Frontal Synchronization Biases in Obsessive-Compulsive Disorders*

Mehmet Akif Özçoban[1], Aydin Akan[2]

***Abstract*— Obsessive Compulsive Disorder (OCD) is one of the most common neuropsychiatric disorder in the community. Several neuroimaging systems shows that OCD causes functional disorders in the frontal lobe. In this study, the effects of the OCD on the frontal part are investigated with Inter-Channels Phase Clustering (ICPC) method. According to the Significant desynchronization was detected in slow EEG bands for 7 electrodes on the frontal lobe. These findings are consistent with the previous results that obtained by other neuroimaging devices. The results are also showed that loss of frontal synchronization cause functional disconnectivity. In addition to this, it can be concluded that OCD may cause many cognitive dysfunctions, such as loss of memory.**

I. Introduction

Obsession is determined as intrusive, stressful, repetitive thoughts or images. Compulsion is mental acts and behaviors that are triggered by these thoughts. Obsessive-Compulsive Disorders is a neuropsychiatric disorders and it is characterised by the occurrence of either obsessions, compulsive acts or, most commonly, both [1,2].

Electroencephalography (EEG) device can records electrical activation of brain. EEG was used to investigate neurological and neuropsychiatric disorders. Mutual Information method was used for researching Alzheimer [3], and schizophrenia diseases [4]. Synchronization Likelihood method was used for monitoring epileptic activity in neonates and prediction of seizures [5] and successfully results were obtained in correlation with cognitive functions (working memory) and clinical rating scores [6]. Strong evidences and biomarkers were found in early diagnosis of Alzheimer disease with Stochastic Event Synchronization method [7]. Functional connectivity was analyzed by Global Field Synchronization (GFS) method in schizophrenia [8], Alzheimer [9] and OCD [10]. Decreased synchronization was detected in these diseases and it refers functional disconnectivity and cognitive dysfunctions. Global Synchronization Index and S estimator were also used for research in mild cognitive impairment (MCI) [11].

Inter-Channels Phase Clustering (ICPC) Method is derived from Inter-Trial Phase Clustering (ITPC). Method. ITPC method computes phase coupling between EEG epochs but ICPC calculates the phase consistency between EEG channels. Because of this, ICPC can compute regional or global phase synchronization. To our knowledge this is the first study of the method to investigate OCD. In past, ITPC method was used in several study in past. It was used for detecting error-related activity in medial prefrontal cortex (mPFC). Theta phase synchronization between the electrodes, located over the mPFC region and lateral prefrontal cortex (LPFC) give information about error-related activity [12]. Beside this, Autism Spectrum Disorder (ASD) [13] and Parkinson disease was investigated by the method [14].

In this study, OCD effects on frontal phase synchronization, functional connectivity and cognitive functions were investigated. Since the previous neuroimaging studies suggested that OCD causes abnormal functional dynamics in frontal lobe, we analyze only synchronization degree of frontal lobe [15,16].

II. Material and Methods

A. Subjects and EEG Recording

18 OCD patients (8 female and 10 male) and 15 (7 female and 8 male) age and gender matched healthy controls (HCs) volunteers participated in this. The EEG data were enrolled from voluntary patients and age matched healthy controls at the Uskudar University Neuropsychiatry Health Practice and Research Centre. The volunteers had been informed about examination processes by neuropsychiatrist physician. Informative form of written consent was signed by all the participants. Helsinki Declaration the ethical principles for medical research involving human subjects, were obeyed, and the thesis research protocol was approved by Uskudar University Clinical Research Ethics Committee. Neuroscan Synamps II (Neuroscan Products, Compumedics, USA) recording system was used for recording and it is including a quick cap. Scalp potentials are used for determining neural oscillations. Electrodes were placed on sclap as International 10-20 electrode system. The recording room was light controlled and sound attenuated. EEG data were sampled at a frequency of 250 Hz. The analogue-to-digital converter was 16-bit. The impedance values of the Ag/AgCl surface electrodes were maintained at less than 5 kΩ. To remove artefacts originated from eye blinks (EOG signals) or body movements, values were rejected with levels of 50 µVolt peak-to-peak. Both vertical and horizontal bipolar EOG signals were measured by using electrodes, which were placed inferior to the right eye and to the left and right outer acanthi of the eyes. A band pass filter (0.5-70 Hz) was applied to raw data in Scan Edit 4.3 software. Power-line interference of 50 Hz was suppressed by a Notch filter. Finally, muscle

[1] Mehmet Akif Özçoban is with Department of Medical Imaging, Istanbul Gedik University, 34034, İstanbul, Turkey, mehmetakifozcoban@gmail.com.

[2] Aydin Akan is with Department of Biomedical Engineering, Izmir Katip Celebi University, Izmir, Turkey, 35620, aydin.akan@ikc.edu.tr.

artefacts were carefully eliminated by an expert technician. Placement of electrodes is shown as Figure 1.

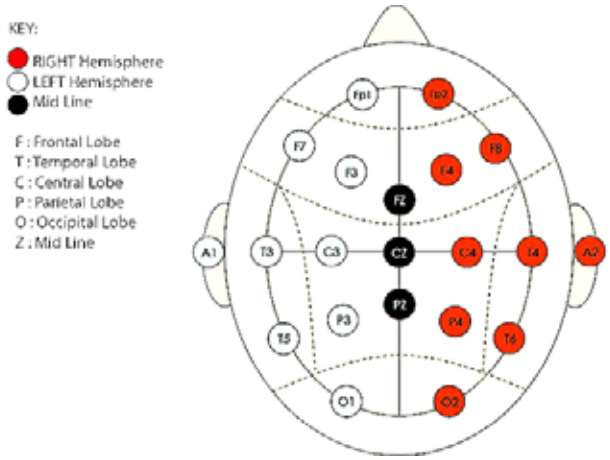

Figure 1:. International 10-20 electrode system (http://cogsci.stackexchange.com/questions/1553/do-the-jungian-cognitive-functions-processes-really-exist)[17]

Synchronization values were computed for slow EEG bands such as delta: (0.0-0.4 Hz), theta (4.0 – 7.0 Hz) [18]

B. Inter-Trial Phase Clustering Method

However, the analyzes of the power spectral values of EEG trials can be computed as simply taking averages the values, this method is not appropriate for taking averages the phase values. Because the phase angle values are radian and they can be illustrated on the unit circle. The averages of these values can be calculated with the following equation (1) according to the ITPC method.

$$ITPC_{tf} = \left| \frac{1}{n} \sum_{r=1}^{n} e^{-ik_{tfr}} \right| \qquad (1)$$

where '*n*' denotes the number of EEG epochs, '*tf*' is time-frequency point, '*r*' is one trial and '*k*' refers to phase angle.

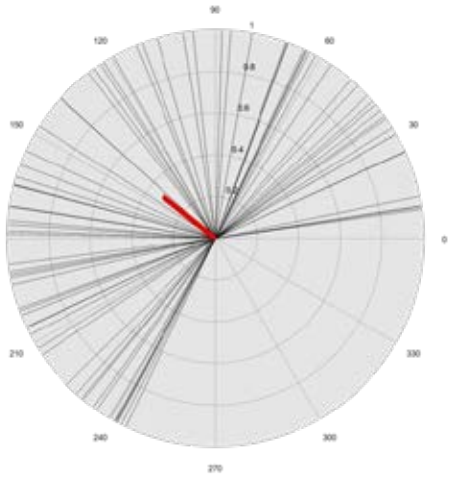

Figure 2: Illustration of ITPC method.

C. Inter-Channels Phase Clustering Method

The inter-Channel phase clustering method was created by performing some renovations in the ITPC calculation algorithm to compute the regional or global phase synchronization power in the resting state EEG records (without excitation and stimulation).

3-minutes EEG records are not separated. In this way, edge artifacts were not affect the results. Morlet Wavelet Transformation (MWT) method was applied all data and thus frequency component can be obtained. Phase angles of these frequency components can be computed with equation 2. The phase values are radian and they can be illustrated as a vector on the unit circle. Each vector represents the phase angle of one channel. Example of the calculation are illustrated as Figure 2. Average vector are illustrated as red line. Length of the vector indicate the synchronization degree. Synchronization degree values are 0 through 1.

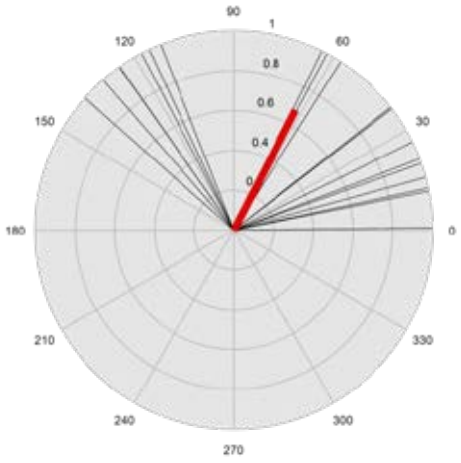

Figure 3: Illustration of ICPC method.

One of the best advanteges of the method is that it can compute the global phase synchronization value for the whole brain as well as provide information about regional (frontal, parietal, temporal, occipital) synchronization value. ICPC method can be calculated with equation 2.

$$ICPC_{tf} = \left| n^{-1} \sum_{r=1}^{n} e^{-ik_{tfr}} \right|$$

where 'n' denotes the number of EEG channels, 'tf' is time-frequency point, 'r' is one trial and 'k' refers to phase angle.

III. RESULTS

In the present study, we investigated that OCD effects on neurophysiological mechanism such as brain wave's synchronization and functional connectivity between brain structures, cognitive processes in frontal lobe. ICPC method very successfully applied in past but these are generally studied event related potentials and investigating the effects of stimulation. The ICPC algorithms was adapted for investigating resting state EEG data. Synchronization values was computed both each channel and each EEG band such as delta (0.0-4.0 Hz), theta (4.0-7.0 Hz). 15 HCs and 18 OCD data was analyzed. Analyzes results was shown in Table 1.

TABLE I. STATISTICAL ANALYZES RESULTS

	Delta Band	**Theta Band**
OCD Synchronization Values	0.350	0.348
Standart Deviation	0.014	0.011
HCs Synchronization Values	0.312	0.3245
Standart Deviation	0.011	0.028
p value	0.0001	0.0001

The ICPC values were computed for OCD patients and HCs volunteers. Statistical analyses of results were performed by nonparametric Mann-Whitney-U test. The values were computed separately for slow frequency bands and differed significantly between the groups in the delta band ($p < 0.001$) and theta band ($p < 0.001$) were found.

IV. DISCUSSION AND CONCLUSION

Our results are consistent with findings of previous neuroimaging studies [15,16]. The loss of synchronization observed in the frontal region by the ICPC method can be calculated more powerful than the differences in other synchronization studies. In previous studies, decreased synchronization in schizophrenia was investigated in theta band by using GFS method [8]. It was found that OCD causes in frontal desynchronization in a study [10]. In these studies, the loss of synchronization was assessed as a decrease in the functional disconnectivity between brain networks. Our findings show that OCD causes a decrease in functional connectivity in the frontal region. EEG source localization studies show that theta waves have been generated from hippocampus and it manage to memory functions. Since this region also manages memory functions, our results can be assessed as OCD causes to impairment on memory functions.

V. REFERENCES

[1] McKay, D., Abramowitz, J.S., Calamari, J.E., Kyrios, M., Radomsky, A., Sookman, D., Taylor, S., and Wilhelm, S.: 'A critical evaluation of obsessive–compulsive disorder subtypes: symptoms versus mechanisms', Clinical psychology review, 2004, 24, (3), pp. 283-313

[2] Abramowitz, J.S., Taylor, S., and McKay, D.: 'Obsessive-compulsive disorder', The Lancet, 2009, 374, (9688), pp. 491-499

[3] Jeong, J., Gore, J.C., and Peterson, B.S.: 'Mutual information analysis of the EEG in patients with Alzheimer's disease', Clinical neurophysiology, 2001, 112, (5), pp. 827-835

[4] Na, S.H., Jin, S.-H., Kim, S.Y., and Ham, B.-J.: 'EEG in schizophrenic patients: mutual information analysis', Clinical Neurophysiology, 2002, 113, (12), pp. 1954-1960

[5] Altenburg, J., Vermeulen, R.J., Strijers, R.L., Fetter, W.P., and Stam, C.J.: 'Seizure detection in the neonatal EEG with synchronization likelihood', Clinical neurophysiology, 2003, 114, (1), pp. 50-55

[6] Pijnenburg, Y., Vd Made, Y., Van Walsum, A.V.C., Knol, D., Scheltens, P., and Stam, C.: 'EEG synchronization likelihood in mild cognitive impairment and Alzheimer's disease during a working memory task', Clinical neurophysiology, 2004, 115, (6), pp. 1332-1339

[7] Dauwels, J., Vialatte, F., Musha, T., and Cichocki, A.: 'A comparative study of synchrony measures for the early diagnosis of Alzheimer's disease based on EEG', Neuroimage, 2010, 49, (1), pp. 668-693

[8] König, T., Lehmann, D., Saito, N., Kuginuki, T., Kinoshita, T., and Koukkou, M.: 'Decreased functional connectivity of EEG theta-frequency activity in first-episode, neuroleptic-naıve patients with schizophrenia: preliminary results', Schizophrenia research, 2001, 50, (1), pp. 55-60

[9] Koenig, T., Prichep, L., Dierks, T., Hubl, D., Wahlund, L.O., John, E.R., and Jelic, V.: 'Decreased EEG synchronization in Alzheimer's disease and mild cognitive impairment', Neurobiol Aging, 2005, 26, (2), pp. 165-171

[10] Özçoban, M.A., Tan, O., Aydin, S., and Akan, A.: 'Decreased global field synchronization of multichannel frontal EEG measurements in obsessive-compulsive disorders', Medical & Biological Engineering & Computing, 2017, pp. 1-8

[11] Wen, D., Xue, Q., Lu, C., Guan, X., Wang, Y., and Li, X.: 'A global coupling index of multivariate neural series with application to the evaluation of mild cognitive impairment', Neural Networks, 2014, 56, pp. 1-9

[12] Cavanagh, J.F., Cohen, M.X., and Allen, J.J.: 'Prelude to and resolution of an error: EEG phase synchrony reveals cognitive control dynamics during action monitoring', Journal of Neuroscience, 2009, 29, (1), pp. 98-105

[13] van Noordt, S., Wu, J., Venkataraman, A., Larson, M.J., South, M., and Crowley, M.J.: 'Inter-trial coherence of medial frontal theta oscillations linked to differential feedback processing in youth and young adults with

autism', Research in Autism Spectrum Disorders, 2017, 37, pp. 1-10

[14] De Hemptinne, C., Ryapolova-Webb, E.S., Air, E.L., Garcia, P.A., Miller, K.J., Ojemann, J.G., Ostrem, J.L., Galifianakis, N.B., and Starr, P.A.: 'Exaggerated phase–amplitude coupling in the primary motor cortex in Parkinson disease', Proceedings of the National Academy of Sciences, 2013, 110, (12), pp. 4780-4785

[15] Saxena, S., Brody, A.L., Schwartz, J.M., and Baxter, L.R.: 'Neuroimaging and frontal-subcortical circuitry in obsessive-compulsive disorder', The British Journal of Psychiatry, 1998

[16] Veale, D., Sahakian, B., Owen, A., and Marks, I.: 'Specific cognitive deficits in tests sensitive to frontal lobe dysfunction in obsessive–compulsive disorder', Psychological medicine, 1996, 26, (6), pp. 1261-1269

[17] http://cogsci.stackexchange.com/questions/1553/do-the-jungian-cognitive-functions-processes-really-exist

[18] Bear, M.F., Connors, B.W., and Paradiso, M.A.: 'Neuroscience' (Lippincott Williams & Wilkins, 2007. 2007)

[19] Cohen, M.X.: 'Analyzing neural time series data: theory and practice' (MIT Press, 2014. 2014)

[20] Kahana, M.J., Sekuler, R., Caplan, J.B., Kirschen, M., and Madsen, J.R.: 'Human theta oscillations exhibit task dependence during virtual maze navigation', Nature, 1999, 399, (6738), pp. 781

[21] Klimesch, W., Schack, B., and Sauseng, P.: 'The functional significance of theta and upper alpha oscillations', Experimental psychology, 2005, 52, (2), pp. 99-108