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The complexity of occupational stress electroencephalogram

Honger Tian[1], Lili Cao[1], Jun Wang[2*], Tian Xu[1], Yongguo Zhan[1], Ling Liu[1]

[1]Key Laboratory of Environment Medicine and Engineering, Ministry of Education, School of Public Health, Southeast University, Nanjing, China
[2]Image Processing and Image Communications Key Lab, College of Geo & Bio Information, Nanjing University of Posts & Telecomm, Nanjing, China; [*]Corresponding Author: tianhonger0@163.com

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ABSTRACT

It is an important method for using electroencephalogram (EEG) to detect and diagnose occupational Stress in clinical practice. In this paper, the complexity analysis method based on Jensen-Shannon Divergence was used to calculate the complexity of occupational stress electroencephalogram from students and nurses. The study found that the complexity of nurses' EEG was higher than that of students' EEG. The result can be used to assisted clinical diagnosis.

Keywords: Occupational Stress; Electroencephalogram; Students; Nurses; Jensen-Shannon Divergence

1. INTRODUCTION

Since Jensen-Shannon Divergence (JSD) [1] (which was used to measure the difference between the probability distribution of random variables) was proposed in 1991, it was widely applied to the symbol sequence analysis and characterization [2], such as pattern recognition [3], DNA sequence segmentation. JSD is the result of symmetrizing and smoothing the Kullback-Leibler Divergence (KLD). The non-negativity, symmetry, continuity [4,5] and boundness features of JSD have been widely used in the analysis of time series. Electroencephalogram (EEG) can also be seen as a time series, so we consider using JSD complexity based analysis method to achieve recognition and detection of EEG. In this paper, 12 graduate students from Southeast University and 12 nurses from a third-grade class-A hospital were chosen for comparative analysis.

Nurses need to withstand pressure from work, patient and family. The occupational stress can cause changes in psychology, physiology and behavior, such as anxiety, irritability, depression, chronic fatigue syndrome, sleep disorders, immune system suppression, cardiovascular system disease, aggression, and bad habits [6-9]. Graduate students in universities relatively have lower occupational stress than the nurses. So their EEG should have a different dynamic complexity. The Jensen-Shannon Divergence was used to quantitatively analyze time series. As a statistic parameter in information statistics, Jensen-Shannon Divergence described the complexity between different signals and the entropy value increased with increased complexity.

2. JENSEN-SHANNON DIVERGENCE (JSD)

Proposed that p_1, p_2 were two probability distribution of discrete random variables X. KULLBACK defined direct difference I as:

$$I(p_1, p_2) = \sum_{x \in X} p_1(x) \log \frac{p_1(x)}{p_2(x)} \quad (1)$$

It can be seen from Equation (1) that differences I has non-negativity and incremental feature, but it does not have symmetry. In order to meet this point, the form of a symmetric difference—J difference was proposed:

$$\begin{aligned} &J(p_1, p_2) \\ &= I(p_1, p_2) + I(p_2, p_1) \\ &= \sum_{x \in X} (p_1(x) - p_2(x)) \log \frac{p_1(x)}{p_2(x)} \end{aligned} \quad (2)$$

Distance change in the of two probability distributions can meet the metric nature. The distance change was defined as follows:

$$V(p_1,p_2)=\sum_{x\in X}\left|p_1(x)-p_2(x)\right| \quad (3)$$

For the relationship between the direct differences *I* and distance changes *V*, it was found the minimum value of the differences *I* based on the *V*:

$$I(p_1,p_2)\geq \max\left\{L_1(V(p_1,p_2)),L_2(V(p_1,p_2))\right\} \quad (4)$$

where,

$$L_1(V(p_1,p_2)) = \log\frac{2+V(p_1,p_2)}{2-V(p_1,p_2)}+\frac{2V(p_1,p_2)}{2+V(p_1,p_2)},\ 0\leq V(p_1,p_2)\leq 2 \quad (5)$$

$$L_2(V(p_1,p_2))=\frac{V^2(p_1,p_2)}{2}+\frac{V^4(p_1,p_2)}{36}+\frac{V^6(p_1,p_2)}{288},\ 0\leq V(p_1,p_2)\leq 2 \quad (6)$$

But there are not a general representation of the maximum value for direct differences *I* and differences *J* based on *V*. So there exists some limitations when measuring the difference between the probability distribution.

For generally descripting the maximum limit of the difference, papers [1,9] gave the amended definition of *I* and *J*:

$$K(p_1,p_2)=\sum_{x\in X}p_1(x)\log\frac{p_1(x)}{\frac{1}{2}p_1(x)+\frac{1}{2}p_2(x)} = I\left(p_1,\frac{1}{2}p_1+\frac{1}{2}p_2\right) \quad (7)$$

The corresponding symmetrical form difference was as follows:

$$L(p_1,p_2)=K(p_1,p_2)+K(p_2,p_1) \quad (8)$$

It can be seen from Equation (8) that, the difference between *K* and *L* was not only meeting the non-negativity but also having limitation and semi-bounded. That is:

$$\begin{aligned}&K(p_1,p_2)<+\infty, K(p_1,p_2)\geq K(p_1,p_1)\\ &L(p_1,p_2)<+\infty, L(p_1,p_2)\geq L(p_1,p_1)\end{aligned} \quad (9)$$

$$L(p_1,p_2)=2H\left(\frac{p_1+p_2}{2}\right)-H(p_1)-H(p_2) \quad (10)$$

Now setting π_1 and π_2 were the weight of two probability distributions, and meeting $\pi_1,\pi_2\geq 0,\pi_1+\pi_2=1$, Jensen-Shannon Divergence (JSD) was defined as:

$$JS_\pi(p_1,p_2)=H(\pi_1p_1+\pi_2p_2)-\pi_1H(p_1)-\pi_2H(p_2) \quad (11)$$

where $H(P)=\sum_{j=1}^{N}p_j\ln(p_j)$ is Shannon Entropy.

For more than two but a limited number of probability distributions $p_1,p_2,\cdots,p_n$, the corresponding weight were $\pi_1,\pi_2,...,\pi_n$ respectively, JSD was defined as:

$$JS_\pi(p_1,p_2,\cdots,p_n)=H\left(\sum_{i=1}^{n}\pi_ip_i\right)-\sum_{i=1}^{n}\pi_iH(p_i) \quad (12)$$

3. DATA ANALYSIS

The EEG data we used were taken from 12 students and 12 nurses. The sampling frequency was 200 Hz. We used JSD to analyze the complexity of the EEG data of 12 students and 12 nurses and the corresponding results were shown in **Table 1**.

According to **Table 1**, we can plot the complexity measures of three ECG signals and twelve were shown in **Figure 1**.

It can be seen from the **Figure 1** that, the Jensen-Shannon Divergence value of students is less than that of nurses. The T test value of the two groups was equal to 4.414 which confidence probability is 0.001. It indicated that high level of occupational stress had a higher Jensen-Shannon Divergence value than low level, and EEG should be more complex. So students and nurses can be statistically distinguished.

4. CONCLUSION

In this paper, the complexity analysis method based on Jensen-Shannon Divergence was used to calculate the complexity of occupational stress electroencephalogram

Table 1. Complexity measures of twelve ECG signals (2000 points).

Subjects	Student	Nurse
1	0.2163	0.2215
2	0.2175	0.2787
3	0.0599	0.2813
4	0.2092	0.2403
5	0.1929	0.2659
6	0.0694	0.2793
7	0.2171	0.2727
8	0.2358	0.2809
9	0.0692	0.2714
10	0.2145	0.2707
11	0.2055	0.2798
12	0.0621	0.2743
mean ± STD	0.1641 ± 0.0738	0.2681 ± 0.0184

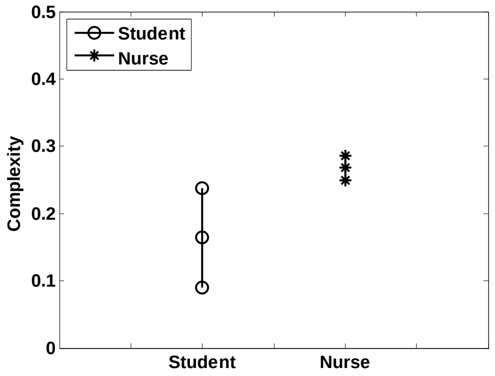

Figure 1. Dynamic range of two kind signals' complexity (N = 2000) (mean ± STD). ○ (Student), * (Nurse).

from students and nurses. The study found that the complexity of nurses' EEG was higher than that of students' EEG. The result can be used to assisted clinical diagnosis.

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