An early warning method for structural safety based on EEG

Jailong Li, Wei Zheng* and Qing Zhao

Key Laboratory for Optoelectronic Technology and System of the Education Ministry of China, College of Optoelectronic Engineering, Chongqing University Chongqing, 400044, China

* E-mail: zw3475@163.com

Abstract. It is an important part in the field of structural safety detection to warn the monitored results accordingly. Studying the effect of visual environment on EEG can provide theoretical evidence for structural security warning. Most of the existing studies on the effect of visual environment on EEG are based on a single factor of color or frequency, and seldom involve the effect of shape on EEG. In order to solve these problems, this paper carried out an experiment to explore the effect of color, frequency and shape on EEG. The EEG signal was pretreated by EMD-HHT algorithm. It was found that the effects of visual signals on brain waves were concentrated in the first 20 seconds. By the observed β power in the first 20 seconds we found that when the color is red or yellow, the frequency is 10 Hz, the shape is circular or triangular, the β power will increase significantly, it's the electroencephalogram most relevant to attention.

1. Introduction
Electroencephalogram (EEG) is a potential change recorded on human or animal scalp. It is a signal that reflects the characteristics of brain electrical activity. When the brain receives external information, it generates EEG signals [1-2]. Visual stimulation is an intuitive and easy way to study the effect of different environmental factors on EEG. Because EEG recording is simple and has no side effect on human body, most of the current brain-computer interface (BCI) technology is based on EEG[3].

Many scholars have done research on EEG by using visual stimulation. Myunch used an arc-ozone-free Xenon lamp (1200W) and a monochrome lamp with grating monochrome with the same photon density to produce blue, green, red and white light to study the effect of different color light stimulation EEG on high-density EEG[4]. Amah Rakshit used interstitial 2 fuzzy spatial classifier to distinguish different color EEG signals, which proved that color could affect human cognitive activity and mental arousal level[5]. All these studies only focused attention on a single factor, and did not discuss the effect of shape on EEG in visual stimulus test.

To solve these problems, an experiment was designed to observe the effect of color, flicker frequency and shape factors on EEG simultaneously, in order to find out the effect of these factors on EEG when they interacted. The experiment uses software to generate visual stimulating source, and the adjustable range of color is greatly increased by RGB scheme. The specific frequency is generated by the timer inside the computer, which enlarges the adjustable range of frequency and makes the frequency more stable. Furthermore, different shapes of light stimulation are realized by software. It increases flexibility and reduces hardware dependence.
2. Formatting the title, authors and affiliations

2.1. Device platform
The device platform is consisted of TGAM module, Bluetooth receiver and transmitter, measuring electrode, reference electrodes and noise reduction headphone. In the experiment, the TGAM module is used to record EEG data, Bluetooth receiver and transmitter are used to transfer data, and the data is transmitted to the computer for storage and processing. Active noise reduction headphone are used to reduce the effect of auditory channels on EEG acquisition. The experimental device is shown in figure 1.

![Device Platform](image)

Figure 1. Device platform

2.2. Software platform
The different color, scintillation frequency and shape are synthesized by computer software processing. Through the RGB scheme, the adjustable range of color is greatly increased, and the specific frequency is generated by the timer inside the computer, which enlarges the adjustable range of frequency and makes the frequency more stable. The light stimulation of different shapes such as square, triangle, circle and star are realized by software. The above measures make the experiment very flexible and reduce the hardware dependence on the traditional indicator lamp.

2.3. EMD-HHT processing algorithm
EEG signals are characterized by strong levels of randomicity, non-stationarity, non-linearity, noise interference, and weak signals. Analyzing these signals using traditional Fourier transform and wavelet transform methods based on the harmonic basis function and wavelet basis function pose difficulties. Empirical mode decomposition (EMD) is a new adaptive signal time-frequency processing method that decomposes signals according to the time scale characteristics of the data itself and does not need to preset any basis functions[6]. It is especially suitable for the analysis and processing of non-linear and non-stationary signals because it is unconstrained by basis functions.

Empirical mode decomposition operates on the assumption that any data can be decomposed into a set of simple IMFs. These IMFs must satisfy the following two conditions:
1. For the whole data set, the difference between the number of extreme points and zero-crossing points is 0 or 1.
2. At any point in time, the envelope of the local maximum (upper envelope) and the envelope of the local minimum (lower envelope) must be zero on average.

After satisfying these two points, there can be only one instantaneous frequency at any point on the IMF and no other frequency components are superimposed.

Let the original data signal be \( x(t) \), The process of decomposing it into a series of IMFs is as follows:
Step 1: Find all local maxima and local minima of the signal \( x(t) \).
Step 2: Using the interpolation method to calculate maximum interpolation and minimum interpolation pairs, the corresponding maximum envelope $e_{\text{max}}(t)$ and minimum envelope $e_{\text{min}}(x)$ are obtained.

Step 3: Compute local mean $m(t) = [e_{\text{min}}(t) + e_{\text{max}}(t)]/2$.

Step 4: The oscillation signal $h(t) = x(t) - m(t)$ can be obtained by subtracting the local mean $m(t)$ from the original signal $x(t)$.

Step 5: Judge whether $h(t)$ satisfies two basic conditions of IMF. If satisfied, it becomes an IMF; otherwise, replace $m(t)$ in Step 1 with $h(t)$ and repeat Step 1 to Step 5.

Step 6: Let it be the first IMF component and find its corresponding residual $r_1 = x(t) - c_1$. When $r_1$ still contains the frequency information of the original data, use $r_1$ as a new signal, then repeat all the above steps to get the second IMF component.

In this way, n IMF components and one residual are obtained, and the original signal can be expressed as $x(t) = \sum_{i=1}^{n} c_i + r_n$.

Hilbert transform is a commonly used method to deconvolute narrowband signals and calculate their instantaneous frequencies. The definition is as follows:

$$HT[x(t)] = h(t) \ast x(t) = \int_{-\infty}^{\infty} x(\tau) h(t - \tau) d\tau = \frac{1}{\pi t} \int_{-\infty}^{\infty} \frac{x(\tau)}{t - \tau} d\tau$$

Where,

$$h(t) = \frac{1}{\pi t}$$

Fourier transform of $h(t)$ can be obtained.

$$H(j\omega) = -j \text{sgn}(\omega)$$

From the spectrum, it can be seen that the signal function is to keep the amplitude unchanged, shift the phase of the positive frequency part by $\frac{\pi}{2}$, and the negative frequency part by $-\frac{\pi}{2}$.

3. Formatting the text

A total of 7 people participated in the experiment. First, the participants were made to wear active noise reduction headphones in order to reduce interference via the auditory channel as much as possible. Then the EEG was measured with the TGAM module, and the reference electrode was clamped unto the ear. According to the 10/20 system method proposed by the International Federation of Clinical Neurophysiology, the measuring electrodes are placed in Fp1 position to measure the EEG of the forehead. In the experiment, participants closed their eyes for 2-5s to achieve calm and reduce mental distraction. All of these measures were carried out in order to ensure that the participants’ physiological and psychological state were at an optimum condition, so as to alleviate the interference from factors intrinsic to participants.

In the experiment, 3s of black background appeared on the screen, and then different colors flashed at different frequencies, and shapes appeared in turn. The order of occurrence is s1(red,10Hz,circle),s2(yellow,10Hz,circle),s3(blue,10Hz,circle),s4(green,10Hz,circle),s5(red,1Hz,circle),s6(red,3Hz,circle),s7(red,5Hz,circle),s8(red,20Hz,circle),s9(red,10Hz,triangle),s10(red,10Hz,rectangle),s11(red,10Hz,star).

Each state lasted for 60s, and a black background for 3s between each state served as a buffer. At the same time, the collected EEG data were transmitted to the host computer through Bluetooth and saved to the database by the host computer.
4. Result

The β rhythm is a brain wave with a frequency range of 13-30 Hz and has the strongest correlation with human attention[7]. β rhythm can be obtained directly from the hardware.

The results of EMD and HHT on the raw data are as shown in figure 2. Most of the high-frequency noise has been removed and almost all of the EEG signals have been retained in IMF5. It is observed that the observation of IMF5 will show significant peaks in the first 20 seconds. And 20 seconds later, as we gradually adapt to this stimulus, the impact of the stimulus on us will become smaller and smaller. In the follow up processing, only the first 20 seconds of data are studied, which will reduce the impact of 20-60 seconds of abnormal data on subsequent data processing, and it is easier to reveal the influence of the external environment on the electroencephalogram signal.

![Figure 2. EMD and Hibert Transfrom results of typical EEG signals](image)

The collected data are grouped according to the color, frequency, and shape of the visual stimuli. First look at the signals in the time domain and select the first four groups of data of the first experimenter to observe its time domain waveform as shown in figure 3. These four groups of data represent different colors. It is difficult to observe obvious laws from the time domain.
Figure 3. Time domain waveform

Then observe the frequency domain, the energy of their β rhythms is calculated separately. The results are shown in figure 4:

Figure 4. Result of EEG visual experiment

The subgraph a shows the effect of light stimuli of different colors on β rhythm. All red β power was larger than blue β power in seven groups. Through further observation, β power satisfies that red is bigger than yellow except N5, and yellow is bigger than blue except N4. The blue-green comparison showed that three groups of blue were larger than green, and four groups of green were larger than yellow. Therefore, it can be concluded that the effect of different colors on the β power of EEG is the highest in red, the second in yellow, the lowest in blue and green.

The subgraph b shows the effect of light stimuli of different flicker frequency on β rhythm. Almost most of the experimenters had the most obvious β rhythm at 10 Hz. There is no obvious feature for other frequency stimuli, which shows that the effect of the others frequency flicker on the β wave of EEG is not much different.

The subgraph c shows the effect of light stimuli of different shapes on β rhythms. It can be concluded that the effect of different shapes of stimuli on the β rhythm power of brain waves is the highest in circle, the following is the triangle, and the rectangle and star are the lowest.

5. Conclusion

In this work, an experiment to study the visual environment factors for the EEG β rhythm was designed to find EEG evidence for structural safety warnings. We found that when a stimulus acts on our brain, the time domain spectrum of EEG signal will produce a relatively large peak in the first 20 seconds. As time goes on, we gradually adapt to a stimulation, and the amplitude will gradually stabilize. Then we calculate the β power of the first 20 seconds after each acquisition. We find that when the color is red and yellow, the frequency is 10 Hz, and the shape is circle and triangle, the β power will be larger than other states. It's a good guide to the design of warning signs.
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