Effect of Chinese Zither Performance Training on Brain Function of Autistic Children

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Abstract: Based on the EEG signal analysis method of power spectrum and sample entropy, this paper analyzes the EEG signals of children with autism (ASD) after different cycles of training, and studies the effect of Chinese Zither performance training on the brain function of ASD children. Eight ASD children, with an average age of 13, were trained in zither performance for 4 months, and EEG signals were collected once a month. The results showed that the relative power of alpha frequency band increased after the training of Chinese Zither performance, and the occipital lobe was more obvious, and there was a gradual upward trend with the increase of training cycle; the relative power of theta band decreases, and the parietal lobe is more obvious, and has a gradual downward trend; the sample entropy is higher than that before training, showing a gradually increasing trend, and the complexity of the brain is also gradually increasing. It proves that Chinese Zither performance training has a positive impact on the brain function of ASD children, and Chinese Zither performance training may become a new direction of intervention and treatment of autism.

1 INTRODUCTION

Autism, also known as autism, that is, autism spectrum disorders (ASD), is characterized by social language disorder, rigid and strange behavior, accompanied by growth retardation, etc (Kocsis 2013). Generally, the symptoms of autism will show some characteristics in the early stage of children's development, about 3 years old(Hu 2021).The intelligence of autistic children is mostly lower than the normal level. At the same time, autism is usually accompanied by a series of health problems. Therefore, most patients with autism cannot live alone, which brings great pressure to the family. At present, there are more than 10 million people with autism in China, and the number is increasing year by year. Autism has gradually attracted extensive attention from the society.

Nowadays, although the research on autism is more and more in-depth, its etiology has not been found. Many studies on genetic inheritance show that autism may be a genetic comprehensive disease, but no authoritative person gives a clear conclusion. There is still no clear plan for the treatment of autism, so we can only carry out some nondestructive and harmless intervention treatment. Therefore, the in-depth study of autism still has a long way to go.

Music therapy combines many disciplines, integrates the knowledge and skills of psychology and pedagogy into music, and achieves the purpose of helping patients improve their cognitive ability, emotional state and psychological situation by means of music activities(Sun 2018). The developmental disorders of autistic children have strong specificity, and different patients have different manifestations. It is very difficult to select subjects in various studies, and music therapy is usually treated alone, so the number of subjects is small. The adaptive music training of Chinese Zither for autistic children conforms to the international advanced education concept of autism-cultivating one skill, making use of the low sensitivity of the sound of Chinese Zither

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instruments and the adaptive advantages of playing methods, and taking Chinese Zither music and its performance as the intervention medium to provide adaptive education and teaching theories and implementation strategies for autistic children. To improve the musical ability of autistic children, such as zither playing, Chinese Zither performance training involves multiple human sensory channels, which are completed by multiple regions of cerebral cortex(Huang 2019).These areas participate in performance in different forms. This multi regional cooperation can promote the network connection and all-round development of the brain, promote the changes of brain structure and function, and obtain the development of brain plasticity(Pu 2015). At the same time, Chinese Zither performance training will also promote the changes of other cognitive functions of individuals.

EEG signal is the best index to reflect the working state of human brain, because EEG collects the electrical signal sent by brain neurons. EEG is closely related to mental disorders. A large number of studies show that EEG has abnormal characteristics such as amplitude, power and left-right asymmetry for autistic patients, which are different from those of healthy people(Han 2018). With the continuous development of EEG signals and the achievements of mental disorders through EEG analysis, researchers believe that EEG contains useful information for the treatment of autism patients.

More and more studies have proved that there are some differences between EEG signals of ASD patients and normal EEG signals(Li 2021). At the same time, with the development of EEG analysis methods, it has a more solid theoretical basis for the analysis of EEG signals. It is more direct and effective to evaluate the effect of intervention treatment in ASD children based on EEG signals and evaluate their brain function from the perspective of brain cell electrophysiological activities.

In this study, Chinese Zither performance training is used to intervene autistic children, not only through auditory music perception, but also through the combination of hearing and movement. After long-term and systematic Chinese Zither performance training, autistic children can play complete music and even participate in Chinese Zither performance activities, so that they can experience the joy and sense of achievement brought by zither playing, build self-confidence, and better integrate into the school and society. At present, the evaluation methods of various intervention effects are mainly behavior observation, scale statistics, parent description and so on. By collecting EEG signals of autistic children and analyzing the characteristics of EEG signals from the perspective of frequency domain and nonlinearity based on power spectrum and sample entropy, this study can objectively reflect the impact of Chinese Zither performance training on the intervention effect of autistic children, and then make an objective judgment.

2 METHOD

2.1 Chinese Zither Performance Training

Chinese Zither is one of the unique and important national musical instruments in China. It has beautiful timbre, wide range, rich playing skills and strong expressiveness (Li 2020). Chinese Zither training is a complex task, including long-term, large and diverse skill training. In the field of hearing, ASD children must learn to focus on distinguishing subtle differences in pitch, rhythm, volume and timbre, and learn to distinguish and remember complex auditory patterns. In the field of sports, they must learn how to control their arms, hands and fingers. They must also integrate auditory and motor functions to control different motor responses. When playing Chinese Zither, players need to develop asymmetric manual dexterity, pluck the string with the right hand, play the melody and master the rhythm, and the left hand conforms to the tension of the string and controls the changes of the string sound, so as to adjust the pitch and improve the melody (Wu 2020). Through such a complex audio motion conversion, EEG signals have obvious characteristics in the process of performing this conversion.

2.2 Power Spectrum

In the frequency domain analysis method of EEG signals, parameters such as power spectral density and relative power need to be calculated on the basis of power spectral quantification (Cheng 2021). When an abnormal change occurs in a certain part of the brain, the trend of EEG will change, and its power spectrum will change accordingly. The power spectrum calculation of EEG signal overcomes the subjectivity of traditional naked eye observation of EEG signal waveform, so that the physiological information contained in the waveform can be transmitted with quantitative numbers, and the accuracy of EEG in disease diagnosis has been improved (Li 2020). The power spectrum can be

obtained by integrating the power spectral density in the frequency domain.The nonparametric estimation method of Fourier transform is selected to calculate the power spectral density function and estimate the spectrum of time series. The specific steps are as follows:

The random function x(n) is known, the autocorrelation function r(k) is estimated, and the power spectral density function is obtained by Fourier transform of r(k), which is recorded as P(ω), as shown in formula (1).

$$P(\omega)=\sum_{k=-\infty}^{+\infty} r(k)e^{-j\omega k} \tag{1}$$

The classical method is the periodic graph method for nonparametric spectrum estimation. When the time series is of finite length, the expectation and limit values are ignored to obtain the periodic spectrum estimation, as shown in formula (2).

$$\hat{P}(\omega)=\frac{1}{N}\left|\sum_{n=1}^{N} x(n)e^{-j\omega k}\right|^2 \tag{2}$$

Welch is improved on the basis of: segment the data to make them overlap each other; use a variety of window functions to add windows. Divide the data into k segments, each segment is marked as x(n), and the length is L. The signals of two adjacent segments overlap each other. Calculate the power spectral density of each segment and average it, as shown in formula (3).

$$P(f)=\frac{1}{K}\sum_{i=1}^{K}\frac{1}{LU}\left|\sum_{n=0}^{L-1} X_{i(n)}d(n)e^{-i2nfn}\right| \tag{3}$$

Where U is the normalization factor, ω(n) is window function. Hamming window function is selected in this study. The calculated results of each section of data are superimposed and averaged, and the power spectral density is the mean.

The absolute power can be calculated by dividing the EEG activity of a single frequency band by the average power of each frequency band. The average power can be calculated from the power spectral density of each channel. The absolute power is easily affected by individual differences and has errors, that is, the absolute value of the power spectrum has errors, which affects the objectivity of the final data conclusion. Therefore, in order to avoid random errors, this paper selects the feature of relative power. The relative power calculation method is: the energy ratio of each frequency band to the whole frequency band.

2.3 Sample Entropy

Entropy originates from the physical concept and is a measure of the uncertainty of random variables. The greater the probability of generating a new model, the more complex the sequence, and the greater the value of entropy, which can directly reflect the complexity of the sample system (Zhao 2019). At the same time, it can also reflect the distribution of energy in space. The more chaotic and uneven the energy distribution is, the smaller the entropy is; the more uniform the energy distribution, the entropy tends to the maximum. Sample entropy (SampEn) algorithm is simple, does not compare with itself, has good relative consistency, and is more conducive to predicting the probability of new information (Wang 2013). Construct an m-dimensional vector for a given time series, as shown in formula (4).

$$\begin{aligned} &x_i=\left[x_i,x_{i+1},\ldots,x_{i+m-1}\right],\\ &i=1,2,3,\ldots,N-m+1 \end{aligned} \tag{4}$$

Define the maximum distance between two vector elements as d, as shown in formula (5).

$$\begin{aligned} &\left[x_i,x_j\right]=\max\left[\left|x_{i+k}-x_{j+k}\right|\right],\ j\neq i,\\ &k=0,1,2,\ldots,m-1,\ j=1,2,\ldots,N-m+1 \end{aligned} \tag{5}$$

Define the threshold r, count the number n less than the threshold r, calculate the ratio of n to the total number, and record it as C, as shown in formula (6).

$$\begin{aligned} &C_i^m(r)=\left\{\frac{n}{N-m+1}\right\},\\ &i=1,2,3,\ldots,N-m+1 \end{aligned} \tag{6}$$

Find the average value, as shown in formula (7).

$$P(\omega)=\sum_{k=-\infty}^{+\infty} r(k)e^{-j\omega k} \tag{7}$$

Add 1 to the above dimension to make it a vector of m+1 dimension, and repeat the above steps(Song 2016). Based on the above, the sample entropy is defined, as shown in formula (8).

$$SampEn(m,r,N)=-\ln\frac{C^{m+1}(r)}{C^m(r)} \tag{8}$$

Where m is the embedding dimension and r is the threshold.

3 EEG SIGNAL ACQUISITION AND PREPROCESSING

3.1 Research Object

In this study, 8 ASD children were selected as subjects, with an average age of 13 years, no history of brain injury, no history of epilepsy and no implants in the body. All of them were diagnosed as autistic children by the diagnostic certificate issued by the municipal third class hospital. All parents who participated in this study fully understood the experimental process and signed the consent form. All 8 ASD children received Chinese Zither learning for a year or so, which had a certain foundation. Due to COVID-19, the Chinese Zither performance training lasted for at least 8 months.

When selecting the tested children, the non probability sampling method of judgment sampling is used to select the relatively homogeneous and representative children from the collected autistic children as the research object, so as to realize the research purpose of understanding the whole from part. After the actual sampling, the sample quality shall be evaluated, and the sample quality, representativeness and deviation shall be preliminarily tested and measured to prevent the experimental results from being affected by the excessive deviation of the sample.

3.2 Experimental Design and EEG Acquisition

The selected 8 ASD children were taught Chinese Zither adaptive music instruction for four months, fixed for half an hour a week, and taught one-on-one by professional Chinese Zither teachers. From the first acquisition of EEG signals, EEG signals are collected once a month as a training cycle. In each acquisition process, EEG signals in resting state before Chinese Zither performance training and in resting state after Chinese Zither performance training are collected for 30s, the flow chart is shown in Figure 1.

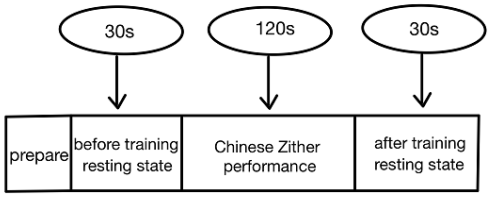

Figure 1: Schematic diagram of EEG signal acquisition process.

EEG signal acquisition uses g.Nautilus high-precision wireless bioelectric signal acquisition and analysis system. The motor is placed in the 10/20 system according to the international standard, and the FPZ(Gun) electrode is used as the reference electrode. The specific location distribution is shown in Figure 2. Set the impedance value of each electrode less than 50 KΩ, the reference electrode less than 10 KΩ, 24bit (1.024mhz internal sampling per channel), and the sampling rate is 500Hz.

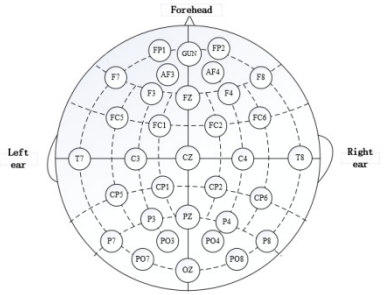

Figure 2: EEG electrode diagram.

3.3 Research Object

16 channels were selected from all 32 channels, which were located in 4 brain regions: frontal lobe (AF3, AF4, F3, F4), parietal lobe (C3, C4, CP1, CP2), temporal lobe (FC5, FC6, T7, T8) and occipital lobe (PO3, PO4, PO7, PO8). Remove artifacts such as eye movement, electromyography, ECG, baseline drift and outliers, filter 50Hz power frequency interference, and carry out band-pass filtering of 0.5 ~ 45.0 Hz.

4 RESULTS AND AANALYSIS

4.1 Based on Power Spectrum Analysis

The collected EEG signals are decomposed to obtain four frequency bands. The energy ratio of each frequency band to the whole frequency band is calculated to obtain the relative power of each frequency band. Previous studies have confirmed that the alpha band power spectrum energy of ASD children in resting state is lower than that of normal group, and the theta band power spectrum energy is significantly higher than that of normal children. This study focuses on the analysis of the relative power of alpha and theta frequency bands, occipital alpha frequency band and parietal theta frequency band in ASD children.

In this study, the relative power of 16 channels of all 8 subjects was averaged to obtain the relative power of alpha and theta frequency bands of all subjects, and the relative power of alpha frequency band of occipital lobe and theta frequency band of parietal lobe were analyzed. The changes of relative power of each brain region in alpha band before training and at rest after each training cycle are shown in Figure 3 and Figure 4, and the relative power of theta band is shown in Figure 5 and Figure 6.

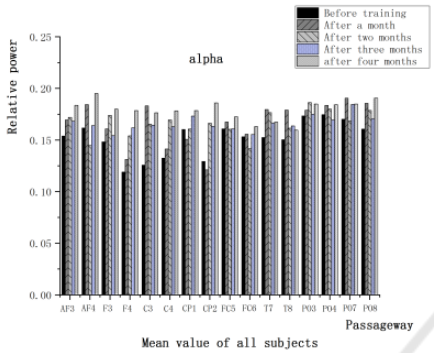

Figure 3:Relative power of all subjects before alpha band training and after each training cycle.

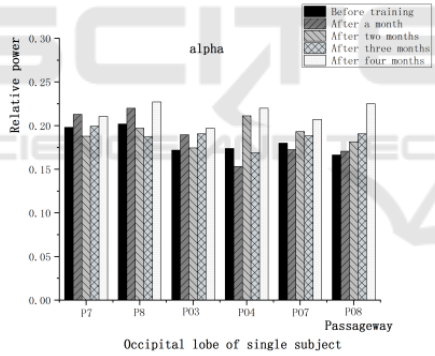

Figure 4: Relative power of single subject before training and after each training cycle in alpha band of occipital lobe.

As shown in Figure 3 and figure 4, in the alpha band, the average relative power of all subjects and the relative power of a single subject are compared and analyzed. Compared with the EEG signals collected before and after Chinese Zither performance training, the relative power of the four brain regions in the resting state increases to varying degrees, especially in the occipital lobe, the relative power of individual channels increases gradually with the increase of training time.

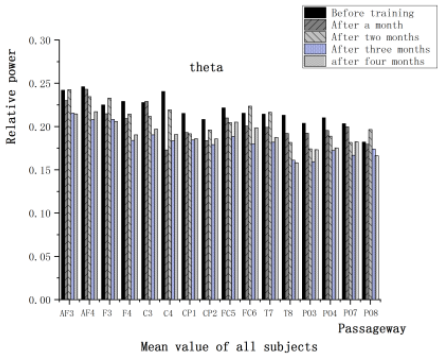

Figure 5: Relative power of all subjects before theta band training and after each training cycle.

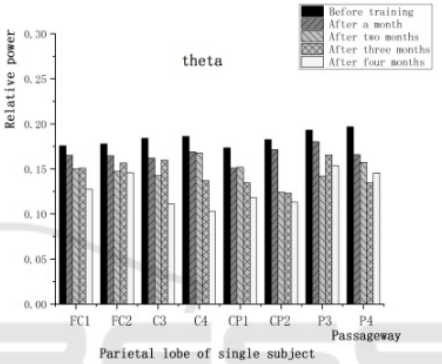

Figure 6: Relative power of single subject before training and after each training cycle in theta band of parietal lobe.

As shown in Figure 5 and figure 6, in theta band, the relative power of most channels of EEG signals in resting state after Chinese Zither performance training is lower than that before training, the parietal effect is significant, and individual channels show a decreasing trend with the increase of training time.

4.2 Based on Sample Entropy Analysis

Sample entropy mainly reflects the chaotic degree of the sequence. The greater the chaotic degree, the greater the entropy and the higher the complexity; on the contrary, the smaller the entropy, the more regular the sequence, and the lower the generation rate of new mode signals (Wu 2020). Previous studies have confirmed that the sample entropy of EEG signals in autism is significantly lower than that in healthy people, and the entropy parameter can be used as a parameter to analyze the brain function of autism. In this study, the EEG signals of four brain regions of 8 children were analyzed based on sample entropy. The sample entropy analysis results are shown in Figure 7.

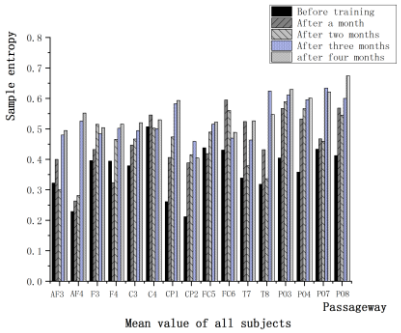

Figure 7: Results of Sample Entropy Analysis.

According to figure 7, the sample entropy of the four brain regions of ASD children after Chinese Zither performance training increased in varying degrees, and some channels showed a gradual upward trend with the increase of training cycle, while others fluctuated in varying degrees, but showed an overall upward trend.

5 CONCLUSIONS

For a long time, because the etiology of autism is not clear, most of the treatment methods are non-invasive intervention. In recent years, music therapy has been accepted by more and more patients and their families. Based on the power spectrum and sample entropy, this paper analyzes the resting EEG signals of ASD children after different cycles of training, and obtains the following conclusions.

1. The analysis results based on power spectrum show that although the relative power of alpha band of ASD children in resting state fluctuates after receiving zither performance training, it generally shows an upward trend, and some channels gradually increase with the increase of training cycle, especially in occipital lobe. The relative power of theta band decreases, and some channels have a gradual downward trend, especially in the top lobe. This proves that Chinese Zither performance training has a positive intervention effect on ASD children from the perspective of EEG frequency domain.

2. The analysis results based on sample entropy show that after Chinese Zither performance training, the sample entropy of ASD children in resting state is higher than that before training. Although there are fluctuations in individual channels, with the increase of training time, the sample entropy generally shows a gradually increasing trend, and its complexity also gradually increases. This proves that Chinese Zither performance training plays a positive role in improving the complexity of ASD children's brain from the perspective of nonlinearity.

3. Chinese Zither performance training is not only to let the ASD children who receive training feel music passively, but to play actively, even play. The analysis results of EEG signals show that Chinese Zither performance training can improve the brain function of the tested children to a certain extent, which has a positive impact. Therefore, Chinese Zither performance training can provide a new direction for the intervention of autism.

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