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Complexity Analysis for Drinkers' EEG via Wavelet Entropy *

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Abstract

This paper investigates the influence of alcohol on brain complexity. Considering electroencephalogram (EEG) has the nonlinear dynamics characteristic of time-varying and non-stationary, we introduced the Wavelet Entropy (WE) analysis. We denoise EEG signal by using wavelet decomposition, then calculated the wavelet entropy of the denoised signal and analyzed the nonlinear complexity of the signal. The results shows that the EEG wavelet entropy of drinkers' is markedly greater than the EEG wavelet entropy of normal people's. The EEG complexity of drinkers' is higher and the brain of drinkers' is in a more chaotic state. In the case of three kinds of external stimulus, we can get the change rule of the normal people's and alcoholics' EEG, and then analyze the WE and the effects of alcohol on the brain through a long duration of time. The long-time excessive drinking causes damages to the nerve cells, which means the human brain consciousness becomes poor, and response is slow.

Keywords: EEG; Wavelet Transform; Wavelet Entropy; Complexity

1 Introduction

Drunk driving is the major reason for traffic accidents. The regularity of drinkers' brain function change is an interesting topic. Generally, dizziness, tinnitus and show; response especially for emergency, are typical symptoms after drinking. Brain is composed of a huge amount of nerve cells

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and each nerve cell are connected to other nerve cells, making brain a complex non-linear system. Complexity can reflect the regularity of dynamic systems. The behaviour of various systems is different, and thus the regularity of the behaviour from these systems is also different. Complexity is capable of describing these differences and then further discriminating these systems.

Electroencephalogram (EEG) is a non-invasive, low-cost and effective technique for examining electrical activity of the brain and diagnosing brain diseases in clinical setting [1]. EEG is a type of non-stationary time series signal. It's hard to analyze EEG by linear method, such as time domain analysis and frequency domain analysis because of the no-regularity caused by nonlinear and non-stationary factors. Therefore non-linear analysis methods could better facilitate opening out the characteristics and mechanisms of EEG [2] [15].

With the rapid development of non-linearity theory, complexity analysis is becoming a popular field for studying nonlinear dynamics of EEG time series. Although different methods have provided indirect evidence for synchronization EEG processes [3, 8], a tool for a quantitative evaluation of the complex EEG signal synchronization and its temporal dynamics is still lacking. In the information theory, 'entropy' represents the irregularity of systems, and many complexity concepts are related to entropy. Entropy is a concept handling predictability and randomness, with higher values of entropy always related to less system order and larger randomness [4]. Approximate entropy (ApEn) was first put forward by Pincus et al. [5]. In [6], an ApEn-based epileptic EEG detection system using artificial neural networks was studied. These methods are based on information theory, such as Permutation Entropy (PE), ApEn, and other ones based on chaos theory. SampEn was an improved algorithm based on approximate entropy (Richman et al. 2000) [7].

PE and ApEn are better in distinguishing the EEG between drinkers and the control, but they can't be used for on-line analysis as it is too time consuming. ApEn's counting process adopts Heaviside function, which is very sensitive to the threshold value and phase space dimension, and vulnerable to noise interference. It lacks relative consistency and the result shows much dependence on data length. SampEn displays relative consistency and less dependence on data length. Nevertheless, the similarity definition of vectors in SampEn is based on Heaviside function as in ApEn. Due to the inherent flaws of Heaviside function, problems still existed in the validity of the entropy definition, especially when small parameters were involved. To overcome these limitations, Wavelet Entropy (WE) [13] (Osvaldo A. Rosso et al. 2001), a new nonlinear dynamic analysis method, can be used for analyzing the short time signal. WE algorithm needn't consider any parameters during the process of calculation. It can reduce the influence of noise, reflect the signal's confusion degree of frequency components and provide the dynamics characteristics. And it is simple and possesses both time-frequency limitations and robustness.

In this paper, we investigated the influence of alcohol on brain complexity based on wavelet entropy. The work is organized as follows. Section 2 introduces wavelet entropy method. Section 3 WE performances to the nonlinear signals are discussed. In Section 4, by calculating the wavelet entropy of drinkers' and normal people's EEG signal, we analyze the complexity of drinkers' and normal people's EEG signal. Finally, Section 5 draws the conclusions.