



Time-Frequency Coherence Analysis Of Alcoholic's EEG

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Abstract: This study investigates the changes in functional connectivity between different regions of the alcoholic's brain. The functional connectivity was estimated using the electroencephalographic (EEG)-based coherence function. The coherence function was estimated using the wavelet transform. The wavelet-based coherence method showed comparatively significantly larger values of coherence for alcoholic subjects at frontal and occipital regions of the brain. These significantly larger coherence values were observed both at lower (4-13) Hz and higher frequency components (50-60) at optimal time and frequency resolutions. The results presented in this study are novel and will provide more insight into the neurophysiological mechanism of alcoholic effects on the human brain.

Keywords: Wavelet Coherence. Time-Frequency Analysis. EEG. Alcoholics.

1. INTRODUCTION

Over the years EEG technique has been successfully used in the study of various cognitive and neurological disorders. It has been also used in the study of alcoholic effects on human brain. For example, various studies have reported changes in EEG activity of alcoholic subjects as compared to the non-alcoholic subjects (Enoch et al. 2002 Sviderskaia et al. 2002). The period of alcoholism was taken more than 10 years and rate of alcoholic consumption was 40-50 units per week in these studies. One unit of alcohol was taken around 10-13 ml. Apart from the conventional visual analysis of EEG, literature reports the use of signal processing techniques on EEG signals of alcoholics. Among them the most commonly used technique is based upon the power spectral density (PSD) function. Literature reports increase in PSD function in EEG signals of alcoholic subjects as compared to those obtained for non-alcoholic subjects (Kaplan et al. 1985; De Bruin et al. 2004). The another commonly used technique in the study of alcoholic's EEG is based upon the coherence function. This function is used to measure a linear correlation between signals. It has been successfully used in EEG analysis to reveal functional relation between different brain regions for various neurological disorders including the disorder caused due to the alcoholism (Mormann et al. 2000; Sherman et al. 1997; Nunez and Srinivasan 2005; Klein et al. 2006). Literature reports larger values of coherence for alcoholic's EEG as compared to those obtained using the non-alcoholic's EEG (Kaplan et al. 1985; Moselhy et al. 2001; De Bruin et al. 2004; Marsdlek et al. 2006).

The major disadvantages of studies for coherence analysis of alcoholic's EEG, mentioned in literature, are following. (1) Study on EEG-based coherence analysis of alcoholism does not address the alcoholic effects on coherence function for higher frequency components such as above 50Hz. (2) The volume conduction due to various

uncorrelated sources present in the brain (VCUS) have not taken into account whereas VCUS effects might introduce the biased estimates into the true value of coherence (Nunez et al. 1997; Nunez et al. 2007).

This study, addressing the above mentioned limitations, uses the EEG-based coherence function for examining the effects of alcoholism on functional connectivity of the human brain. The coherence function was estimated using the wavelet transform because it provides the analysis of signal in both time and frequency domains. Moreover it is useful for analyzing the given signal both at low and high frequency components at optimal time and frequency resolutions.

2. MATERIAL AND METHODS

Data collection

EEG data of the event related potentials (ERPs), recorded from alcoholics and abstinent alcoholics (average 10 years of abstinence) performing a visual discrimination task, was used in this study. The data was recorded from 15 alcoholic and 15 non-alcoholic subjects. The period of alcoholism was more than 10 years with the average drinking rate of 45-50 units per week whereas one unit of alcohol was taken around 11-14 ml. The data was recorded while subjects were busy in discriminating the difference in two visual pictures shown to them through the computer monitor. The subjects were instructed to press the mouse key in case they felt confident in detecting the change. The successful response of subject was called change detection trial otherwise it was called change blindness trial. All the important precautions to avoid EEG artifacts were taken.

3. RESULTS AND DISCUSSION

The coherence function itself is a complex number and therefore the magnitude square of coherence (MSC) was used in this study since it provides the real values. The difference in MSC between alcoholic and non-alcoholic subjects was assessed using the t-test. MSC

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across the time region of [100-200]ms showed clear difference between alcoholic and non-alcoholic subjects as compared to other time regions. Therefore we examined difference of MSC across this time region. Furthermore, the MSC across this time region was examined for three standard frequency bands called alpha, theta, and gamma bands of frequencies. Hence the averages of EEG-based MSC values across these three frequency bands each of with the time region of [100, 200]ms were used in this study. These average MSCs are called alpha, theta and gamma MSCs in this study.

Unlike the previous studies on coherence analysis of alcoholic's EEG in which issue of VCUS effects have been ignored, this study has taken into account this issue. This is because VCUS effects can significantly introduce the biased estimates into the true coherence value (Nunez and Srinivasan, 2005). During this study, various MSCs showed significant effects of VCUS effects for inter-electrode spacing of around 3.2 to 7cm. Therefore such MSCs were excluded from further analysis. Only those MSCs were selected whose spectra were closely resemble to the true values of coherence function. The presence of VCUS effects was determined using the study of Nunez *et al.* 1997 in which comprehensive discussion about the VCUS effects on coherence has been given.

Theta (4-8), alpha (8-13) and gamma (50-60) band MSCs showed significantly larger values of MSC for alcoholic subjects as compared to those obtained for non-alcoholic subjects. In addition to this, these significantly larger values of MSCs were observed at frontal and occipital regions of the brain. However no significant difference was observed for other regions of the brain. Keeping in view the definition of coherence function, these results lead to the conclusion that alcoholism might increase the functional connectivity at frontal and occipital regions of the brain. The results reported in this study are consistent to the previous studies about coherence analysis of alcoholic's EEG. However increase in gamma band MSC in the frequency range of 50-60 Hz is not reported in literature and therefore this result will provide more insight into the neurophysiological mechanism of alcoholic effects on human brain.

4.

CONCLUSION

This study examines the effects of alcoholism on functional connectivity of brain using the wavelet coherence analysis of EEG signals. The time-frequency analysis based on wavelet proved to be useful in detecting the significance coherence difference between EEG signals of alcoholic and non-alcoholic subjects in low (alpha and theta frequency bands in the range of 4-13Hz) and high frequency (gamma frequency band in the range of 50-60 Hz) components with optimal time-frequency frequency resolution. This is the first study which provides the evidence that alcoholism can affect the coherence function of EEG signals in high frequency components of 50-60 Hz.

REFERENCES:

- DeBruin E., S. Bijl S, C. Stam, K. Bocker, J. Kenemans and M. Verbatenn (2004) Abnormal EEG synchronisation in heavily drinking students. *Clin Neurophysiol*, 115 (9): 2048-55.
- Enoch, M.A., K.V. White, C.R. Harris, J.W. Rohrbaugh and D. Goldman (2002) The relationship between two intermediate phenotypes for alcoholism: low voltage alpha EEG and low P300 ERP amplitude. *J Stud Alcohol*, 63 (5): 509-517.
- Kaplan R., B. Glueck, M. Hesselbrock and H. Reed (1985) Power and coherence analysis of the EEG in hospitalized alcoholics and nonalcoholic controls. *J Stud Alcohol*, 46 (2): 122-127.
- Klein A., T. Sauer, A. Jedynak and W. Skrandies (2006) Conventional and wavelet coherence applied to sensory-evoked electrical brain activity. *IEEE Trans Biomed Eng*, 53 (2): 266-72.
- Mormann, F., K. Lehnertz, P. David and C.E. Elger (2000) Mean phase coherence as a measure for phase synchronization and its application to the EEG of epilepsy patients. *Physica D*, 144 (3-4): 358-369.
- Moselhy, H.F., G. Georgiou and A. Kahn (2001) Frontal lobe changes in alcoholism: A review of the literature. *Alcohol and Alcoholism*, 36 (5): 357-368.
- Marsdlek, T., V. Matousek, P. Mautner, M. Merta and R. Moucek (2006) Coherence of EEG signals and biometric signals of handwriting under influence of nicotine, alcohol and light drugs. *Neural Network World*, 16 (1): 41-60.
- Nunez, P. L and A. F. Westdorp (1994) The Surface Laplacian, High Resolution EEG and Controversies. *Brain Topography*, 6 (3): 221-226.
- Nunez, P. L., R. Srinivasan, A. F. Westdorp, R. S. Wijesinghe, D. M. Tucker, R. B. Silberstein and P.J. Cadusch (1997) EEG coherency. I. Statistics, reference electrode, volume conduction, Laplacians, cortical imaging and interpretation multiple scales. *Electroencephalography and clinical neurophysiology*, 103 (5): 499-515.
- Nunez, P. L and R. Srinivasan (2005) *Electric fields of the brain*. Oxford university press.
- Sherman, D.L., Y.C. Tsai, L.A. Rossell, M.A. Mirski and N.V. Thakor (1997) Spectral analysis of a thalamus-to-cortex seizure pathway. *IEEE Transactions on Biomedical Engineering*, 44 (8): 657-664.
- Sviderskaia, N.E., V.A. Glazkova, and O.B. Abolmasova (2002) Dynamics of EEG-indicators in alcohol abstinence. *Zh Vyssh Nerv Deiat Im I P Pavlova*, 52 (2): 156-165.
- Winterer, G., M. A. Enoch, K.V. White, M. Saylan, R. Coppola and D. Goldman (2003) EEG phenotype in alcoholism: increased coherence in the depressive subtype. *Acta Psychiatrica Scandinavica*, 108 (1): 51-60.