Visualization of Abstract Audio-visual Information: An Analysis of Art Cognitive Activity Based on Electroencephalogram

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ABSTRACT

Common short signals and special graphic signals are taken as targets to measure changes in the waveforms related to brain's events of artists so as to explore the reasons why artists can create high-quality works from the perspective of electroencephalogram (EEG). It is found that the occurrence of brain wave peaks in ordinary human brains delays and the wave amplitude reduces; under the stimulation of common signal, the occurrence of brain wave peaks in artist's brains delays and the wave amplitude reduces. However, after taking appropriate amount of alcohol, the brain wave peak time delays, the wave amplitude rises and area of the waveform increases under the stimulation of the graphic signals that they are interested in. The phenomenon of artists' high creativity often lies in some biographical literary works or historical materials, but few people analyze their principles from a scientific perspective. The author analyzes people's thinking process from the perspective of thinking signal formation and information processing operation, as well as uses EEG measurement method to study the reasons why artists create high-quality works.

Key Words: Audio-visual Information, Visualization, EEG, Art Cognitive Activity

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Introduction

Music and brain wave are two similar signals in form, and both are the result of functional activities of the brain, so both must follow certain specific scientific laws. Music melody is a combination of tune, rhythm, strength, timbre, and performance style and other basic elements that can reflect the main content or all thoughts of music according to a certain music mode, which sometimes refer to as "music" in this paper (De Venuto *et al*., 2016). To explore the scientific relationship between music melody and brain wave signals, the influence of music melody in a specific form on the active state of brain and signal characteristics can be interpreted by studying brain wave signals stimulated by music. This becomes an effective means to explore brain perception and processing music information capabilities, which is of great scientific significance to psychology, clinical medicine, and neurobiology (Jiao *et al*., 2018). With the leap of science and technology and the flourishing of new ideas and methods, the brain has been unveiled mysterious veil (Liu *et al*., 2014). With the help of large amounts of neurological and neurosurgical researches, Luria proposed the concept of three function units that work together. According to his opinions, people's psychological activities are complex function systems which are not located in the narrow and localized areas of the brain, but are realized with the participation of three function units (Baek *et al*., 2012).

The three basic function units are: the unit that regulates tension and wakefulness; the unit that accepts, processes, and saves external

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information; and the unit that develops procedures, regulates, and controls mental activities. The central system is a self-regulating system. As for bioelectricity, it appears as rhythmic potential fluctuations without any stimulation. This EEG model is called spontaneous EEG. In the 1960s and 1970s, people had a deeper understanding of spontaneous EEG. There are four rhythms in the brain wave: δ(0.5-3HZ), θ(4-7HZ), α(8-12HZ), and β (13-30HZ). What kind of rhythm will appear depends on factors such as age, state of excitement, and part of guidance.

By organizing the tune and rhythm with different instruments, different music melody can express the rich music thoughts and emotions through different strength (Koike *et al.*, 2011). Human's emotions are easily affected by external environmental factors. Music melody played by the instrument can directly stimulate human's cerebral cortex through auditory sense, allowing people to actively or passively accept the thoughts and emotions or certain feelings expressed in the music. At this time, changes in electrical activity in the cerebral cortex can be demonstrated by means of EEG (Edelman *et al*., 2016). The research idea in this paper is: changes in the electrical activity of the cerebral cortex are induced by different music melody forms (rhythm, tune, timbre, and strength). The electrical activity of the cerebral cortex appears as differences of EEG. (DelPozo-Banos *et al*., 2015).

The basic theory of EEG and the relationship between audiovisual information and EEG

Characteristics and classification of EEG

The bioelectrical activity of the cerebral cortex is divided into two types, namely evoked potential (EP) and spontaneous potential (SP). EP is a bioelectrical activity generated in the cerebral cortex under external or internal stimuli, reflecting changes in the electrical activity of the central nervous system in specific functional states. At present, the main clinical EPs include visual EP, auditory EP and somatosensory EP. SP reflects the electrical activity of the cerebral cortex without external stimuli. The clinical EEG examination is obtained by enlarging the recording of the spontaneous biopotential of the scalp through an electroencephalograph. EEG signal is a strong rhythmic continuous bioelectrical signal. The characteristics of various brain waves are shown in Table 1.

The waveform of brain waves varies with people's mental states and physiological conditions. Normally, when the excitement is increased, the EEG changes from slow wave to fast wave, and its amplitude changes from high to low; on the contrary, when the fast wave changes into slow wave, the amplitude changes from low to high, when it is the Inhibition strengthening process.

Table 1. EEG wave characteristics

	Frequency	Magnitude	Status
α wave	8-13Hz	20-100μV	Clear, quiet, closed eyes
β wave	14-30Hz	50-20μV	Excited
Θ wave	4-7Hz	10-50μV	Drowsiness, sleep, lack of oxygen, depth
δ wave	1-3.5Hz	20-200μV	Anesthetic or cerebral organic disease

The relationship between audio-visual information and EEG

Music directly stimulates the cranial nerves through human's auditory sense and stimulates the simultaneous discharge and simultaneous termination of the brain's nerve cells in the same phase, and then the brain wave, namely EEG, is recorded. The "Mozart Effect" means that listening to Mozart's music can improve related behavioral abilities or change neurophysiological activities. Researchers have repeatedly proved the "Mozart Effect" through experiments and finally established the relationship between music and spatial dialectical abilities. JohnHughes, a Neurology expert specializing in studying epilepsy in University of Illinois, used Mozart's "Sonata for Two Pianos in D Major" and other musicians' classical music as music materials to do experiments on his patients. The result showed that only Mozart's music had a clear and sustained effect on patients (Adamos *et al.*, 2016). Hughes believed that the key to significant result may lie in repetition mode of Mozart's music. Hughes mentioned that Mozart's music structure was relatively simple, and many of his music always repeated a certain melody, and it was precisely this model that was consistent with the preferences of our brain's operation. Through repeated comparison, researchers find that Mozart's music organization is high and his music mode repeats by about 20-30 seconds, and the repetition rate of melody with note length of 4-80 is the highest, which is similar to the duration of the brain waves and is also consistent with the length of partial activities of the central nervous system. This may be the secret of Mozart's music that brings unbelievable results to people.

Researches of the Max Planck Center for Human Cognition and Brain Sciences point out the richness of music activities determines that music is one of the most ideal tools for studying the brain's functions (Mihajlović *et al.,* 2015). The above researches show that the human brain has cognitive competence for music melodyand different forms of music have different effects on the brain. This conclusion can be proved by EEG in addition to human subjective feelings.

Principle and measurement of human brain's problem solving

The human brain's problem-solving process is actually the use process of brain energy. Each problem has a certain degree of difficulty and also corresponds to a certain amount of energy requirements. If the effective intelligence level applied to the problem exceeds the difficulty of the problem, the problem will be solved; otherwise, the problem cannot be solved. Thus, measuring the operating state of brain energy can measure the corresponding ability level at that time.

Assume that the main working area of the brain is S when thinking about a problem, and the boundaries of the area are (X1, X2), (Y1, Y2), and (Z1, Z2). The time interval used for thinking is (T1, T2), then the energy for thinking about the problem is

$$E = \int_{T_1}^{T_2} \int_{Z_1}^{Z_2} \int_{Y_1}^{Y_2} \int_{X_1}^{X_2} X\left(x, y, z, t\right) dxdydzdt \qquad (1)$$

Theoretically, this algorithm can calculate the energy used in the process of thinking, but the model established by this theory has a certain error in measurement because the thinking process itself is not a continuous process of thinking energy of the brain but a combo of multiple thinking pulses that are superimposed (Punsawad *et al.*, 2014). That the energy of the thinking process is calculated by the method of superimposition of energy corresponding to multiple pulses can reduce error and will be closer to the actual situation. The calculation process is

$$E = \sum E_i$$

$$E_t = \int_{t_1}^{t_2} f\left(t\right) dt \qquad (2)$$

Where, E is the total energy of the thinking process, Ei is the energy of the i-th thinking pulse, ti1 is the start time of the i-th pulse, and ti2 is the end time of the pulse.

Transmission process of thinking pulse

External stimulus signals are constantly transmitted to the human brain through sensory organs in various parts of the body, leading to changes which can be reflected by EEG and MEG in the bioelectricity and biological magnetic field in the corresponding areas of the brain. However, not all electromagnetic changes in the brain can be realized by people, and only strong changes caused by strong stimulus can be felt by people. The thinking process is mainly the transmission and amplification process of electrical signals. Its principle is similar to amplification circuits of audio/video signals. The schematic diagram of the thinking pulse from its formation to its operation is shown in Figure 1.

The stimuli-evoked electromagnetic signals are divided into two ways in the brain: on way runs outside the consciousness directly to the problem; another way of strong signal goes into the post stage for amplification through the pre-stage amplitude starting device, and then outputs to the brain display area so that people get a clear impression and think differently. The function of the starting device is to block weak signals by strong signals to ensure that subjective thinking is not interfered by too much information. The signals that automatically operate outside the consciousness will trigger the sub-starting circuit and enter the display and thinking system after they have accumulated for a period of time to reach sufficient intensity. After active thinking, part of the output signals are divided into two ways in turn: one way is input to the terminal of the signal amplifier circuit to control the energy input to active thinking about the problem; the other way of signals are transmitted to the front end to control the energy input for the problem running outside of consciousness. The entire process forms a two-stage feedback loop.

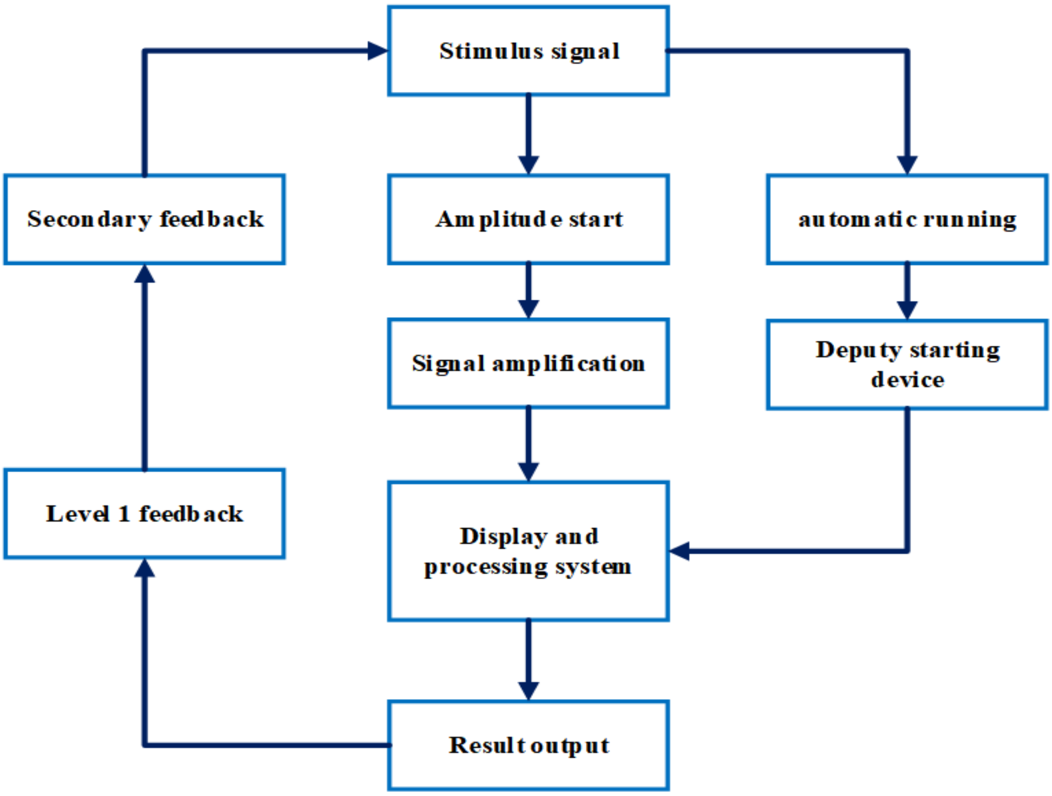

Figure 1. Schematic diagram of thinking

Measurement of thinking energy

It is difficult to accurately measure the energy in the entire thinking process with the existing equipment for the complexity of thinking energy while the measurement accuracy is relatively high to measure the individual's thinking energy invested in the same problem under different conditions. The thinking pulse is a process amount. The event-related potential that is most closely related to time can be used to measure the EEG wave form of an individual under different conditions. In this way, the amount of thinking energy under different conditions can be compared.

Because the time of the stimulus signal in this kind of experiment is short before people's consciousness which is seldom affected by subjective consciousness, the result is of good reference value. The electrode cap is used to record 64 EEGs, and the resistance of scalp is less than 5 5kΨ. 12 ordinary people and 12 artists whose age span ranges from 22 to 55 are chosen as experimental subjects. Artists are engaged in composition, lyrics, calligraphy, painting, and poetry creation. The geometric pattern is used as the non-target stimulus and the short tone is taken as the target stimulus, and the ratio of non-target stimulus and target stimulus is 90%:10%.

Experimental analysis

Results and statistics of music's impact on center of gravity frequency

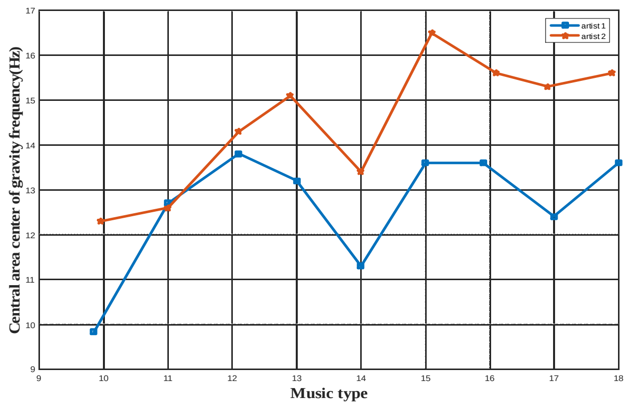

Figure 2. The frequency of the center of gravity of the lead in the Central District of the two artists in different musical forms

The change of the center of gravity of EEG can reflect the change of people's emotional state to a certain extent. Music can affect people's inner activities. The mean value of the center of gravity frequency in different music forms changes significantly compared with that in the quiescent condition. Besides, the author studies whether music major is also one of the factors affecting the center of gravity frequency. The center of gravity frequency of two subjects in C3 under different music forms is shown in Figure 2.

Results and statistics of music's impact on synchronization

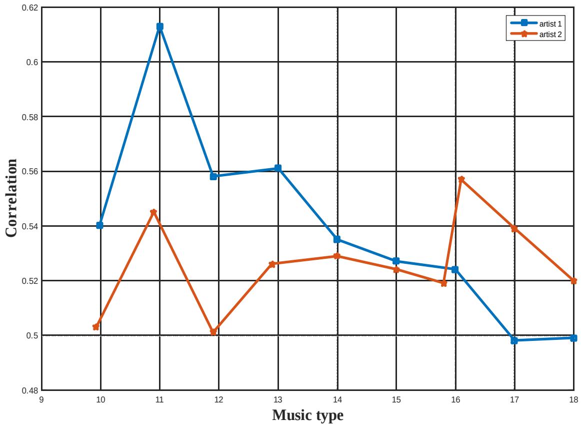

Figure 3. The cross-correlation of the pillow area between two artists in different musical forms

Cross-correlation is an index measuring linear synchronization of two signals in the time domain and correlation an index measuring the linear synchronization of two signals in the frequency domain. Cross-correlation and correlation, as the characteristics of information exchange, are used to evaluate the synchronization of EEG. The wave (14-30 Hz) appears in excitement state of the brain, so the wave is selected as the rhythm wave to analyze correlation at a certain frequency band. In the state of music, the brain nerves are stimulated directly by the auditory sense, and the synchronization of each brain area will have different degrees of changes compared with that in the quiescent condition. The cross-correlation of occipital area (O1, O2) of two subjects in different music states is shown in Figure 3.

Results and statistics of music's impact on mutual information

Information entropy is increasingly used by people to analyze complex EEG signals. Mutual information is one kind of information entropy, which can reflect the dependence degree of two EEG signals. After the statistical calculation of the characteristic value of EEG signals of the subjects, it is found that the mutual information value of EEG signals under different music forms varies differently and the effects on the subjects are also the same. The mutual information of the two subjects in the central area (C3, C4) under different music forms is shown in Figure 4, indicating that the brain activities of subjects are affected under the music state. However, the specific effect model of various music factors and musical major factors on EEG still needs the following specific analysis.

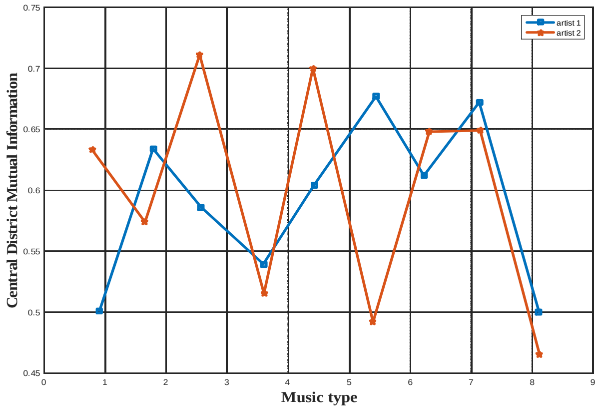

Figure 4. The mutual information of the two artists in the central district under different musical forms

Conclusions

People's thinking and exercise depend on the cooperation of various areas of the brain. The brain is divided into several major brain areas according to their functions and different brain areas are responsible for different functions. The function of the frontal area is related to physical exercise, language, and high-level thinking. The function of the parietal area is related to senses, language, and gustation. Occipital area is closely related to visual information and the temporal lobe area is closely related to auditory, language, and memory functions. And the central area is responsible for managing exercise and feelings of the body. There is research proving that the prefrontal area is responsible for the identification, integration, coordination, and control of music information while the left occipital area has the function of decoding music information. The influence of rhythm and tune on the various characteristics of EEG is significant. The influence of the temporal area and the central area is most significant, followed by the frontal area, the prefrontal area, and the occipital area. The influence of the top area is smallest. This is basically consistent with the main function of the brain area and also further confirms the brain's cognitive and processing functions of music information. Besides, music major factors also have a particularly great influence on EEG. Professional training can improve the brain's cooperative capability for information processing, which confirms that the nerve function has certain plasticity. The increase in the center of gravity frequency can accelerate people's excitement movement and the increase in synchronization of EEG and information transmission can promote the improvement of thinking ability and increase the coordination of activities. Therefore, music has become an effective way of intelligence development and neurological rehabilitation for adolescents.

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