of simple descriptive statistics (M, SD), kurtosis, asymmetry, and Kolmogorov-Smirnov test for normal distribution, were performed and subjects were labeled in different categories.

3-2- Time-Frequency Domain Analysis

The signal segment x[n] of N samples is obtained using

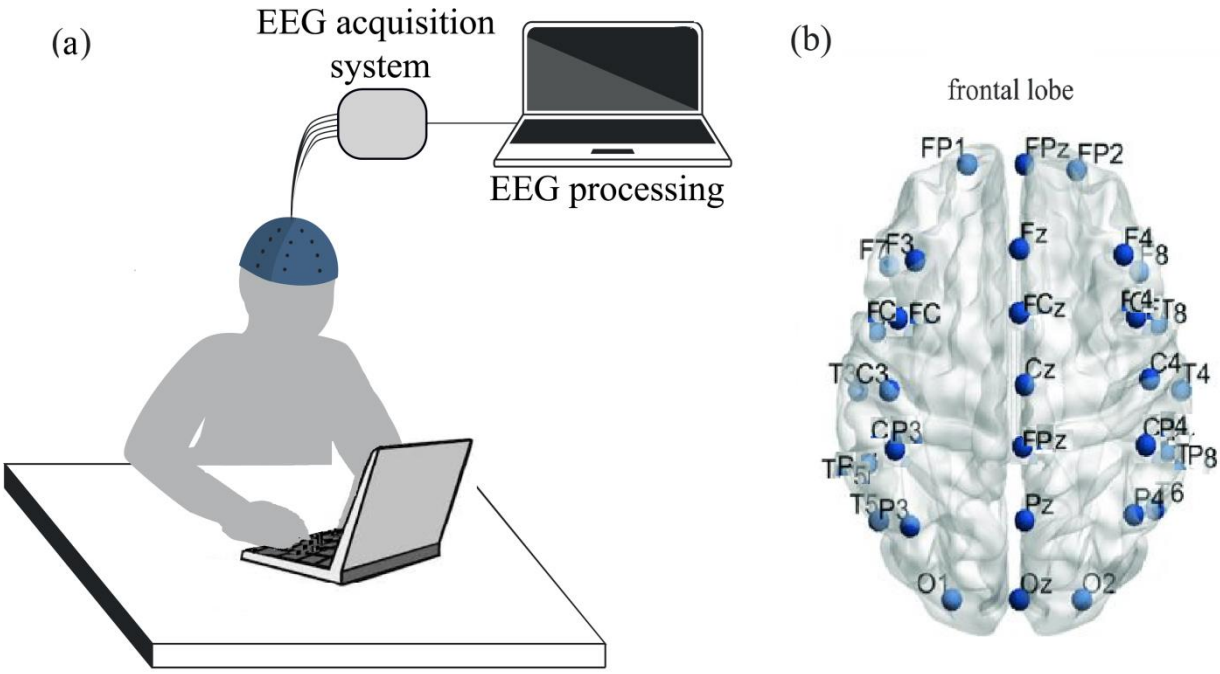


Fig. 1. Experimental Design. (a) Demonstration of the experimental procedure (b) Layout of the EEG electrodes arranged according to a 10–20 standard international system

the fast Fourier transform (FFT) defined by:

$$fft[\omega]=\sum_{n=1}^{N}x[n]e^{-i\omega n},\ \omega=\frac{2\pi m}{N},\ 0\le m\le N-1,$$

where $\omega=2\pi f/f_s$ characterized the angular frequency of N samples. In addition, the Hamming window is utilized to minimize spectral leakage windowing of signal segments. Also to avoid losing the information from the time domain, the signal was reconstructed using the inverse Fourier transform through:

$$x[n]=\frac{1}{N}\sum_{\omega=0}^{2\pi(N-1)/N}fft[\omega]e^{i\omega n},\ \ 1\le n\le N$$

In our study, power spectral density was estimated using the coefficients of the fast Fourier transform (FFT):

$$per[\omega]=\frac{1}{N}\left|fft[\omega]\right|^2$$

A periodogram was normalized by the total signal power as follows:

$$per_{norm}[\omega]=\frac{1}{N}\left|fft[\omega]\right|^2/\sum_{\omega=0}^{2\pi(N-1)/N}per[\omega]$$

Wavelet is a function of limited power and for which the following is valid, and the wavelet that is shifted in time for ‹ b › samples and scaled by dilation parameter ‹ a › is given in the following:

$$\sum_{n=-\infty}^{\infty}\left|\psi[n]\right|^2<\infty,\ \sum_{n=-\infty}^{\infty}\psi[n]=0$$

$$\psi_{ab}[n]=\frac{1}{\sqrt{a}}\psi[\frac{n-b}{a}]$$

Through changing ‘ a ’, the wavelet (a = 1) modifies its width, which it spreads (a > 1) and contracts (0 ≤ a < 1) in the time domain. For non-stationary signals, the possibility of modifying the width of the wavelet presents an advantage of this technique, realizing the fact that wider wavelets can be utilized to extract slower changes. The wavelet transform

coefficients are calculate as:

$$w_{ab}[n] = \sum_{\tau=1}^{N} x[\tau]\psi_{ab}[n-\tau],\ 1 \le n \le N$$

Furthermore, the extracted features of the data are those frequencies that are within the wavelet frequency range. Based on these coefficients the data can also be reconstructed taking advantage of an inverse wavelet transform. Choosing an appropriate wavelet function that closely matches the signal to be processed is of essential in wavelet applications (Graps, 1995).

In addition, it is essential to choose the appropriate type of the wavelet and the numbers of levels into which the signal will be decompose.

After analysis of different types of the wavelets, the tenth-order Daubechies wavelet was selected for the analysis since it has desired localizing properties in frequency and time domains (Daubechies, 1992; Petrosian, Prokhorov, Homan, Dasheiff, & Wunsch, 2000). Due to its smoothing feature, and morphological shape Daubechies wavelet has demonstrated perfect capabilities of specifically EEG data preprocessing. The discrete wavelet decomposition was performed at four levels which leads to five bands of clinical interest. The standard deviation (SD) and the average power of the Daubechies wavelet coefficients have extracted as corresponded features in the time-frequency domain.

4- RESULTS

4-1- NEO Personality Feature

Table 1, shows the mean score of five personality traits: neuroticism (13.25), extraversion (32.66), flexibility (29.05), self-fascination (34.13) and responsibility (39.75). Regarding personality traits, responsibility means observing the rules, norms and organizing the tasks in the organization is at the highest state and neuroticism was at the lowest mean among individuals, showing the emotional stability of individuals. There was a significant difference between these personality traits using ANOVA and there was a significant difference between personality traits ($P<0.05$), extraversion ($P<0.05$), flexibility ($P<0.05$), self-fascination ($P<0.05$) and responsibility ($P<0.05$).

4-2- Associations between the Personality Traits and EEG Frequency Bands

To study associations between personality traits and EEG brain activity, the Pearson correlations were calculated for the selected 30 representative cortical sites (Fp1, Fp2, F7, F3, Fz, F4, F8, Ft7, Fc3, Fcz, Fc4, Ft8, T7, C3, Cz, C4, T8, Tp7, Cp3, Cpz, Cp4, Tp8, P7, P3, Pz, P4, P8, O1, Oz, O2), as shown in Figure 1, in each EEG frequency bands included, theta, delta, alpha, beta and gamma rhythms, with personality traits.

Figure 2 (A-E), indicated the correlation analyses. Significant correlations were found with the low frequency bands. As shown in this Figure, flexibility in all the frequency bands, in the frontal, temporal, and parietal areas are observed. Our data revealed that extraversion is significantly reflected in the alpha, beta, and delta bands in the frontal and temporal areas (Figure2: A-E, $P< 0.05$, Wilcoxon sign rank test).

Extraversion reflected in the beta frequency band in the temporal region, and in the delta band in the frontal region. The most significant correlation was found in the delta correlation coefficient of 0.784. We also found a significant relationship in the low frequency bands, with the most channels activity (Figure 2(A-E), $P< 0.05$, Wilcoxon sign rank test) and it clearly reflects the personality traits.

Introversion and compatibility are reflected in the theta, alpha, beta and gamma bands in the frontal and parietal areas. Responsibility reflected in the gamma and delta bands in the frontal area (Figure 2A and D). Adding on, irresponsibility is observed in the alpha and theta bands.

Self-fascination and neuroticism personality traits are not significantly correlated with any frequency band

Table 1. Sample Statistics Regarding NEO Personality traits

Sub-scale	Mean (M)	SD	Asymmetry		Kurtosis		Kolmogorov-Smirnov	
			As	SE	Spl	SE	Statistic	df
Responsibility	39.75	4.82	-0.33	0.39	-1.15	0.76	0.18	40
Self-Fascination	34.13	4.59	0.031	0.39	0.06	0.76	0.093	40
Flexibility	29.05	4.18	-0.26	0.39	-0.77	0.76	0.12	40
Extraversion	32.66	5.47	-0.23	0.39	0.98	0.76	0.091	40
Neuroticism	13.25	7.05	0.47	0.39	0.43	0.76	0.103	40

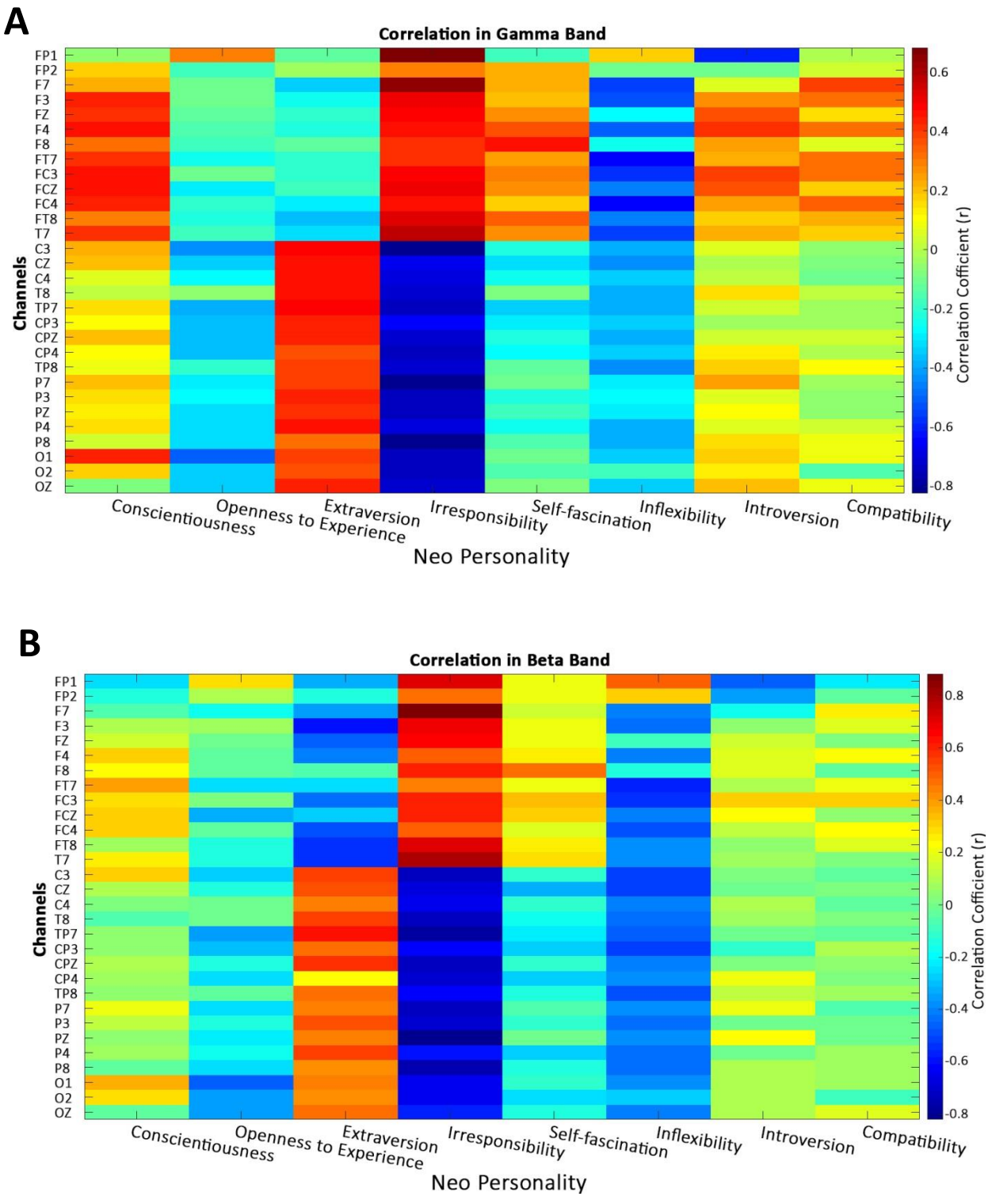
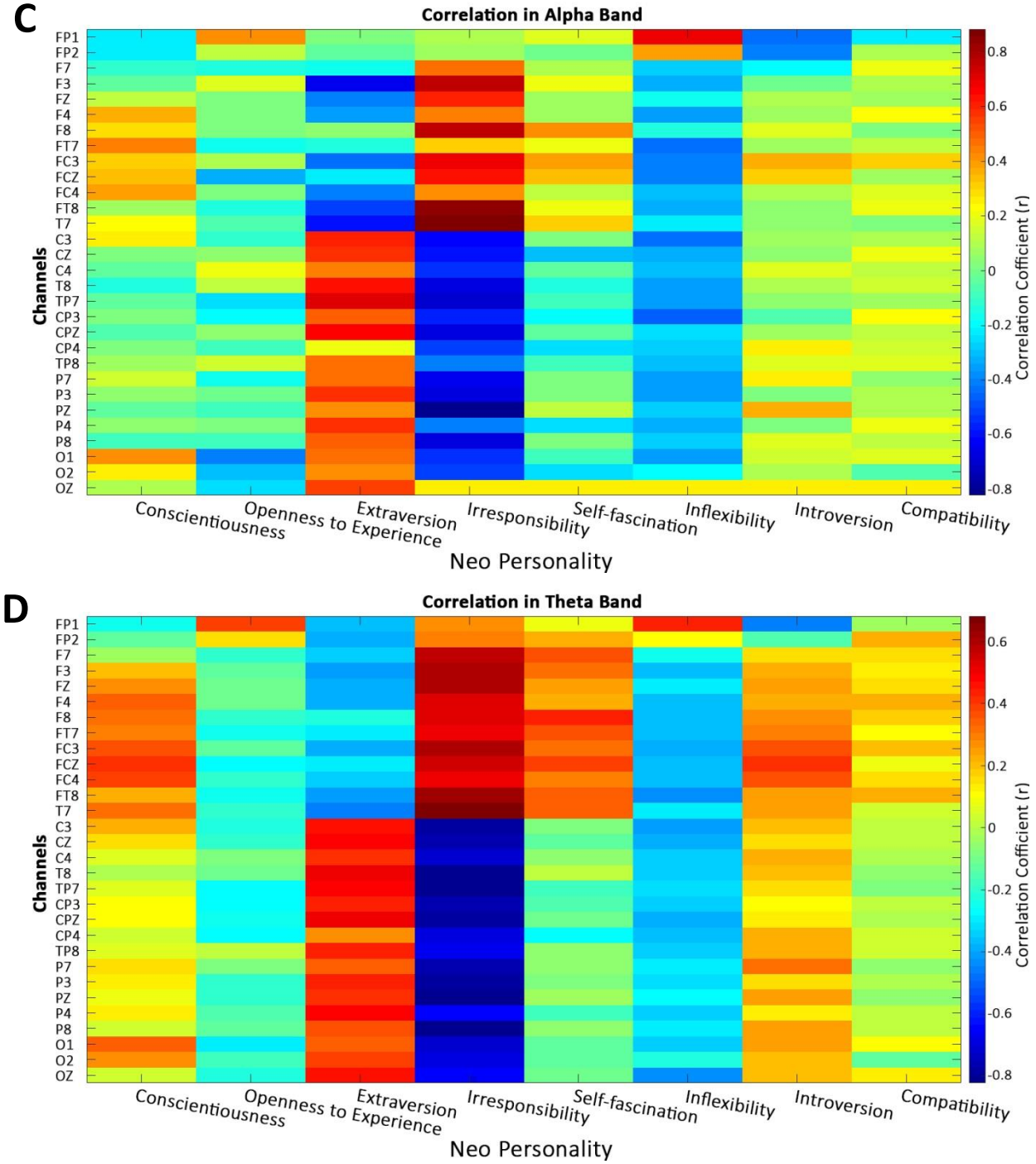
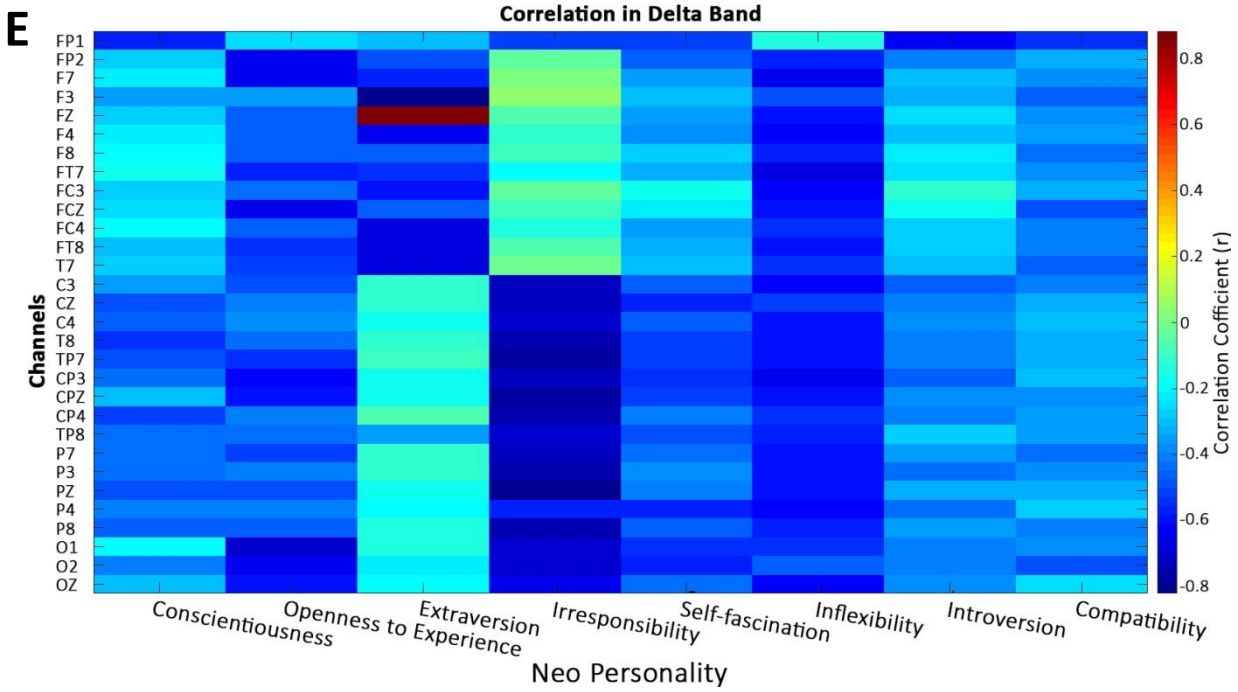


Fig. 2. Correlation between NEO personality trait and neural oscillation in the (A) Gamma, (B) Beta, (C) Alpha, (D) theta and (E) delta frequency bands.



Continued Fig. 2. Correlation between NEO personality trait and neural oscillation in the (A) Gamma, (B) Beta, (C) Alpha, (D) theta and (E) delta frequency bands.



Continued Fig. 2. Correlation between NEO personality trait and neural oscillation in the (A) Gamma, (B) Beta, (C) Alpha, (D) theta and (E) delta frequency bands.

(Wilcoxon signed rank test; P<0.05). We also found that extraversion was significantly associated with the left frontal region and enhanced right posterior region activities and conscientiousness was associated with the right frontal and increased right posterior region activity (Wilcoxon signed rank test; P<0.01).

Significant correlations between alpha oscillations were observed with extraversion (Figure 2B, Wilcoxon signed rank test; P<0.01). This was mainly found in the frontal, central and parietal sites. Conscientiousness reflected in the theta, alpha, beta and gamma bands in the frontal area (Figure 2A-E). No consistent relation were observed between alpha rhythm activity and personality traits. Consistent negative relations were found between all neural oscillations and Inflexibility. Considering Figure 2 (A-E) personality traits in the delta frequency band are negatively correlated with all channels except Fz channel.

Moreover, gamma and beta frequency bands are correlated with irresponsibility and extraversion in parietal and frontal areas. In general, irresponsibility is correlated with the activity of all frequency bands in the most areas. Additionally, we found that neuroticism not reflected to any frequency bands and its correlation coefficient is very low in most areas.

4-3-Correlations between Personality Traits and Psychophysical Health

We used a short self-assessment scale of psychophysical health (SPFZ-2) to evaluate of five types of most common psychosomatic problems experienced by employees in order to find the factors cause negative effects reduction and increasing employees' mental and physical health.

We investigated the exhaustion, social behavioral disorders, physical disorders, depressive reactions, and fear and anxiety on subjects from the Employees of the Social Security Organization, and investigate its relation with the NEO personality trait (Figure 3).

The questionnaire consists of 15 item in 5 dimensions, physical health complaints, fear and anxiety, depressive reactions, fatigue and social behavioural disorders. The scale of this questionnaire is a 4-point Likert with possible answers are "No", "Yes, but not often", "Yes, often" and "Yes, every day".

Table 2 show the average results for all participants in terms of Psychophysical Health Scale. Our data indicated that the level of fatigue and social disturbance among participants are inappropriate in relation to other psychometric properties. In addition, depression has the lowest level, which indicates that people in this organization are not severely depressed.

The correlation between the sub-scales of psychophysical Health and NEO personality trait is shown in Figure3.

We observed that there is a significant negative correlation (Wilcoxon signed rank test; P<0.001) between the sub-consciousness and fatigue with the coefficient (0.464). In addition, to agreeableness and social behavior disorders (-0.124, p<0.05), fatigue (-0.873, p<0.05), Physical health (-0.15, p<0.001) has a significant negative correlation. Finally, there is a significant positive (Wilcoxon signed rank test; P<0.001) relationship between neuroticism and fatigue (0.436), Depressive reactions (0.175) and physical health (0.705).

Table 2, Sample statistics on Psychophysical Health

Dimension	M	SD	Asymmetry		Kurtosis		Kolmogorov–Smirnov test	
			AS	SE	Spl	SE	statistic	df
Physical health complaints	4.94	1.45	0.835	0.398	0.621	0.778	0.199	40
Fear and anxiety	4.31	1.38	1.004	0.398	0.395	0.778	0.2	40
Depressive reactions	3.54	0.78	1.724	0.398	1.668	0.778	0.753	40
Fatigue	5.17	1.42	0.004	0.398	0.053	0.778	0.177	40
Social behavioral disorders	5.11	1.36	0.515	0.398	0.491	0.778	0.162	40

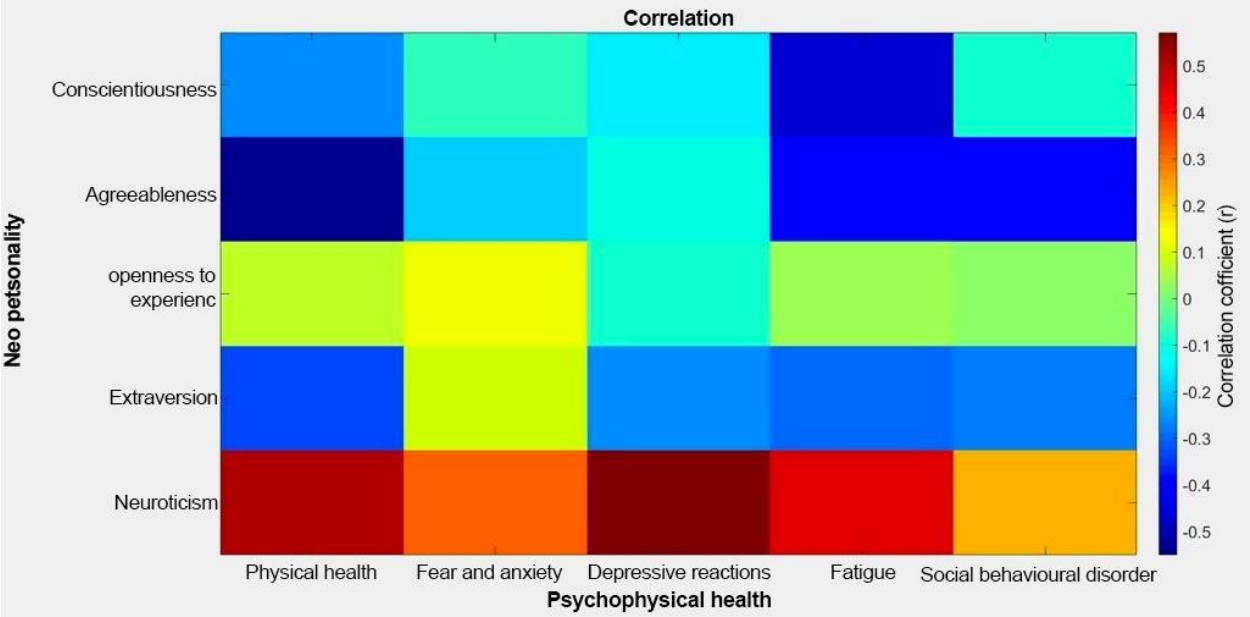


Fig. 3. Correlation between NEO personality trait and Psychophysical Health

Table 3. A Hierarchical regression with Fatigue

B	Std. Error	Beta	t	sig	sub-scale
-0.09	0.06	0.27	-1.52	0.14	conscientiousness
-0.02	0.06	-0.05	-0.28	0.78	agreeableness
0.08	0.04	0.35	1.87	0.07	neuroticism

These results indicated that if a conscientiousness employee has sense of friendship with others (agreeableness), her/his fatigue decreases, and consequently becomes less tired than others. A neuroticism person -means having feelings like sadness, anger and distaste- experience more fatigue in the workplace, and his physical health is also in crisis, and leads to physical discomforts, such as headache and digestive discomfort. On the other hand, people with neuroticism tend to have more depressed moods because they carry the feelings of hatred and anxiety continuously. People with agreeableness are less likely affected by their social behavior.

In Figure 3, the blue squares represent a negative correlation between fatigue and accountability as well as agreeableness with fatigue. On the other hand, there is a

Table 3B. Hierarchical regression with Physical health

B	Std. Error	Beta	t	sig	sub-scale
-0.08	0.09	-0.21	-0.89	0.38	agreeableness
0.09	0.05	0.38	1.98	0.06	neuroticism

Table 3C. Hierarchical regression with Depressive reactions

B	Std. Error	Beta	t	sig	sub-scale
0.09	0.02	0.63	4.66	0.00	neuroticism

Table 3D. Hierarchical regression with Social behavioral disorders

B	Std. Error	Beta	t	sig	sub-scale
0.11	0.06	-0.3	-1.78	0.09	agreeableness

Table 3E. Hierarchical regression with Fear and anxiety

B	Std. Error	Beta	t	sig	sub-scale
0.07	0.04	0.032	1.97	0.05	agreeableness

significant positive relationship between neuroticism and fatigue, Depressive reactions and Physical health.

4-4- Regression Analysis of Personality Traits and Psychophysical Health

Tables (3A-E) show the results of regression analysis through multivariate method, in order to determine the contribution of NEO characteristic (predictive variable) on the variance of psychophysical health (criterion variable). These variables with the t-ratio statistic predict the relative confidence of the factors changes in group members according to the coefficient mentioned.

5- CONCLUSION

We have studied the correlation between EEG neural oscillation and Neo personal characteristics during complicated psychological questionnaire tasks to study human personality. We considered time-frequency structures of multichannel EEGs in 40 participants, who performed and completed the NEO test during EEG recording. Based on the EEG signals analysis, we divided all participants into different groups depending on the specific features of their personal characteristics.

We identified a pattern of neural oscillation in response to NEO personality test and illustrated the relation between EEG features and personality traits. At the same time, all subjects performed Psychophysical Health tests in order to estimate the contribution of NEO characteristic on the variance of psychophysical health. As a result, our data revealed strong differences between the different personality groups in terms of their frequency activities and provided understanding of the neural basis of the personality characteristic.

COMPLIANCE WITH ETHICAL STANDARDS

The datasets are available from the corresponding author on reasonable request. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Iran national research committee in biomedical research and its later amendments or comparable ethical standards.

COMPETING INTERESTS:

The authors declare no competing interests.

INFORMED CONSENT

Informed consent was appropriately gained from all participants in full compliance with ethical standards.

AVAILABILITY OF DATA AND MATERIAL

Please contact author for data requests.

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REFERENCES

[1] Aftanas, L. ., Pavlov, S. ., Reva, N. ., & Varlamov, A. . (2003). Trait anxiety impact on the EEG theta band power changes during appraisal of threatening and pleasant visual stimuli. *Int. J. Psychophysiol.*, *212*, 205 – 212.

[2] Balconi, M., Falbo, L., & Brambilla, E. (2009). BIS/BAS responses to emotional cues: Self report, autonomic measure and alpha band modulation. *Pers Indiv Differ.*, *47*(9), 858–863.

[3] Broadhurst, Q., & Glass, A. (1969). Relationship of personality measures to the alpha rhythm of the electroencephalogram. *British Journal of Psychiatry*, *115*, 199±204.

[4] Costa, P. ., & McCrae, R. . (1992). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI): Professional Manual* (Psychologi).

[5] Daubechies, I. (1992). *Ten lectures on wavelets. Philadelphia* (PA: Societ).

[6] Eysenck, H. . (1990). *Biological dimensions of personality. Handbook of Personality: Theory and Research.* (Pervin, L.). Guilford Press, New York.

[7] Eysenck, H. J. (1967). *The Biological Basis of Personality* (Thomas). Springfield.

[8] Fink, A., & Neubauer, A. . (2004). Extraversion and cortical activation: effects of task complexity. *Pers. Individ. Differ.*, *36*, 333 – 347.

[9] Gale, A., Coles, M., Kline, P., & Penfold, V. (1971). Extraversion±introversion, neuroticism and the EEG: basal and response measures during habituation of the orienting response. *British Journal of Psychology*, *62*, 533±543.

[10] Gale, A., & Edwards, J. . (1983). *Physiological Correlates of Human Behaviour*. Academic Press, London.

[11] Graps, A. (1995). An introduction to wavelets. *IEEE Comput Sci Eng*, *2*, 50–61.

[12] Hagemann, D., Naumann, E., Lurken, A., Becker, G., & Maier, S. (1999). EEG asymmetry, dispositional mood and personality. *Pers. Individ. Differ*, *27*, 541 – 568.

[13] Joseph, R. (1999). *Neuropsychiatry, Neuropsychology, and Clinical Neuroscience* (B. Williams & Wilkins, ed.).

[14] Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Res. Rev.*, *29*, 169 – 195.

[15] Knyazev, G. ., & Slobodskaya, H. R. (2003). Personality trait of behavioral inhibition is associated with oscillatory systems reciprocal relationships. *Int. J. Psychophysiol.*, *48*, 247 – 261.

[16] Minnix, J. ., & Kline, J. P. (2004). Neuroticism predicts resting frontal EEG asymmetry variability. *Pers. Individ. Differ.*, *36*, 823 – 832.

[17] Petrosian, A., Prokhorov, D., Homan, R., Dasheiff, R., & Wunsch, D. (2000). Recurrent neural network based prediction of epileptic seizures in intraand extracranial EEG. *Neurocomputing*, (30), 201–218.

[18] Savage, R. D. (1964). Electrocerebral activity, extraversion and neuroticisim. *British Journal of Psychiatry*, *110*, 89–110.

[19] Schmidtke, J. ., & Heller, W. (2004). Personality, affect and EEG: predicting patterns of regional brain activity related to extraversion and neuroticism. *Pers. Individ. Differ.*, *36*, 717 – 732.

[20] Tran, Y., Craig, A., Boord, P., Connell, K., Cooper, N., & Gordon, E. (2005). Personality traits and its association with resting regional brain activity B. *International Journal of Psychology*, *60*(2006), 215–224. https://doi.org/10.1016/j.ijpsycho.2005.05.008

[21] Tran, Y., Craig, A., & McIsaac, P. (2001). Extraversion –introversion and 8 – 13 Hz waves in frontal cortical regions. *Pers. Individ. Differ.*, *30*, 205 – 215.

[22] Yamasue, H., Abe, O., Suga, Yamada, H., Inoue, & Tochigi, M. (2008). Gender-common and -specific neuroanatomical basis of human anxiety-related personality traits. *Cereb Cortex*, *81*, 46–52.

[23] Zuckerman, M. (1991). *Psychobiology of personality* (Cambridge). Cambridge.

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