

## Physiological and Psychological Reactions to the Hue of Aqueous Solution

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**Abstract:** It is thought that color can have an effect on relaxation and awakening. The purpose of this paper is to focus on the physiological reactions given by the hue of bathing salts, quantify the effects, provide basic data for practical product development, and to make life richer and more comfortable. For the measurement of physiological reactions, performed by the EEG, the subject observes the hue of aqueous solutions. The mid-alpha wave of the subject is detected during wakeful relaxation in the bathtub which is filled with bath salts in variety of colors. The results obtained from the dopamine-sensitive neurons of the frontal lobe and the visual cortex of the occipital lobe indicated that in both genders, energy values as well as the mid-alpha wave tend to increase as increasing turbidity levels.

**Keywords:** Physiological reactions, EEG, mid-alpha wave, hue, bath salts

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### I. INTRODUCTION

In today's "stressed society," there are many opportunities to feel stress in a variety of situations. Hence, products that provide relaxation have been developed by many and attract a great deal of attention. These products have a relaxing effect by using colors and fragrances effectively. Color (hue) has been determined to have a "relaxation effect," "refreshing effect," and "healing effect". [1] Therefore, by using color effectively, it is thought that the relaxation effect is increased further. When entering the bath, the body temperature rises, capillaries of the skin expand, blood flow improves, and it is a very pleasant feeling. Moreover, the skin's waste products are removed and increasing one's metabolism can mitigate fatigue and pain. Also, because there is pressure on the body's fluids, the blood collected on the limbs is pushed back, the heart becomes more active, and the blood and the lymph can flow better. Bathing salts are a familiar example that utilize color as part of their effect on people. The effects of each color bath salt are summarized below. [2]

Red bathing salts would be expected to lift moods and make one more energetic. Pink's softness is considered to be mild and soft which may prolong good feeling after a nice day. Blue, the color of the sea, would feel refreshing and bring calmness. Bath salts with the color yellow of citrus fruits, such as lemons, are thought to have the effect of refreshing or inducing positivity in both males and females. The open feeling of an outdoor bath in the forest or meadow is expressed in the green bath salts, which would also make one feel refreshed and relaxed. Color brown has the same function as well. White bath salts are one of the popular colors. Color white symbolizes milk which is considered to make beautiful skin. Color white is also associated with cleanliness, purity and would probably be the most suitable color for a bath salt when one wants to relax. Therefore, it is possible to influence the mood of a person based on the hue of the bathing salt. [2]

In Colorimetry, the Munsell Color System is a method that specifies colors based on three characteristics: hue, value (lightness), and chroma (color purity). Conceived in the 1890's by the American artist and educator Albert H. Munsell (1858-1918), [3] it was described as a theoretical color model in 1905. The Munsell Color system is set up as a numerical scale with visually uniform steps for each of the three color attributes — in Munsell color notation, each color has a logical and visual relationship to all other colors. [4] Munsell divided colors into five principal hues: Red, Yellow, Green, Blue, and Purple, along with 5 intermediate hues, each halfway between adjacent principal hues. Munsell's system, particularly the later renovations, is based on rigorous measurements of human subjects' visual responses to color, putting it on a firm experimental scientific basis. [5][6] Because of this basis in human visual perception, Munsell's system has outlasted its contemporary color models. It is still in wide use today. [7]

The history of EEG is detailed by Richard Caton, a physician practicing in Liverpool. He presented his findings about electrical phenomena of the exposed cerebral hemispheres of rabbits and monkeys in the British Medical Journal in 1875. [8] German physiologist and psychiatrist Hans Berger recorded the first human electroencephalogram (EEG) in 1924. He characterized the wave patterns, including  $\alpha$  and  $\beta$  waves, and coined the term "electroencephalogram." He described or touched upon a large number of normal and abnormal EEG phenomena, for example, EEG changes associated with attention and mental effort, and alterations in the EEG associated with cerebral injury. [9] EEG is used extensively in neuroscience, cognitive science, cognitive psychology, neurolinguistics and psychophysiological research.

EEG is an electrophysiological monitoring method to record electrical activity of the brain. It is typically noninvasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used in specific applications. [10] EEG measures voltage fluctuations resulting from ionic currents within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp. [11][12]

EEG can be classified into four categories: delta-wave, theta-wave, alpha-wave, and beta-wave. The delta-wave shows the rhythm of the 1hz-3hz. It appears when a person sleeps so deeply that they do not dream. The theta-wave shows the rhythm from 4hz-7hz. In a shallow sleep condition, the temporal advantage appears when meditating. The alpha-wave appears at the back of head and shows the rhythm from 8hz-13hz, which appears at the time of awakening, and appears when the brain is not mentally active. [13] The slower alpha-wave (8-9hz) appears during a sleeping state, mid-alpha wave (9-11hz) appears during a relaxed state, and fast alpha-wave (11-13hz) occurs during a tense state. [14][15] The beta-wave shows a rhythm of 14 Hz or more and is the most common during the consciousness state, and is recorded in the center of the frontal part. [16]

The purpose of this study is to provide basic data for the development of practical products to make life richer and more comfortable by quantifying its effect. We will study and consider the physiological reactions (relaxation effects) and compare them with psychological effects. An EEG will obtain information on how the "hue" of the bath salts affects the physiological reaction (relaxation effect).

In this study, the bathing method used is the footbath and is convenient because it does not require the removal of clothes. Since the whole body is concentrated on the foot and blood circulation is occurring, the detoxification effect can be expected.

## II. EXPERIMENTAL

In this experiment, EEG data was obtained while the subject was taking a foot bath. The electrodes of 19 poles were placed based on the International 10-20 system on the scalp of the subject. The colors of the bath salts used in the experiment are R (red), Y (yellow), G (green), B (Blue), and P (purple). The turbidity was also changed to four levels in each hue, starting with degree 0 turbidity, where salt was not added.

The aqueous solution was prepared in a container which is 60cm in length, 40cm in width, 38cm in height, and contain water up to a depth of 20cm. And of course the container is prepared in color white as a bathtub in real life. The experiment was carried out under the inverter-type white fluorescent lamp and the water temperature was consistently 40°C throughout the experiment.

The subject would put both feet into water for an allotted time without seeing the aqueous solution. This is to remove the effect of the aqueous solution's heat. After the subject acclimated to the water temperature, the subject was allowed to see the hue of the aqueous solution and the EEG was used to obtain data. (Figure.1)

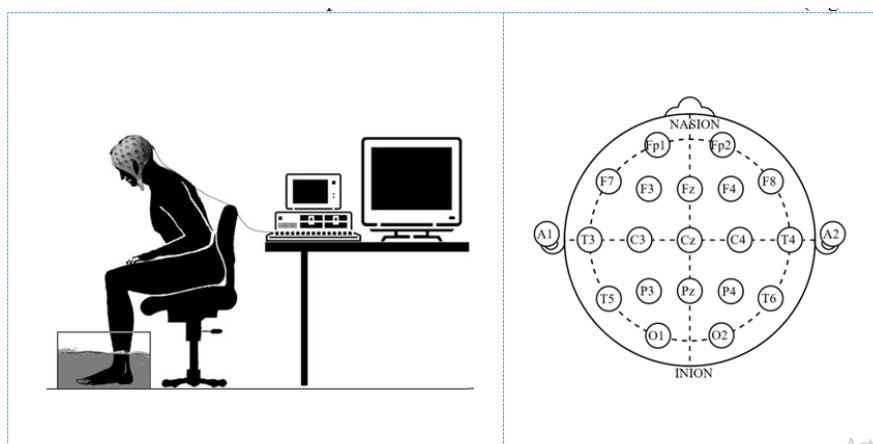


Figure.1 Image of experimental and Electrode locations of International 10-20 system for EEG

First, an electrode was placed on the subject and the subject was allowed to rest for 5 minutes. Then, the subject was allowed to close their eyes 5 minutes with the EEG recording data for one minute. Then, the subject would put both feet in the aqueous solution and get acclimated to the water temperature before seeing the hue while the EEG recorded data. Then, after another 5 minutes of a break with closed eyes, the EEG would record for one minute. Continue to experiment with the same procedure, this time with another hue. The number of individual subjects participated in the experiment was 40 (20 males, 20 females). The subject would put both feet into water for an allotted time until acclimated to the water temperature. Then, the subject was allowed to see the hue of the aqueous solution while the experimenter began to obtain data.

**III. RESULTS AND DISCUSSION**

Figure 2 is a diagram of the brain's reaction to each hue. As shown in the figure, with an increase in turbidity, the frontal lobe (upper part) became active.

In the structure of the human brain, the frontal lobe functions are to engage in emotions. Also, when seen from the EEG diagram, the electrodes that placed on the frontal lobe area are Fp1, Fpz, and Fp2.[17] Therefore, we can obtain the dopamine-sensitive response of the frontal lobe by analyzing the signals of electrode Fp1, Fpz, and Fp2.

As an example, Figure 4 showed the signals of Fp1, Fpz and Fp2 in the case of Yellow of degree 0 in the subject. The horizontal axis is frequency, the vertical axis is energy value. In all results, the highest energy value moves between the alpha waves of the frequency 8 ~ 13hz. The alpha wave of 8 ~ 13hz is figured out when relaxing. In addition, the peak value of all results comes out at the time of the mid-alpha wave in a relaxed state of 9 ~ 11hz. Therefore, in this study, the analysis is performed using the average of the power value of the mid-alpha wave band, which is in a relaxed state of 9 ~ 11hz.

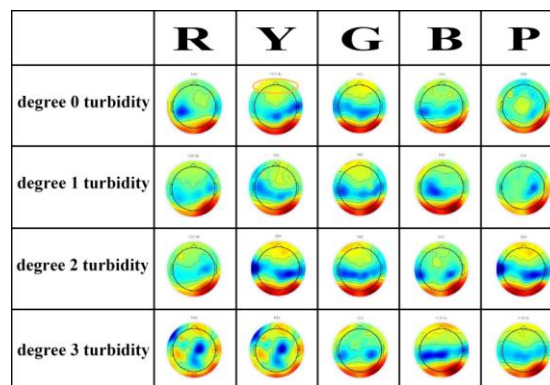


Figure.2 the diagram of the brain's reaction to each hue

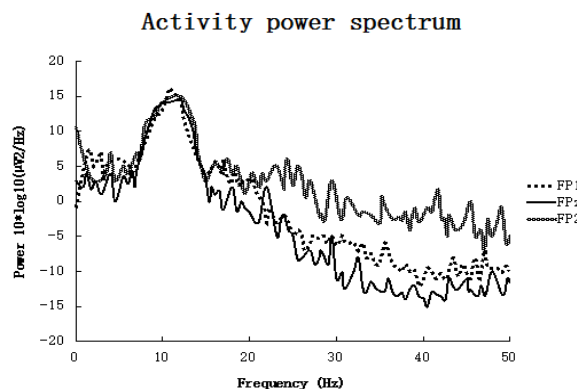


Figure.3 the signals of Fp1, Fpz and Fp2 in the case of yellow of degree 0 turbidity

The results of this study were divided into males and females for analyzing. The results obtained by the visual nerves with an increase in turbidity, found that, in both sexes, the tendency of the signal of the mid-alpha wave is shown to be higher. And males had high signal rates of the alpha-wave with the turbidity degree of 0 in Green and Yellow colors, whereas in females it was in Purple, Green, and Yellow colors. In preceding research, it has become clear that "exhilaration" such as cheery feel and gentle feel are high in these hues.

This experiment, when performing the analysis of the EEG, as a method of examining the magnitude of the relaxation effect, it was shown that a method of comparing the mid-alpha wave occupancy rate and the change of energy of the frontal lobe is useful. In addition, the results obtained by the emotional nerves of the frontal lobe increases in turbidity, the energy value tends to increase, the change in the occupancy rate of the mid-alpha wave of the frontal lobe showed the same thing. In all results, the highest energy value moves between the alpha waves of the frequency 8 ~ 13hz. Therefore, the results are considered to be much more precise to compare the signals of the mid-alpha wave than to compare the values to each other.

The hue with a high degree of cloudiness has the comfort and the healing effect. And, it became clear that the hue of the cloudiness degree 0 which was light "exhilaration" by the psychological effect also gives the person a relaxing effect.

In short, it is possible to quantify the psychological effect of the physiological reaction by hue, and it is useful in the product development in the future. As for the physiological reaction, the mid-alpha wave is said the frequency which comes out to the head when the research report on a lot of EEG is relaxed. It is thought that it is necessary to examine the EEG that the most relaxed state represents in the experiment in the future for certainty.

First, the change in the factor analysis of the psychological response value. It is a value that adds the one which multiplied each contribution rate to the factor analysis of the bland and exhilarating each. We will examine the correlation between the factor analysis of psychological reactions and the change of alpha wave occupancy rate of physiological reactions. For physiological reactions, using three alpha waves, the slow alpha wave of each hue, the mid-alpha wave, the occupancy rate of the fast alpha wave each, as the turbidity 0 reference value 0, the calculated turbidity degree 1, 2, is a change value of 3.

Also, we analyze the correlation between the factor analysis of psychological reaction and the energy change value of the frontal lobe of the physiological reaction. The correlation between the psychological reaction and physiological reaction, the mid-alpha wave has a strong correlation and a moderate correlation. And, there was a strong relationship to the fast alpha wave, either, it can be seen that the mid-alpha wave correlation is stronger than the fast  $\alpha$  wave and slow alpha wave. The energy change value of the frontal lobe was shown to have a correlation with the psychological reaction.

#### IV. CONCLUSION

When performing the analysis of the brain waves, as a method of examining the magnitude of the relaxation effect, it was shown that the method of comparing the mid-alpha wave occupancy rate and the change of energy of the frontal lobe is useful.

The hue with a high degree of cloudiness has the comfort and the healing effect. And, it became clear that the hue of the cloudiness degree 0 which was light "exhilaration" by the psychological reaction also gives the person a relaxing effect. In other words, it is possible to quantify the psychological reaction sequence physiological reaction by hue, it is considered to be useful in the future of product development.

It was possible to show the significance of the subjective evaluation experiment by the SD method by the physiological reaction experiment.

Then, the relaxation effect of the hue method of performing the comparison of the occupancy rate of the mid-alpha wave, it was shown to be very useful.

Also, since the results of the change value of the energy value of the frontal lobe emotional nerve is also strongly correlated, when considering the relaxation effect of the future hue, the change value of the energy value of the frontal lobe emotion nerve it is considered to be helpful.

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