

To judge what color the subject watched by color effect on brain activity

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Summary

Moods are known to be changed by color. In order to observe the activity of the brain with the color stimulus, the event-related potential (ERP) and electroencephalogram (EEG) images are used to be analyzed. The ERP and EEG of alpha brainwave could be considered whether the person is under relaxation. In the other hand, the beta brainwave means the people represent arousal. In this paper, based on experiment data, we analyze the brain responses which come from color stimuli. The result gives us a measure to estimate the color stimulus.

Key words:

color stimulus, alpha brainwave, beta brainwave, event-related potential (ERP), electroencephalogram (EEG)

1. Introduction

Color is a fundamental aspect of human perception. It has been known that color also affect human's spirit. Some researchers have proposed that red enhances cognitive task performance as compared with blue or green [1, 2]; others have shown exactly the opposite [3, 4]. The moods and behaviors can be changed by the colors [1]. In some researches, red is made linking to the highest level of hazard and also the highest level of compliance [5, 6]. In contrast, blue is often associated with openness, peace, and tranquility [e.g., ocean and sky [7]]. Because of this, different color has been shown to have different associations within the cognitive domain.

From the physiological view, the brain activities are changed by color [3]. Color can activate an avoidance (versus approach) motivation and subsequently can enhance performance on detail-oriented (versus creative) cognitive tasks [8], so color give us different results of the brain activities changing [9, 10]. In the last years, the researchers wanted to find out how to conclude what colors the people get from the brain activities. Generally, we used the electrodes on visual area (V1, V2, and V3) to get the brain activities. Most researches focused on the beginning of stimulus happened. The brain has responses between 100ms and 500ms after the stimulus happened (visual response latency) [10, 11, 12]. In this work, we would like to talk about the brain activities during the stimulus started for a long time (>1s, in general, it is well

known that the responses of brain became stable after this period.). When people watch the color, the power of brain varies following emotion. So we can judge what color is watched by the subject according to the change of the brain's power.

In this paper, we report the electrophysiological study of the brain activity, not only analyze the activities of brain during the stimuli happened. The state of the brain activity, which was obtained after the subject gets the stimuli for a long time, has been described. The results of this experiment will give us a method and guidance to conclude what color the people watched for using a simple computing method.

2. Materials and methods

Subjects

Four healthy volunteers, included 2 women, aged between 22 and 30, participated in the examination procedure. There were three kinds of colors (red, blue and green) which have four types in this experiment (fig. 1) to be the stimuli.

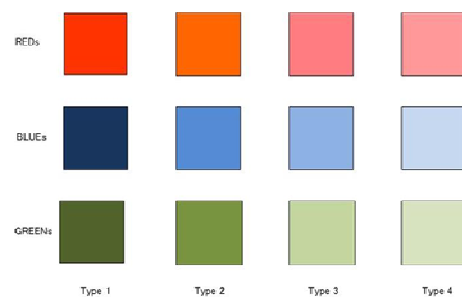


Fig.1 The samples of the colors stimulus in the experiment

Recordings

In this study, the Active Two System produced by BioSemi Inc. with 64 channels is used to get the signals of the brain activity. The original data is analyzed by the EEGLab which is the toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data using independent component analysis (ICA), time/frequency analysis, artifact rejection, and several modes of data visualization. For filtering the other brain

wave which we unused, we insert many events randomly in every trial data and average.

In the laboratory, the room is completely closed without noise and light. The display is put on the front of the subjects, and changes the color in 2 min after the stimulus appeared 1second. Between red blue and green, the volunteers should have a rest between two stimuli.

3. Results and Discussion

Brainwaves are categorized into four groups, such as α brainwave, β brainwave, δ brainwave, and θ brainwave. The frequency of α brainwave is from 8 Hz to 13 Hz. α brainwaves emerge in the brain of a person who is in the rest state, such as the concentrated state, meditation state and relaxed state. The frequency of β brainwave is form 15 Hz to 30 Hz and it shows the characteristics of strongly engaged mind. Because of these, we analysis the data in kinds of frequency ranges just like α brainwave and β brainwave. The highest power of the brain ERP images indicates the exciting state of brain during the person looking colors in every frequency range.

It is reported that different colors elicit differential arousal levels [13]. In daily life, the exciting states of people who watch the colors are like this: red > blue > green. In the other words, the brain also has the same expressions. Here, each color will be a more detailed classification in an attempt to more clearly see the effects of colors impact on the brain activities.

The change of the meaning power of the color types are showed from fig. 2 to fig. 5. Each colored trace represents the spectrum of the activity of one data channel. The scalp maps indicate the distribution of power at every frequency. The bold lines show the whole brain power changes according the frequency in the pictures. In accordance with the preceding analysis which we described, we make the ERP images at α brainwave and β brainwave bands for each colors.

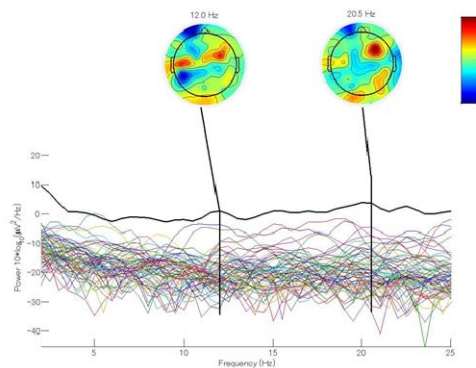


Fig. 2 The ERP images of the type 1 of green. The two scalp maps indicate the distribution of power at 12 Hz and 22Hz.

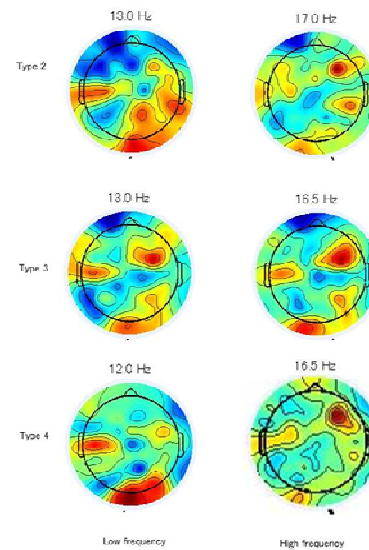


Fig.3 The ERP images of the type 2, 3, 4 of green.

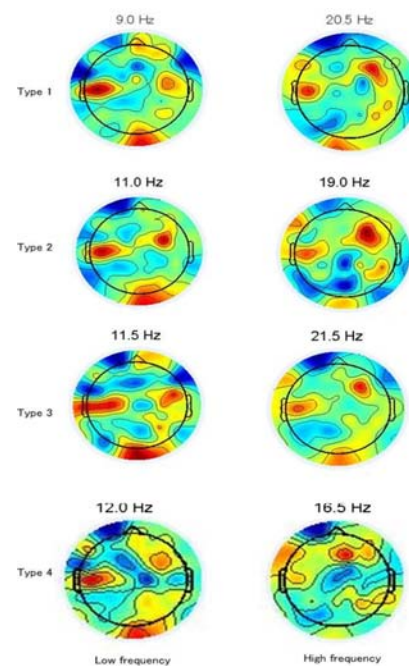


Fig. 4 The ERP images of the types of blue

To give more light on our problem, the color-frequency image is made as figure 6. The points on lines represent the highest power values on the two bands that correspond to frequencies where the ERP images are drawn in the fig. 2 to 5.

In the fig. 2, the bold line shows that the meaning power of the response of the stimulus, which has peak values in α brainwave and β brainwave bands (12.5 and 20.5 Hz). The ERP images indicate the energy of the brain become higher at V1 area when the people watching colors, which

is different from the beginning when the stimuli happened [14]. These are complete visual response.

It is known that, the moods can be changed by the colors when the person watches for long time. From the analysis of brainwave ERP, the red areas (higher than the meaning power) and frequencies should be judged in their

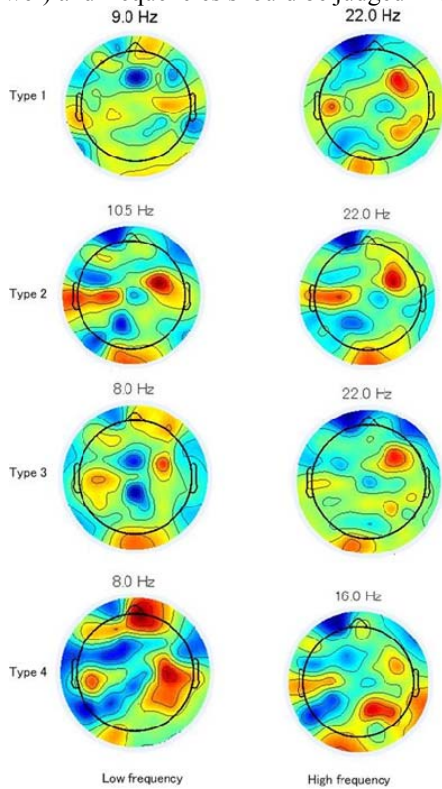


Fig. 5 The ERP images of the types of Red

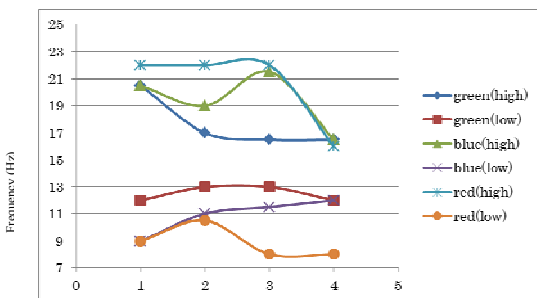


Fig.6 The frequencies dots where the highest powers appeared in α brainwave and β brainwave bands.

appropriate position. The proportion of the red areas of ERP images for the exciting colors stimulus will be bigger than the comfortable colors` in high frequency band (β brainwave band). The judgment from the frequency region has the opposite result, but the frequency has the same situation occurs. Fig. 3, fig. 4 and fig. 5 show the green, red and blue ERP images in the two brainwave bands respectively. They indicate that the different colors induce

different response areas and different frequencies. Based on the images, the areas of the powers which are higher than the meaning are following this order: $P_{G\alpha} > P_{B\alpha} > P_{R\alpha}$, $P_{G\beta} < P_{B\beta} < P_{R\beta}$. (larger area indicates higher power, P_G indicates the area of the powers which are higher than the meaning for green stimulus, P_B is blue and P_R is red). Figure 6 shows the frequencies dots where the highest powers appeared. The horizontal ordinate shows the color type of every kind color from 1 to 4 and vertical ordinate shows the frequencies which the top power appeared. The frequencies also show the relation between these colors: $F_{G\alpha} > F_{B\alpha} > F_{R\alpha}$, $F_{G\beta} < F_{B\beta} < F_{R\beta}$.

According to the discussion, we also consider the relations between color, moods and brainwaves, the changes of brain are depend on the highest powers and their frequencies. In the other words, if the power images and the frequencies are considered simultaneously, the color which the subject gets can be estimated. In one series of the same color, this result also can be used. For example, the color of third blue type is considered as the favorite color in blues by the four subjects, so the frequency has the highest value in the β brainwave band.

So we would like to assume a value which can be considered as the judgment to indicate what color people watched. It is a function which has relationship with the frequencies and energies of α and β brainwave band. For this, a formula will be given in the following:

$$S = A \cdot P_{\alpha} \cdot F_{\alpha} + B \cdot P_{\beta} \cdot F_{\beta}$$

A and B are assumed two factors for α and β brainwave band. S is the verdict which color the subject get. This formula told us, the color-judgment is not only depend on the power and frequency of α or β brainwave band respectively, we should consider both of them

4. Conclusion

According to the ERP images and frequency relationship of the visual stimulus, we provide a method for how to determining what color the subject get. In general speaking, when we judge what color people looking, we should consider two aspects: energy and frequency. This result is based on the emotional perception of colors. In this paper, we also described the effect of the auditory location come from the visual stimulus. Undoubtedly, this effect will appear in a long time after the visual stimulus.

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