FUNDAMENTAL STUDY FOR CONTROL OF ENVIRONMENT LIGHT USING BIOLOGICAL SIGNAL

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ABSTRACT
The objective of this study is to presume the human psychological condition with the biological signal in order to feedback the result to the person and to control the living environment automatically depending on the result. In this paper, the influence of living environment on the human body was examined as a fundamental study. The elements of living environment which compose the living environment includes sound, temperature, humidity and light, etc. Among them, the influence of environment light on biological response was evaluated. Biological reactions stimulated by red, green and blue light were analyzed using an ECG (electrocardiogram), EEG (electroencephalogram) and MEG (magnetoencephalogram).

As a result, a significant difference was observed between green and red light in LF/HF obtained from ECG, in percentage of alpha wave rate obtained from EEG and in latent time of P300 and amplitude of P300 obtained from MEG. In addition, the possibility was suggested that green light induces a rest state whereas red light induces a concentrated state. Based on the results, automated control system of environment light by biological signal was constructed.

KEY WORDS
LF/HF, Alpha wave, P300, Environmental light, Controlling living environment, Feedback

1. Introduction

According to the investigation of the Ministry of Health, Labour and Welfare, 60 percent of workers feel stress.¹ The accumulation of stress will be linked with a risk of reduction in working efficiency or operational errors. Therefore, it is considered that stress reduction is important. On the other hand, extreme low stress, however, causes reduction in working efficiency or operational errors because of lack of intensity. Therefore, it is considered that maintaining appropriate stress is important on working and daily life.

The objective of this study is to construct the automated control system of living environment by using biological signal, in order to improve human QOL on working and daily life. The element that composes living environment includes the light, sound, temperature and humidity, etc. In this study, we focused on the effect of environment light among them.

There have been many researches about the influence of light on human physiology to clarify comfortable light environment for people.²,³,⁴,⁵,⁶ However, the selection of light source is difficult, because there are a lot of kinds of light sources. In this study, we focused on three primary colors of the light (red, green and blue). The human eye has three kinds of photoreceptor cell, and the spectrum sensitivity is different respectively. L, M and S cone reacts to red, green and blue light, respectively. When human eyesight recognizes the color of light, the spectrum distribution of the light can not be detected directly, but the absorption ratio of three kinds of photoreceptor cell is received.

In this paper, the effect that three primary colors of the light influences on human body was examined by using ECG, EEG, MEG and behavioural index. Moreover, the prototype of controlling environmental light system was constructed based on the result.

2. Influence of environment light on human physiology

2.1 Experimental condition

The experiment to clarify the influence of environment light on human physiology was performed. Subjects were 4 healthy male university students who were confirmed to have no abnormality in color vision and not to be under any medication. The experiment was conducted after sufficient informed consent.

The experiment was conducted in the dark room. The room temperature was kept at 25 degree C. It was confirmed that subject don’t feel uncomfortable under the temperature.
The colors of lights used in the experiment are red, green, blue and gray, and RGB (Red-Green-Blue) value of each color is shown in Table I. This value was proofread before the experiment in order to unite illuminance around 17 lx. These colors were displayed to a screen (1620 (W) × 1,220 (H) mm) with a projector (EMP-1710). The color projected on the screen occupied 41 degree of view angle in the front side of the subject. (Figure 1)

<table>
<thead>
<tr>
<th>Color</th>
<th>R</th>
<th>G</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>150</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Green</td>
<td>0</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>250</td>
</tr>
<tr>
<td>Gray</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

Table I. The value of RGB of each color.

The ECG (electroencephalogram) measurement was performed at the electrode position of throat, left-flank and epigastrium (Figure 2). After sampling by 500 Hz, the band pass filter of 10-30 Hz was applied. The EEG measurement was performed at the electrode position of O2, Fpz and A2 of 10-20 methods (Figure 3). After sampling by 500 Hz, the band pass filter of 1.5-30 Hz was applied.

2.2 Experimental procedure

The test subject was instructed to sit on a chair located at 125 cm distant from the screen. Then the subject was instructed to look at a black dot in the center of the screen keeping the rest state. Time schedule of color stimulation was shown in Figure 4. Because time interval of 128 s was necessary to analyze LF/HF, the color stimulus was given for 130 seconds. To avoid the influence of the previous color, the gray color was displayed for 60 seconds. In addition, to reduce influence of body motion, experiment was started about five minutes after experimental setting was finished.

2.3 Analysis of biological signals

LF/HF was used as one of the indexes obtained from the result of the ECG. LF and HF are the indexes to examine a periodical fluctuation of RRI. These indexes were calculated by protocol shown in Figure 5. LF and HF are the results of the frequency analysis of R-wave interval (RRI). LF and HF are sum of the power spectrum of 0.04-0.15 Hz and 0.15-0.4 Hz in frequency band, respectively. The LF/HF ratio shows the balance of sympathetic and parasympathetic activity because LF and HF respectively show parasympathetic and parasympathetic activity. Increase in LF/HF ratio shows domination of the sympathetic nerve activity, whereas decrease shows the domination of parasympathetic activity.

The brain wave was analyzed by the percentage of alpha wave. The alpha wave is one of the brain wave with the frequency band from 8 to 13 Hz, which is an index that shows the state of rest, relaxation and concentration.
Percentage of alpha wave was calculated by the following equation,

\[
\text{Alpha wave content rate(\%)} = \frac{\text{Power value of alpha frequency bands}}{\text{Power value of all frequency bands}} \times 100
\]

2.4 Results and discussion

Figures 6 and 7 show the graphs of the change rate of LF/HF and percentage of alpha wave normalized by the value in red light stimulation. The LF/HF ratio under green light stimulation was lower than that under red light in four people, and 3 of 4 people were lower under blue light than that under red. The percentage of alpha wave under green light stimulation was lower than that under red in four people, and 3 of 4 people were lower under blue light than that under red light.

From the result of LF/HF, a relaxation effect is the highest under green light stimulation, and lowest under red light stimulation. As for the percentage of alpha wave, it was indicated that the relaxation effect is the highest under red light stimulation. The contradiction arised for the interpretation of LF/HF and alpha wave. Here, the alpha wave is an index of not only rest and relaxation, but also concentration. Therefore, it is considered that expression of alpha wave under red light stimulation may indicate the concentrated state. The p value obtained by t-test between each colors was shown in Table II. LF/HF and percentage of alpha wave have significant differences between red and green. Therefore, it was presumed that effective relaxation is obtained by green light, whereas effective concentration is obtained by red light.

### Table 2. P value

<table>
<thead>
<tr>
<th></th>
<th>Blue &amp; Red</th>
<th>Red &amp; Green</th>
<th>Green &amp; Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF/HF</td>
<td>0.512</td>
<td>0.025</td>
<td>0.252</td>
</tr>
<tr>
<td>Alpha wave content rate</td>
<td>0.626</td>
<td>0.024</td>
<td>0.236</td>
</tr>
</tbody>
</table>

3. Influence of red light on physiological function

Physiological index and behavioural index were examined to clarify the concentration effect of red light suggested in the previous section. The latency time and the amplitude of the P300 component measured by MEG (magnetoencephalogram) were used as physiological index. Accuracy rate and reaction time were used as behavioural index.

3.1 Experimental condition

The subject was five healthy male university students who were explained about the procedure of experiment beforehand, and agreement were obtained by the document. The color used in the experiment is gray, red and green, with which a significant difference was obtained in previous experiment. RGB of each color, the value of the illuminance and the distance to the screen were the same as the experiment in the section 2. The system used in this experiment is brain magnetic field measurement system (Neuromag-122™) in National Institute of Advanced Industrial Science and Technology (AIST) Kansai Center. The instrument is set up in the magnetic shield room. The brain magnetic field measurement system has 122 sensors arranged symmetrically in the form of helmet around the head. The active nerve in the brain can be analyzed from the magnetic field distribution. The sampling frequency was 600 Hz.

3.2 Experimental procedure

Figure 8 shows the time schedule of the experiment. Red and the green were projected on the screen in the same repetition. The auditory oddball task was conducted during projection of the colors. Pure tone of 2 kHz (higher frequency: standard stimulation) and 1 kHz (lower frequency: targeted stimulation) was given to right ear randomly at the frequency of 4:1. The subject was instructed to move the forefinger of the right hand only when the auditory stimulation of 1 kHz (lower frequency) was recognized, and the reaction time was monitored with an optical sensor.
3.3 Analysis of biological signals

The amplitude of P300 which is event-related magnetic field, the reaction time and accuracy rate (%) were calculated for MEG measurement with auditory oddball task. P300 is an evoked potential with the top latent time around 300 msec after targeted stimulation when the oddball task is conducted. The amplitude of P300 corresponds to concentrated degree. The latent time of P300 corresponds to concentrated information processing time. This time becomes long when stress is accumulated.

3.4 Results and discussion

Figure 10 shows the brain magnetic field chart of 122ch. P300 was observed around the left auditory area because audio stimulus was stimulated from right ear. The data of P300 for 3ch were averaged.

Figures 11 and 14 show the graphs of the change rate of latent time of P300, amplitude of P300, accuracy rate and reaction time normalized by the value in red light stimulation. The latent time of P300 under green light stimulation was shorter than that under red light in 4 of 5 people. A significant difference was obtained for the latent time of P300, the amplitude of P300 and reaction time. From these results, it is suggested that there is an effect of promoting the rest state under green light, and an effect of the promoting the concentrated state under red light.
4. Construction of Environment controlling system

Based on above results, the system was constructed which feedbacks the stress condition and coincidentally control the environmental light corresponding to stress condition. The validity of the constructed system was verified by the stress task test. This system utilizes the effects of green color stimulus and red color stimulus which induces relaxed and concentrated state respectively as shown in section 2 and 3.

4.1 Constitution of program

In this study, LF/HF ratio was used as the evaluation index of stress state. The LF/HF ratio was automatically calculated from results of ECG, and then the stress state was judged by the LF/HF value. The current state was shown in real time. This algorithm was implemented with Labview 8.0 (National Instruments Corporation). Figure 15 shows the flowchart of system.

4.2 Adequacy evaluation experiment of system

Experiments of Pattern 1, 2 and 3 were conducted once. An experiment of pattern 4 was conducted twice. The five-level sensory evaluation with SD method was made, in which the value of 1 corresponds the most relaxed state and the value of 5 corresponds to the most stressful state, when each session was finished.

4.3 Results and discussion

Figure 17 shows the graph which is the integration of the data of five sessions of stress task test. In this graph, the horizontal axis shows sensory value and vertical axis shows change rate of LF/HF. Change rate was calculated by normalizing each LF/HF value by the value in first session. Correlation coefficient was about 0.79, which shows good correlation. Therefore, it is considered that this program is valid program. Moreover, the program in which the background color of the monitor is automatically changed depending on the stress condition was constructed by setting the threshold value, shown at the bottom of Figure 14. This is the program that stress degree was shown by five levels by stress gage and face mark (Figure 18). In addition, in the case of extremely relaxed state, background color changes into red, whereas in case of extremely agitated state, background color changes into green.
5. Conclusion

In this paper, the influence of three primary colors of the light on the physical response was examined. The final purpose of this study is to construct the system that stress degree is evaluated objectively, and in addition, extreme stress is reduced with keeping the concentrated state utilizing the automatic control of environment light depending on the stress condition.

As a result, it was suggested that relaxation is promoted by green light, whereas concentration is promoted by red light. Moreover, the system that stress condition fed back with the stress gauge calculated by LF/HF, and environmental light was controlled due to stress condition. As a result of stress task test, it is suggested that the system was valid.

In the future study, the program which can change the color according to an individual characteristic by the automatic learning function will be developed. Furthermore, it is considered that the sensor that can measure the vital signal easily by the low restraint will be used for bioinstrumentation toward the actual use. Eventually, the results obtained with this system will be applied to many kinds of external device, for example, light in a room or air conditioner. By this improvement, it is considered that present stress condition is understood on the view by a simple method, and the appropriate environment corresponding to the level of the stress can be prvided. It is considered that environment controlling corresponding psychological state of human has the possibility of wide application for working and daily life.

References

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