The Baroque Music's Influence on Learning Efficiency Based on the Research of Brain Cognition

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Abstract— To let the brain be in the best condition for learning is the task faced to teachers for improving the students' abilities of memory, attention, thinking and so on, which is also a work of great significance for improving the teaching quality. This article discusses the influence of the Baroque music on learning state from the perspective of electroencephalogram analysis. First electroencephalogram (EEG) data of the n-back experiments are collected before and after listening to the Baroque music. Then its frequency, the energy, α wave distribution, scalp, event related potential and other components are compared. Specially, the brain's memory and attention are analyzed and estimated by extracting useful EEG information in time-domain, frequency-domain and spatial distribution. The experimental results show that Baroque music has a positive influence on improving learning efficiency. So that teachers can use Baroque music to assist teaching as reform means, which will provide an effective way to improve the learning efficiency and teaching quality.

1. INTRODUCTION

Brain is the organ of learning. Human intelligence activities are closely related to the states of human brain. Only by following the brain activity patterns, the learning efficiency could be promoted and the brain function could be further developed. In recent years, by the technologies such as EEG and fMRI, the brain's memory, thinking, learning, emotional and other advanced features are in-depth studied, which confirms that the brain science is bound up with education and has important guiding value to educational practice. The research on brain science is widely used in the field of education, as the important basis of reforming the traditional teaching methods. Therefore, the rational use of the human brain cognitive rules can help improve students' learning efficiency. For the past few years, the research on close integration of brain science and education has been carried out and become a hot spot. The scientists of many countries are researching it.

In this paper, by using high-resolution 64-channel EEG technology, the EEG data extracted before and after the n-back experiments are analyzed to explore the impact of the Baroque music on learning efficiency.

2. EFFECT OF SOUND WAVES ON THE BRAIN

Music is also an acoustic wave, any sonic vibrations stimulate the auditory systemby the process of converting from mechanical energy of sound source vibrations to neural signals, chemical signals, electrical signals. These signals, interact with each other to form auditory perception, along the neural pathway: the brainstem, the hypothalamus and the brain cortex. For example, musical instruments produce sound. This mechanical energy can cause vibrations in the cochlea, then the hair cells arranged on the base film are stimulated to produce receptor potential, projecting to the neurons nucleus through the auditory nerve fibers. However, we just hear the sound, not knowing what kind of instrument sounds. It needs for various types of cells in the nucleus to make judgments by sound frequency, intensity, and other features. Because there is a gap between the cells, there is no direct electrical coupling, nerve signals can not pass. Fortunately, there is a specific communication joint between neurons, called synapses. Presynaptic neurons by releasing a neurotransmitter convert chemical signals to electrical signals, and then the neurotransmitter carrying music information act on the postsynaptic membrane, then the chemical signals into electrical signals. The music propagation in the auditory system is realized.

There are dozens of brain neurotransmitters, each of which has a special physiological function. By changing the function of neurons, bringing the biological functional effects can produce an effect on mental activity, emotional reactions, learning and memory, and so on. The vibration in different parts of the base film is caused by acoustic wave of different frequencies. Bioelectrical activity of auditory nerve fibers, on behalf of acoustic wave of different frequencies, likes tides ups and downs, forms brain waves. Low frequency components of the brain waves are related to the activities of neurotransmitters. Various neurotransmitters have their unique ultra-slow-wave frequencies. The amplitude variation of brain waves corresponds with the strength of the neurotransmitter. That is, the frequency stimulation of the acoustic wave changes the original EEG rhythm. So music stimulation is changing the brain wave rhythm, while also changing the brain physiological functions.

Baroque music in line with 50 to 70 beats/minute is ideal for rapid enhancing learning efficiency. "Baroque" came from the Portuguese barroco, meaning less rounded pearls. Baroque music is the music generated within the period of 1600–1750. Its effect on learning efficiency is mainly reflected in the impact on the brain α-wave. For a more precise understanding of the effect of Baroque music on learning efficiency, we designed the n-back experiment to test memory. The subjects' EEG data are obtained before and after the music during the experiments. Then the effects of Baroque music on wave frequency, amplitude, and energy distribution are detailed analyzed. Thereby the stimulation of Baroque music on memory and attention during the learning process is clarified.

3. ANALYSIS OF EEG-BASED LEARNING EFFICIENCY

How to determine whether the student's learning state is optimum or not? There are many ways in which EEG is an effective method of analysis. EEG is the most commonly used and most objective physical signs of studying of the human brain. When the person's attention, memory, etc. change, EEG signal recorded will change accordingly. Thus, the degree of students' memory or attention can be estimated by recording and analyzing their EEG signals. This is an effective method to determine whether the brain is in the best learning state or not. The human brain is a very complex nonlinear dynamic systems. EEG is the weak potential difference measured from the scalp, when a considerable number of neurons in the brain neural network are discharging synchronously. Now many laboratory instruments can be used to detect the potential difference, then electroencephalogram can be obtained. In this article, the brain's memory and attention are analyzed and estimated by extracting useful EEG information from the time domain, frequency domain and the spatial distribution.

Time domain information is usually composed of a number of event-related potentials (ERP) composition. ERP is referred to the bio-electric response detected in the corresponding parts of the brain, which is generated with a relatively fixed time interval and the specific phase from the stimulation, when a particular part of the nervous system is given corresponding stimulation. ERP reflects activities of neurons in brain. In all ERP components, P300 is the most classic, first discovered and most extensively studied one. P300 is the positive peak of brain waves around 300 ms after stimulation, which is induced by the endogenous event. The waveform is most obvious near the midline of the parietal lobe, mainly reflecting the brain's cognitive processes to external information. The frequency domain information is the use of power spectrum analysis, obtained the frequency variation of brain waves associated with brain activities. When a person's state of consciousness varies, the frequency of the brainwave is different. According to the frequency from low to high, the brain waves can be divided into δ waves (0.5–4 Hz), θ waves (4–8 Hz), α wave (8–13 Hz), β wave (13–25 Hz), γ wave (> 25 Hz). If the dominant brainwave is α wave, the person could have the feeling of comfort and concentration, achieve extraordinary memory, highly focused and unusual creativity. In particular, high-amplitude α waves can lead to high learning efficiency. Spatial information is focused on the spatial distribution of the EEG signals on surface of the scalp. By recording the EEG signals, we can analyze the activities of different brain regions. This spatial distribution of EEG can also be used as the characteristic information to analyze brain activities.

4. EXPERIMENTS AND DATA ACQUISITION

4.1. *n*-back experiments

The tasks of n-back experiments are a series of continuous implementation, which are widely used to stimulate the brain activities in nerve imaging experiments. It is proposed by Wayne Kirchner in 1958. n-back task is a series of stimulus, the paradigm requires subjects to response when the current stimulus matches the one appeared n times before. Load factor n may be adjusted to vary the difficulty of the task. When $n = 1$, the subjects were asked to compare the current stimulus with the stimulus immediately preceding it; when $n = 2$, then compare the current one with the one two times before; when $n = 3$, compare the current one with the one three times before, and so on, with changing the difficulty of the task.

The position matching task is programmed by using E-prime software. displayed on a computer screen in different positions on white background. The black "+" sign of different position is displayed with white background on the computer screen, the position of "+" sign is random for subjects. each "+" sign appears for a second. The subjects are asked to remember its position and make the appropriate choice by entering the judgment of their vertical position through the computer keyboard. Because the 3-back task is too difficult, this experiment is reduced to 1-back task and 2-back task. When $n = 1$, the subjects are asked to compare the relative vertical position of the current "+" sign and the one previous it, and then press the appropriate key. There are forty "+" signs in all in 1-back task. When $n = 2$, it need to compare the relative vertical position of current "+" sign and the interval one preceding it. There are forty "+" signs in 2-back task too. Two parts are proceeding continuously. They will be carried out before and after Baroque music, which last three to four minutes.

4.2. Experimental Process and EEG Acquisition

In the trials, EEG data of the subjects are collected by NeuroScan's EEG/ERP recorder and the corresponding acquisition system. 20 healthy undergraduate and graduate students as subjects participate voluntarily in the experiment. For the one-dimensional spatial position of visual stimulus ("+" sign), the subjects perform on the memory, judgment and choice. During the experiments, the subjects' EEG data are collected before and after Baroque music. Then the data are comparatively analyzed to study whether Baroque music can affect the improvement of the learning efficiency on some appropriate variables. In the experiment, Vivaldi's "Four Seasons" is used as Baroque music. First, n-back experiment is carried out before the music. Next, subjects listen to the Baroque music, which lasts 30 minutes. And then, n-back experiment is carried out again after the music for the same subjects. EEG data are collected during the experiments.

5. EXPERIMENTS AND DATA ACQUISITION

5.1. Data Processing Method

The reaction time and the correct rate about the location matching task are recorded by E-prime software in the experiment. These can be used as basis of assessing the impact of Baroque music on the learning efficiency.

In the analysis of EEG data, you must preprocess the data firstly. By using Curry 7 software, the collected raw EEG data are preprocessed. It includes filtering, baseline correction, the DC drift premovement, bad channel re-movement, EOG interference exclusion, down sampling, etc.. Since four basic brainwaves frequency ranges from 0.5 to 30 Hz approximately, and δ wave in our research is not considered, so the brain wave information is left only from 1 to 30 Hz by band pass filtering. The EEG data above 30 Hz and below 1 Hz are removed. By comparing the VEO (EOG) waveforms, EOG interference is excluded. The filter range is plus or minus 200 microvolts. While ensuring appropriate data details, the data file is compressed. It can reduce the computer's running burden in the subsequent operation, speed up the data processing and save the storage space.

Analyzed data is from 0 ms to 2000 ms when stimulus appears. After removing artifacts such as unreliable data, ensure that in each test mode, the data superposition averaging are more than 30 segments. Then observe the amplitude of ERP waveform and contrast of energy distribution, especially P300 component, which reflects the brain's cognitive processes to external information.

By the power spectrum analysis, different waves' energy and the distribution of various brain regions are extracted. The excitation of Baroque music is investigated on the α wave.

5.2. Results Discussion

The experimental data are obtained through averaging. The experimental results are shown in Table 1. It can be seen, in both the 1-back and 2-back experiments, the reaction times are decreased after Baroque music. The accuracy of the two tasks are both improved. While the increase of accuracy is not obvious, but the reaction time is shortened more obviously in 2-back compared with the 1-back. It is thus clear that, when task difficulty or memory load increases, the Baroque music is more effective for improving the memory.

Figure 1 shows the power spectral distribution of all channels before and after music. The left is the data before music, right for after the music. We can see after the music. There is an evident energy fluctuation on the rise within α wave band (about 10 Hz). It indicates that α brain waves are excited evidently after stimulation of Baroque music for 30 minutes. So the Baroque music is verified having an effect on stimulating α brain waves.

The two diagrams of Figure 2 show the Event-Related Potentials (ERP) of all channels before and after music. All the data segments (trails) are superimposed on the average in the experiments. After the music, there is an evident P300 waveform close to 239 ms latency. Obviously, by contrast

Table 1: Parameters of analytical pdfs fitted to the empirical data.

average		Reaction time	accuracy
1-back task	**Before music**	594.22 ms	90.10%
	After music	513.61 ms	92.70%
2-back task	**Before music**	928.36 ms	72.30%
	After music	752.57 ms	86.70%

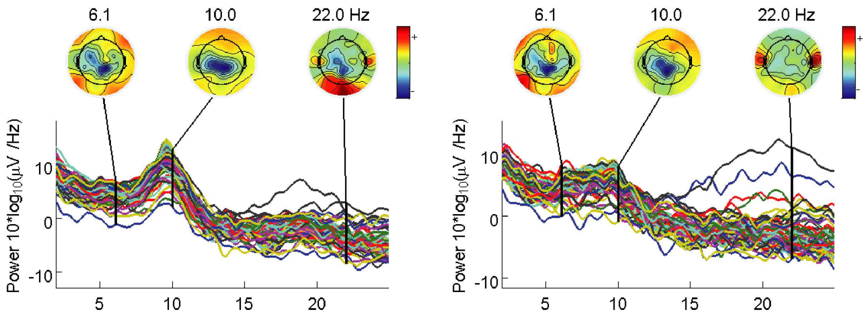

Figure 1: The power spectrum distribution before and after Baroque music.

of EEG data, the amplitude of P300 component has been greatly improved after music. The P300 has great relationship with human activities of identification, discovery, perception and memory. The increase of P300 amplitude, just from the microscopic point of view, verify that Baroque music has positive influence on improving memory and attention.

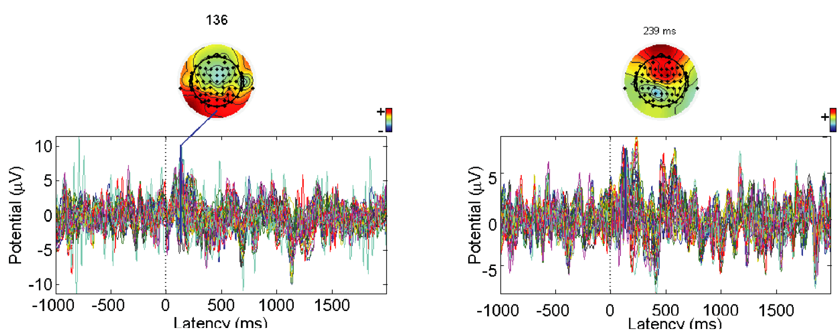

Figure 2: The event-related potentials (ERP) of all channels before and after Baroque music.

In addition, to verify the stimulation effect of Baroque music on α brain waves, the subjects are instructed to do deep breathing exercises with background music — 'The Four Seasons' by Antonio Vivaldi. Within 25 minutes, from drowsy to awake, the changes in the power spectrum of the subjects' alpha brainwave ($8 \sim 13$ Hz) were extracted. Figure 3 shows the changes in the power spectrum of EEG at 10 Hz. It can be seen that the power spectral density of EEG at 10 Hz ascends gradually as the level of vigilance changes. The power spectral density at other frequencies in α band has similar variation. However, it is most obvious around 10 Hz. As time goes on, with

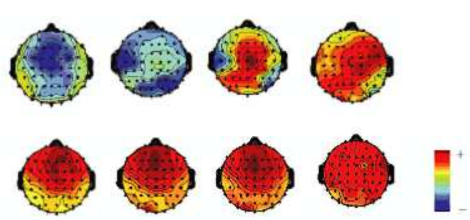

Figure 3: The average energy variations of EEG at around 10Hz. Each sub graph represents.

the stimulation of Baroque music, the power spectral density of α wave changes significantly in 20 minutes. Alpha brainwave gradually became dominant, proving that the subjects have been into the state of relaxed alertness from being sleepy. This experiment has verified the effect of musical stimulation on α wave. the EEG power distribution on the strength at a certain moment.

6. CONCLUSION

This paper explores the optimum learning state from the perspective of brain cognition and EEG-based analysis method is proposed from time domain, frequency domain, spatial distribution. N-back experiments are designed to study the subjects' attention and memory. The results show that Baroque music is beneficial to enhance learning efficiency. It can quickly and effectively stimulate α brain waves, increase the amplitude of ERP, shorten the reaction time, improve the response accuracy, and improve the memory and attention of brains. Baroque music can really make a person to be in a balanced, stable, calm state of mind, and improve their learning efficiency. Therefore, teachers can use Baroque music as teaching reform methods to assist instruction and enhance the students' learning effects. With the deepening of research on the brain's learning mechanisms, our understanding of the teaching process is constantly changing. Brain science's contribution continues to increase its impact on education, which will provide the correct and effective way to improve the quality of teaching.

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