Comparison and diagnosis of resting state EEG in patients with depression and normal person

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Abstract

Depression and other mental diseases are becoming a major problem in today's society, its diagnosis, treatment and monitoring are the focus of attention. Therefore, it is necessary to find more sensitive and specific bio-markers to explain the pathology of all kinds of diseases and distinguish different kinds of mental diseases, so as to perfect the existing clinical methods. This study is based on EEG signals which can accurately and intuitively reflect brain activity, a series of pre-processing methods, such as segmentation, electrode localization, filtering, artifact elimination based on independent component analysis, standard electrode re-reference and so on, have been carried out in the primary data. Then, the signal analysis of spectrum and nonlinear dynamics was carried out, four indexes, including the relative power spectrum, the relative power value of frequency bands, the frequency of gravity center and the power spectrum entropy, were compared and discussed in patients with normal person (100 cases) and depression (100 cases) under the condition of eyes opening and closing at rest. T-test was used to find the indexes which could distinguish normal person and depression significantly at statistical level. Support vector machine (SVM) was used to classify the two groups of subjects based on different index sets, and the classification effects of different indexes were compared at the same time. The results showed that the θ band energy of each channel in normal person group was higher than that in depression group, the energy of β and γ band, the frequency of gravity center and the entropy of power spectrum were lower than that of depression group, and the difference was significant. At the same time, in the classification of support vector machine, spectrum analysis index (especially relative power of θ, β band) has better classification effect, which is expected to be applied to the diagnosis of depression in the future.

Key words

Depression; EEG; spectral analysis; nonlinear analysis; machine learning

Literature review

Many studies have found that patients with normal person and depression have abnormal EEG activity, and study the difference between the two, in order to deepen the study of mental illness pathology and clinical manifestations.

Depression

A large number of studies have shown that there is a close relationship between resting frontal lobe EEG lateralization and depression. COAN is equal to 2004, which suggested that resting frontal lobe EEG lateralization can be used as an objective indicator of depression, guo Jialiang et al examined the forehead asymmetry of depressed patients in resting state and its relationship with the degree of depression, and found that this index can effectively distinguish depressed patients from normal people, qu Xiang and his colleagues made a relatively objective and accurate observation of the electrical changes in the cerebral cortex of patients with depression through the nonlinear analysis of the EEG of patients with depression, it was found that the approximate entropy of EEG in some regions of brain might be a new method to evaluate the effect of drug therapy in patients with depression Yang Chao et al used sample entropy to study the complexity of EEG time series in patients with depression, and found that sample entropy can be used as a sensitive biological index of depression.

Comparative Analysis of Normal person and Depression

Wang Yuanchao analyzed the neurotransmitters in the brain through the ultra-slow fluctuation map of EEG signals, in order to find out some indexes that can distinguish the neurotransmitter content of normal person and depression, Ma Jintang et al used auditory P300 to examine the patients with different mental disorders and compared the results, it was found that both normal person and depression had decreased P300 amplitude, which reflected abnormal processing of cognitive process, but there was no significant difference between these disorders Studies such as Dra en Begi have found differences in power values between normal person and depression, which may be useful in the differential diagnosis of normal person and depression Sun Minghou classifies depression patients and normal controls by comparing their EEG based on modern spectral estimation Through Lem-pel-Ziv complexity (LZC) , Li Yingjie et Al compared the EEG signal complexity of depression and normal person at rest and arithmetic, and found that LZC is sensitive to power spectrum and time amplitude distribution, it is related to the ability of processing task and the cognitive challenge of adapting information processing system, which is helpful to study the interference of information processing in cerebral cortex of patients with depression.

Introduction

In the survey of disease burden in China, mental diseases have far exceeded diseases such as cardiovascular, cerebrovascular and respiratory system, ranking first in disease burden, and mental health problems have become urgent public health and social problems. Mental illness is a disorder of the nervous system that results in abnormal perception, thinking, emotion and behavior because of the disorder of the brain function, depression have become the most common mental diseases in China, which bring people great trouble. According to the latest report released by the World Health Organization in 2017, the prevalence rate of depression is 4.4% globally and about 4.2% in China. However, the diagnosis of depression and other mental disorders is still based on the clinical manifestations of patients to achieve, and the recognition rate is not high, there is still a lack of more sensitive and effective specific biomarkers. More and more researchers are recognizing the benefits of neurophysiological biomarkers, which can detect the early stages of sensory information processing and transition to higher-order cognitive operations at millisecond resolution, it also automatically triggers a response that completes the identification tag without requiring a great deal of effort or effort on the part of the participant. Therefore, the research on the Etiology of normal person and depression, which are neurophysiological biomarkers, has been paid more and more attention, the exploration of clinical diagnosis and treatment monitoring of mental disorders based on neurophysiological indexes is also becoming a major focus of social attention. The purpose of this study is to compare the differences and similarities between normal person and depression in the electrophysiological activities of the brain by analyzing the electroencephalogram (EEG) , a sensitive and objective signal index, from the aspects of spectrum and complexity, it provides reference for clinical and basic research on etiology and pathology of depression. At the same time, this project is expected to focus on the above analysis of some excellent EEG indicators (can be statistically real, now normal person, depression group effective distinction) , machine Learning Algorithm is used to classify normal person and depression, which provides more powerful thinking and decision support for diagnosis and recognition of mental disorders.

Methodology

Considering the types of data and the usage of neural science, Welch and classifier are used to deal with the data in this research. The following methods will be introduced in detail:

Welch methods

With the development of signal analysis theory and technology, signal analysis in the frequency domain has been produced by the original simple Fourier transform in a variety of ways with advantages and disadvantages, such as the period chart method, correlation chart method, Welch method in the classical spectrum analysis, as well as modern spectrum estimation (also called parametric spectrum estimation) , Welch method is used to calculate the power spectrum, the following is a brief introduction to the Welch method in classical spectrum analysis. First, the definition formula for the power spectrum estimate derived from the classical Fourier transform:

$$P_{xx}(e^{j\omega}) = \sum_{n=-\infty}^{\infty} r_{xx}(n)e^{-j\omega n} \dots\dots\dots (6.1.1)$$

If there is a random signal $x(n)$, $n = 0,1,2\dots,N-1$, The estimated spectrum is obtained by dividing the absolute value of $x(n)$Fast Fourier transform by the length of the data N, From this formula (6.1.3) , the power spectrum can be obtained by the periodogram method:

$$\hat{P}_{xx}(e^{j\omega}) = \frac{1}{N}|\sum_{n=0}^{N-1} x(n)e^{-j\omega n}| \dots\dots\dots (6.1.2)$$

However, when the transform domain is changed from the infinity of Formula (6.1.1) to Npoints of formula (6.1.2) , it will cause the shortcomings of low resolution, large variance and large estimation error. Welch method is to improve these shortcomings, to adopt the method of data section window and average again, first the length of the data for the length of N is divided into l segments, each segment length $M = N/L$, and each segment data are partly overlapping, then, the spectral estimation of each segment is obtained by averaging the power spectrum$\hat{P}_{xi}(f)$, as shown in (6.1.3) . The MATLAB-based brainstorm toolkit is used to calculate the power spectrum.

$$P_x(f) = \frac{1}{L}\sum_{i=1}^{L} \hat{P}_{xi}(f) \dots\dots\dots (6.1.3)$$

After calculating the power spectrum of EEG by Welch method, it is necessary to continue to excavate the properties and characteristics of the power spectrum, in this paper, the relative power spectrum, relative power, Barycenter and frequency of each frequency band related to EEG rhythm are calculated from the original power spectrum, through the statistical method comparative analysis of Normal person and Depression in these categories of indicators in the parameters of the differences.

a. for different subjects, the original power spectrum has different baseline state, which will influence the results of comparison and analysis between groups. To eliminate this effect, the power spectrum of all subjects can be converted to the same baseline and the same scale by calculating the ratio of the power value at each frequency point to the total power value, that is, the relative power value. Suppose the original power spectrum is$P_x(f)$, $f = 0,1,2,\dots,N-1$, The formula for calculating the relative power $P_r(f)$is:

$$P_r(f) = \frac{P_x(f)}{\sum_{m=0}^{N-1} P_x(m)} \dots\dots\dots (6.1.4)$$

b. frequency band relative power, EEG signal has rhythm, from its main rhythm, combined with the corresponding physiological significance, research and analysis of the signal, in each rhythm of the energy distribution and its implication:

①δ Frequency Band (1-3Hz) : the largest amplitude, the lowest frequency, generally in infants, children and adults sleep state can be detected;

②θFrequency band (4-7 Hz) : This band is detectable in the parietal and frontal lobes when a child or adult is tired, especially during sleep. Some studies have found that this band is also associated with cognitive ability;

③αFrequency band (8-13 Hz) : occurs rhythmically at the back of the brain, with a low but large amplitude, usually more pronounced when the brain is closed and relaxed; this rhythm is greatly reduced or even disappeared when the brain is focused;

④βFrequency Band (14-30Hz) : In the frontal lobe and parietal lobe more significant, generally considered to represent the brain, the cortex in the excited state;

⑤γFrequency Band (30-60 Hz) :It's mainly related to perception and so on, but more research is needed on its physiological significance.

In this paper, we focus on the frequency below 45Hz after filtering, so we only select the low frequency part of 30-40Hz in the gamma frequency band. If a frequency band is located at the $f_1 - f_2$frequency point of the whole power spectrum,Let the power spectrum be $Px(f)$, $f =$

$0,1,2,\ldots,N-1$, the relative power of the frequency band can be calculated as follows:

$$P_r(f) = \frac{\sum_{m=f1}^{f2} P_x(m)}{\sum_{m=0}^{N-1} P_x(m)} \ldots\ldots\ldots (6.1.5)$$

The relative power of the frequency band can also be calculated from the relative power spectrum $P_r(f)$:

$$P_{fb} = \frac{\sum_{m=f1}^{f2} P_r(m)}{\sum_{m=0}^{N-1} P_r(m)} \ldots\ldots\ldots (6.1.6)$$

c. The frequency of Barycenter f_g is calculated by the corrected relative power spectrum, such as formula (6.1.7) , the relative power spectrum is $P_r(f)$, the frequency range is $f = 0,1,2,\ldots,N-1$.

$$f_g = \frac{\sum_{f=0}^{N-1}[P_r(f) \times f]}{\sum_{f=0}^{N-1} P_r(f)} \ldots\ldots\ldots (6.1.7)$$

According to the formula, the frequency of the center of gravity of the power spectrum curve is equivalent to the Spectral density distribution of the signal, which indicates the frequency of the signal component in the spectrum that occupies a large amount of energy, at the same time, it can also reflect the transfer of power spectrum under different conditions.

Sorter

Two classifiers, NB and SVM, are used in this project. The core of NB Algorithm is Bayesian formula, that is to use Bayesian formula to calculate the probability that the sample belongs to each category, and finally to classify the sample to be classified into the category with the highest probability. The NB logic is simple and easy to implement, but it assumes that the sample features are independent of each other, which reduces the generalization performance of the model.

The main idea of SVM is to map the features to a high-dimensional plane by kernel function, and to find an optimal decision hyperplane in this high-dimensional space, so that the hyperplane can not only classify two samples, moreover, the distance between the hyperplane and the nearest samples on both sides of the hyperplane is maximized so that the hyperplane has good generalization ability. Where the nearest sample to the hyperplane is defined as a support vector. In practice, according to the characteristics of the data, the corresponding kernel function is selected. Eighty per cent of the project data set is used for training and 20 per cent for testing. In the training process, the training data are divided into training set and verification set by K-fold cross-validation (K = 10) , training set is used to train the model, and verification set is used to evaluate the model performance, in this way, the over-fitting phenomenon of the model can be reduced and the stability and generalization ability of the model can be improved. The grid search function is also used to optimize the model.

Results and finding analysis

Relative power spectrum

The average relative power spectrum of the channels in patients with the same disease was compared with that in patients with open and closed eyes, as shown in Fig. 3.1. It is clear that both patients with normal person (NP) and those with depression (DP) can produce very significant α waves (8-13 Hz) when they close their eyes, which strongly supports the idea that α frequency band energy increases significantly this morning when the eyes are closed, this finding (or the effective suppression of the α wave when the eyes are open) also suggests that this basic function is not impaired in patients with both diseases.

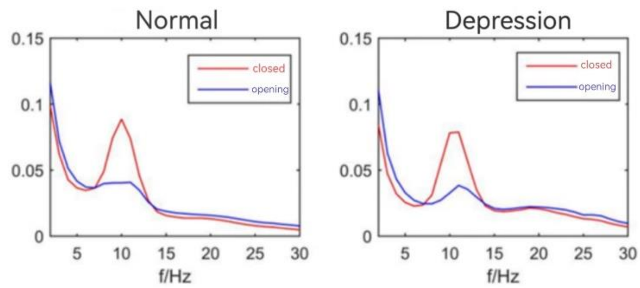

Fig. 3.1 Comparison of mean relative power spectrum of channels in patients with the same disease under the condition of open and closed eyes

The average relative power spectrum and t-test P values of the two groups in the same state are shown in Fig. 3.2. According to the t test, the threshold setting, the result P value less than 0.05 is statistically significant difference, because the relative power spectrum here is 16 channel average result, is relatively rough, but can still see except the frequency band, there were significant differences between normal person and depression in other frequency bands ($P < 0.05$) .

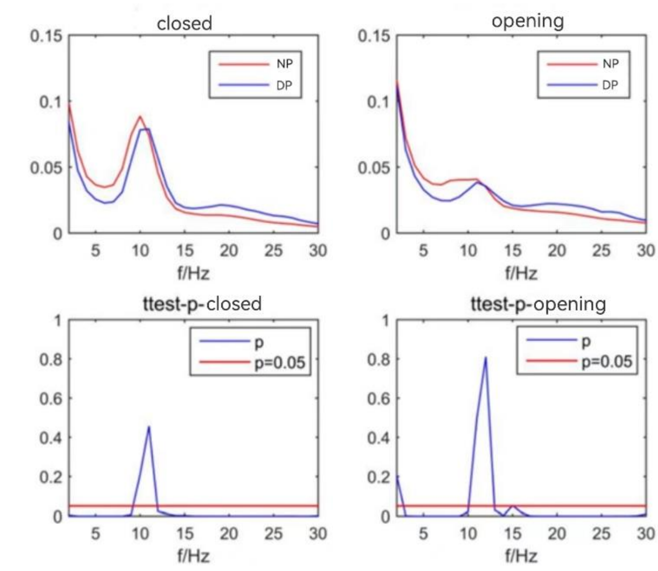

Fig. 3.2 The average relative power spectrum and P value in t-test (t-test was bilateral) of the two groups in the same state

Relative power of each frequency band

The frequency spectrum was divided into δ frequency bands (1-3.9 Hz) , θ frequency bands (4-7.9 Hz) , α frequency bands (8-13.9 Hz) , β frequency bands (14-29.9 Hz) , γ frequency bands (30-40 Hz) according to EEG rhythm, the average relative power and relative power topographic map of each frequency band of normal person and depression in the two states (open/close eyes) are calculated as shown in Fig. 3.3-3.6.

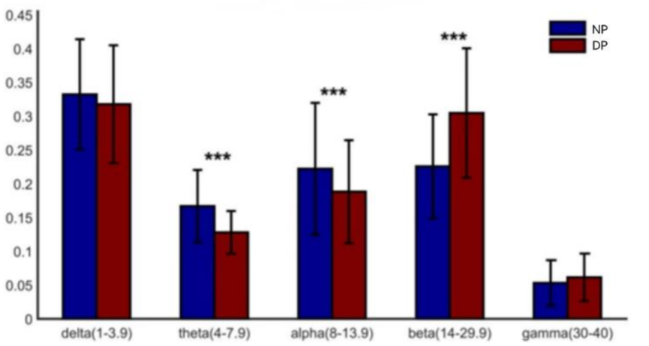

Fig. 3.3 The average relative power of each channel in the two groups with Eyes Open

Note: ***Indicates that there is a significant difference between the two groups in the results of bilateral t test (P <0.05)

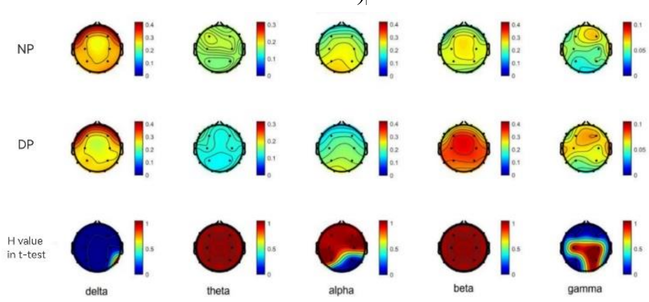

Fig. 3.4 Under the condition of open eyes, the relative power topographic map of each frequency band of the two groups of subjects

Note: NP: Normal person Group DP: Depression Group

Line 3: Bilateral t-test (95% confidence interval) , 1(red)-significant difference, 0(blue)-no significant difference

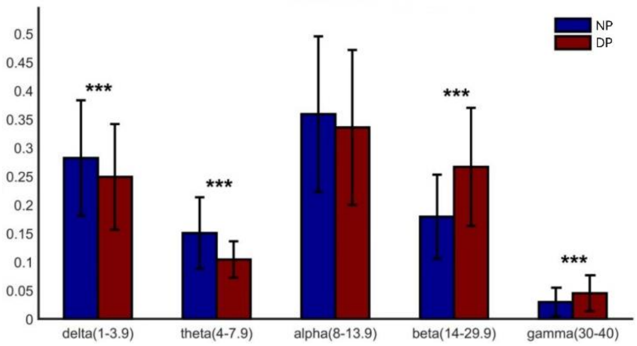

Fig. 3.5 The average relative power of each channel in two groups with eyes closed

Note: ***Indicates that there is a significant difference between the two groups in the results of bilateral t test (P<0.05)

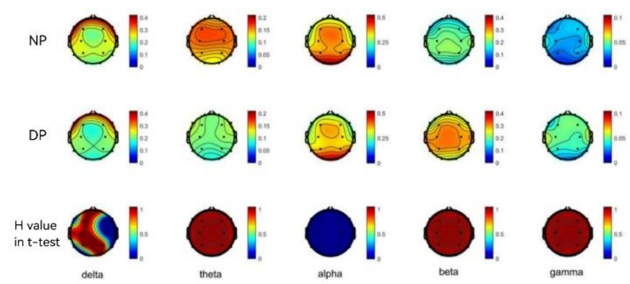

Fig. 3.6 The relative power topographic map of each frequency band of the two groups under the condition of eyes closed

Note: NP: Normal person Group DP: Depression Group

Line 3: Bilateral t-test (95% confidence interval) , 1(red)-significant difference, 0(blue)-no significant difference

There was significant difference ($P<0.05$) in the relative power of the θ、 βfrequency band between the two groups in the open/closed state, this may be related to the pathology of both types of diseases. Significantly, normal person had higher θ band energy than depression, and two high frequency bands（β、γ） had lower band energy than depression. These three bands in turn are related to cognition, excitement and perception. Previous studies have shown that when cognitive ability is impaired, θ frequency bands tend to be enhanced, meaning that wave energy is negatively correlated with cognitive ability, and that the energy of both waves is primarily positively correlated with the ability they reflect.

At the same time, the α wave energy of the two groups was higher when the eyes were closed and there was no significant difference in any channel. Although there were some differences when the eyes were opened, the differences were mainly concentrated in the frontal lobe and the parietal lobe of the brain, and the α wave appeared mainly in the occipital lobe of the brain, the results are not sufficient to distinguish and explain depression, and its implications may need to be further explored.

Center of gravity frequency

The broken-line distribution of the center of gravity frequency and the corresponding topographic map of the two groups of subjects in the same state are shown in Fig. 3.7-3.8.

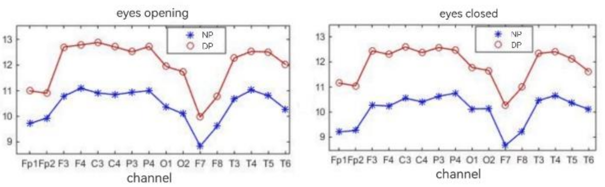

Fig. 3.7 Broken-line distribution of barycenter frequency with eyes open/closed

Note: NP: Normal person DP: Depression

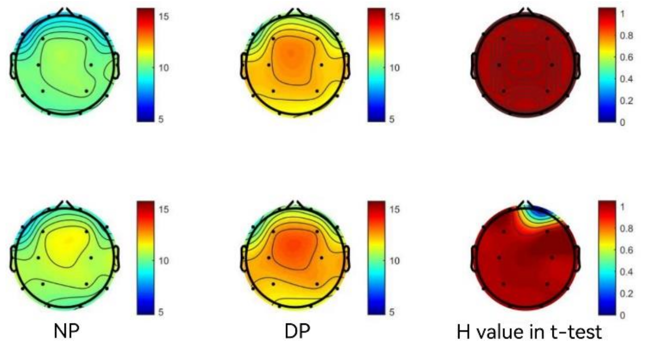

Fig. 3.8 Center of gravity frequency topographic map

Note: Bilateral T test (95% confidence interval) : 1(red)-significant difference (P <0.05).

Conclusion

This paper focuses on the application of Electroencephalogram (EEG) in the study of normal person and depression, analyzes and discusses the Electroencephalogram (EEG) signals of patients with depression, and tries to use machine learning method to study the relationship between normal person and depression, diagnosis of depression.

The EEG data of 100 patients with normal person and 100 patients with depression who were matched by age and sex in Huaxi mental health center were preprocessed, the important step is to detect and eliminate the artifacts of each segment manually based on independent component analysis (ICA) in order to get the pure EEG signal.

The EEG signals of normal person and depression were analyzed by frequency spectrum, and the relative power spectrum, relative power in frequency band and center of gravity power were calculated. The study confirmed that both groups of patients were able to achieve wave enhancement with their eyes closed and wave suppression with their Eyes Open. It also found that the band energy of normal person patients was higher than that of depression patients, and band energy was lower than that of depression patients, the frequencies of Barycenter in each channel were also lower than in the depression group, suggested that the depressions' emotional perception is weaker than normal.

In fact, some studies have found that the frequency of the center of gravity is associated with the level of brain fatigue, and the deeper the level of mental fatigue, the lower the frequency of the center of gravity. Other studies have used the relationship between the frequency of the center of gravity and the angle of convergence to measure the discomfort of watching 3D movies, the decrease in the frequency of the center of gravity reflects the fact that it may be more likely to be uncomfortable at this point, he said. Therefore, it is not difficult to find that the center of gravity frequency at a lower value often corresponds to a more negative, negative practical significance. Under normal conditions, the cerebral cortex is often in a state of excitement, EEG to high-frequency low-amplitude waves mainly, and when the brain appears some negative emotions or in a negative state, the cerebral cortex inhibited degree increased, low-frequency components will increase accordingly. According to the results of this study, the depression degree of cerebral cortex in normal person group was lower than that in depression group, and there were more serious negative emotions.

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