AN EXPERIMENTAL STUDY FOR THE EVALUATION OF SOUND AND OTHER ENVIRONMENTAL FACTORS FROM THE PHYSIOLOGICAL AND PSYCHOLOGICAL POINT OF VIEW

Hirofumi Iwashige *[1], Mitsuo Ohta [2] and Hitoshi Ogawa[3]

[1] Graduate School of Education, Hiroshima University,
1-1-1, Kagamiyama, Higashi-Hiroshima 739-8524, Japan
[2] Professor emeritus of Hiroshima University, Japan
[3] Hiroshima Prefectural University,
1-1-71, Ujina-Higashi, Minami-Ku, Hiroshima 734-8558, Japan
hiroiwa@hiroshima-u.ac.jp (e-mail address of lead author)

Abstract

In general, the environmental comfortableness of the room is investigated by a kind of questionnaire. It seems that mainly it is based on a psychological evaluation method. On the other hand, the related physical environmental factor stimulus such as temperature, sound and illuminance can be measured directly by measurement instrument. It is undoubtedly a kind of physical evaluation. It is difficult to recognize some reasonable relationship between two evaluation methods. We suppose it originates to some physiological change of human body owing to physical environmental stimulus related to the environmental comfortableness of the room. For making sure at least the measurement value of the physiological change, at first, we measured a heart rate, a pulse wave of finger and an electrocardiogram when physical environmental factors stimulus is added. From these measurements, we found that a pulse wave of finger is one of the effective method in explaining a physiological change of body. We made the experiments under the conditions of two kinds of sound level, three kinds of sound frequency band, three kinds of illuminance level and two

Eds.: J. Eberhardsteiner, H.A. Mang, H. Waubke

kinds of room temperature. We obtained some reasonable experimental results of physiological change of human body by physical environmental stimulus. And also, we have confidence that there is comparatively in a close relationship to the psychological evaluation.

INTRODUCTION

The purpose of this study is to find some relationships between the physical factors, the physiological evaluations and psychological evaluations. In general, the environmental comfortableness of the room is investigated by a kind of questionnaire. It seems that

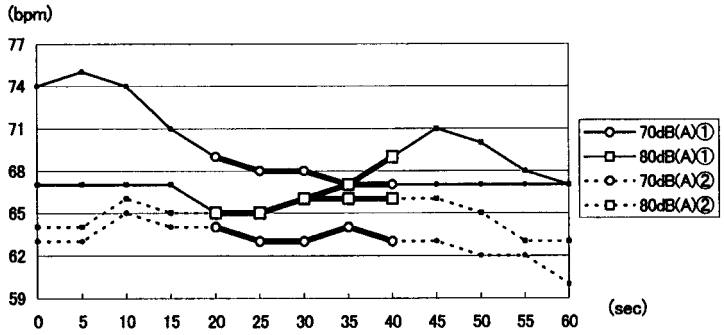

Fig.1 Change of heart rate during exposure of sound stimulus.

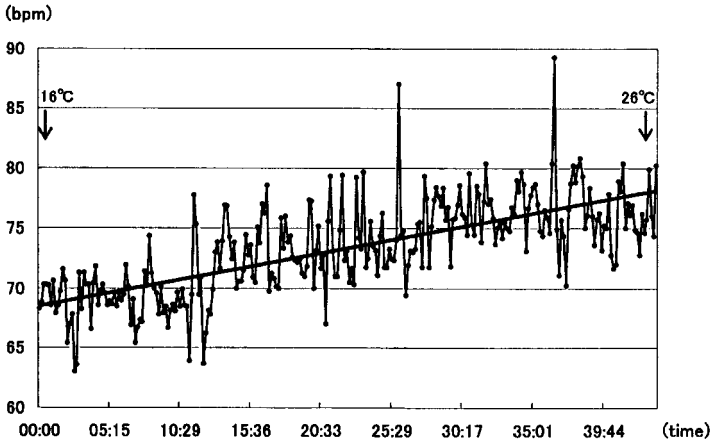

Fig.2 Example of heart rate with the rise in the room temperature.

mainly it is based on a psychological evaluation method. The related physical environmental factor stimulus such as temperature, sound and illuminance can be measured directly by measurement instrument. It is a kind of physical evaluation. It is difficult to recognize some reasonable relationship between two evaluation methods. We suppose it originates to some physiological change of human body owing to physical environmental stimulus related to the environmental comfortableness of the room. For making sure at least the measurement value of the physiological change, at first, we measured a heart rate, a finger pulse wave and an electrocardiogram when physical environmental factors stimulus is added. From these measurements, we want to find the effective method in explaining a physiological change of body.

This paper will present the results of analysis using a physiological response, as a technique for measuring the influence of environments. The results of analysis using psychological response will be postponed till next time. In this study, environmental factors for experiment are chosen under the actual conditions of daily life. We made the experiments under the conditions of two kinds of sound level, three kinds of sound frequency band, three kinds of illuminance level and two kinds of room temperature.

PHYSIOLOGICAL EFFECTS OF INDOOR ENVIRONMENTAL FACTOR CONDITIONS

Experimental Setting

Our experiments are carried out in the climate chamber. A white noise is fed into the chamber by two loudspeakers. The climate chamber is illuminated by twelve sets of white incandescent ceiling lamps. The temperature of the chamber is controlled by heat pump type air conditioners. The environmental factors for experiment are chosen under the actual conditions of daily life. The heart rate, the finger pulse wave and the electrocardiogram are measured when physical environmental factors stimulus is exposed. All subjects are healthy young men and women.

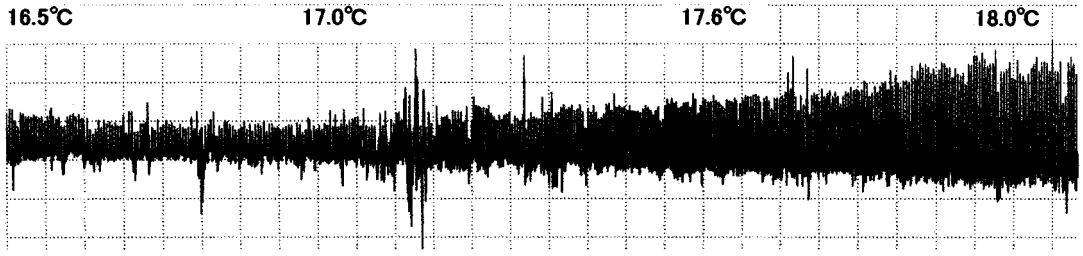

Fig.3 Example of finger pulse waves with the rise in the room temperature.

The influence of sound stimulus on the heart rate

An example of heart rate change is put up as figure. In Figure 1, the heart rate change with the passage of time is shown. In these experiment, two kinds of sound level (70 dB(A), 80 dB(A) white noise) are used. The sound level is measured at the position of subject's ear. The white noise is exposed to subject during 20 seconds (the results are shown with bold line in the figure.) And two kinds of results are marked in the figure.

From this figure, it seems that the value of heart rate by large sound stimulus is higher than that of small sound stimulus. And during sound exposure, there is some difference of heart rate value between the value at sound exposing time and that of previous time or the other time.

The influence of room temperature on the heart rate

This is an example of heart rate change with the passage of time. The value of heart rate changes rapidly. This is a figure during about 40 minutes. In Figure 2, the value of asymptotic line for heart rate moves gradually with the rise in the room temperature

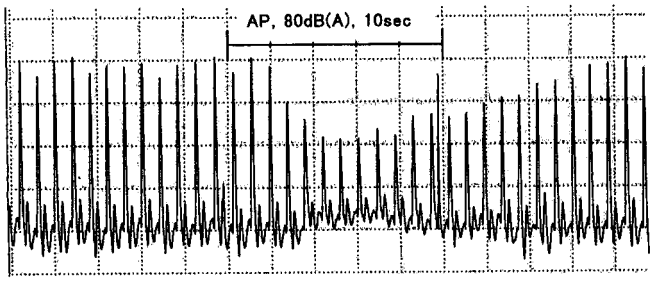

Fig.4 Relative change in finger pulse wave with stimulus.

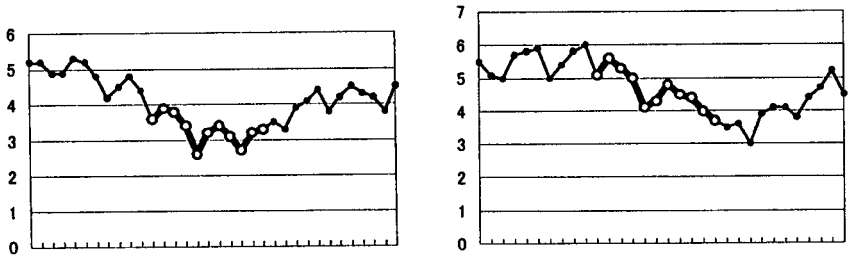

Fig.5 Change of amplitude length during stimulus exposure.

(from 16°C to 26°C). So, it seems that the value of heart rate relate to the room temperature.

The response of pulse amplitude to room temperature

Figure 3 is one example of finger pulse waves. This is a figure during about 5.5 minutes. The finger pulse amplitudes in the wave (finger plethysmograph) enlarge gradually with the rise in the room temperature from 16.5°C to 18.0°C. From this figure, we found that there is comparatively remarkable relationship between the finger pulse amplitude and the room temperature.

The large amplitude of finger pulse means that the large amount of blood flow in this condition. There are a few loads to body in the condition of large amount of blood flow. It means to be relatively comfortable environment. From these experiments, the change of electrocardiogram by environmental stimulus is not clarified.

INFLUENCE OF ENVIRONMENTAL SOUND AND OTHER FACTORS ON FINGER PULSE WAVES

We conducted experiments to investigate the effect of physiological parameters at different environmental factors.

Experimental Conditions

The experiment was performed in our climate chamber. Environmental factors for experiment are chosen under the actual conditions of daily life. Two categories of noise

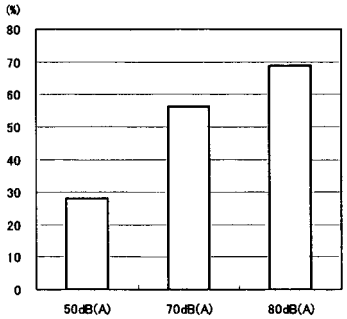

Fig.6 Comparison of amplitude reduction occurrence.

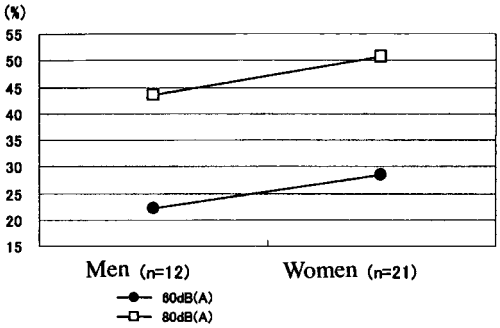

Fig.8 Comparison of men and women with amplitude reduction.

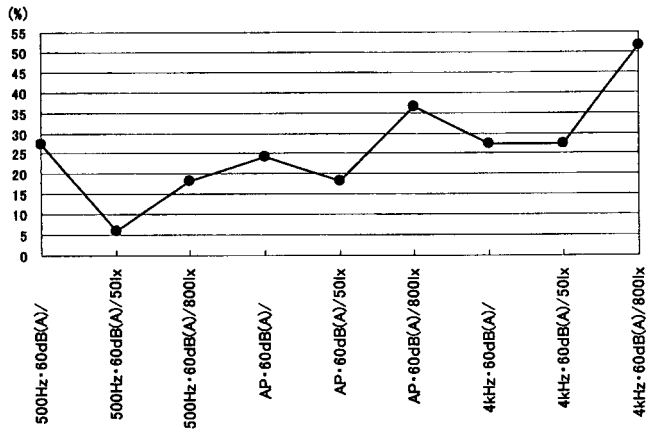

Fig.7 Degree of the effects occurrence with various conditions.

level (60 dB(A) and 80 dB(A)) with three kinds of frequency band (500 Hz, 4kHz and All Pass), three categories of illuminance (Dark, 50 lx and 800 lx) and the thermal exposure (about 26^{o}C) are used. The change of standing of finger pulse waves is observed to obtain the evaluation value for many complex living conditions. The finger pulse amplitude is measured at index finger of subjects when regular blood pressure. The 33 volunteers are the subjects for this experiment. All subjects were healthy young men and women.

The change on standing of finger pulse by environmental factors

Figure 4 is an example of finger pulse amplitude with environmental factors, such as sound, illuminance and temperature, during 30 seconds. This is the case with sound level 80 dB(A) (All pass, White noise), illuminance 50 lx and room temperature 26^{o}C. The finger pulse amplitude (finger plethysmograph) is reduced obviously when the stimulus factors (sound and illuminance) are exposed during 10 seconds. The decrease in amplitude of finger pulse in the wave means the smaller amount of blood flow. There are big loads to the body. And it is uncomfortable environment.

In Figure 5, two examples of the measured length for the amplitude of finger pulse are shown. The length for the amplitude becomes smaller in general when the sound and illuminance factor stimulus are added 10 seconds. These are shown by bold line in the figure. The smaller or minimum value of relative amplitude is obtained. The response of finger pulse wave amplitude is concluded to be sensitive enough to used as a physiological index of noise and other factors.

The reduction of pulse amplitude with various conditions

We define that there is a significant physiological effects, if the mean value of finger pulse amplitude during when the environmental factors exposed 10 sec is less than 0.85 value that of before exposing. For quantitative analysis of the response, the changed pulse wave amplitude are expressed in percentages of its initial value. The degree(%) of the occurrence of significant physiological effects (0.85) is shown in Figure 6 in comparison with three kinds of sound level (50, 70 and 80 dB(A)). From this figure, the high degree of effects occurrence is found with large level of sound stimulus like 80dB(A). There will be big loads to a body.

In Figure 7, the degree of the significant effects occurrence with many kinds of environmental conditions is shown in the case with 60 dB(A). A small difference of occurrence degree is seen with the level difference of illuminance. The comparison of effects occurrence by gender is shown in Figure 8. This is the case with 60 dB(A) and 80 dB(A). The large sound stimulus makes large degree of significant effects. And the significant physiological effects of women is considered being more sensitive than that of men. The response of finger pulse wave amplitude was concluded to be sensitive enough to used as a physiological index of noise and other factors.

CONCLUSIONS

In this study, we tried to find some relationships between the physical values of environmental factor, the physiological evaluations and psychological evaluations. In general, the environmental comfortableness of the room is investigated by a kind of questionnaire. It seems that mainly it is based on a psychological evaluation method. The related physical environmental factor stimulus such as temperature, sound and illuminance can be measured directly by measurement instrument. It is a kind of physical evaluation. It is difficult to recognize some reasonable relationship between two evaluation methods. We suppose it originates to some physiological change of human body owing to physical environmental stimulus related to the environmental comfortableness of the room. For making sure at least the measurement value of the physiological change, we measured a heart rate and a finger pulse wave, when physical environmental factors stimulus is added. The environmental factors for experiment are chosen under the actual conditions of daily life.

It seems that the value of heart rate relates to the room temperature. The finger pulse amplitude is reduced obviously when the stimulus factors are exposed. It means that there are big loads to a body during stimulus exposure. From these measurements, we found that a finger pulse wave is one of the effective method in explaining a physiological change of body. We obtained some reasonable experimental results of physiological change of human body by physical environmental stimulus. From these studies, physiological evaluation methods are proposed for environmental factors. We have confidence that there is comparatively in a close relationship to the psychological evaluation, but its concrete results of analysis using psychological response will be postponed till next time. At least, some unified theory from a bottom-up way viewpoint

which will solve the above experimental results has to be found based on this fundamental study on physical -> physiological -> psychological effects. This study contributes to the enlightenment regarding the influence of heat, noise and lighting on physiological effects. Further studies should be concerned with precision of physiological combined effects of environmental conditions.

REFERENCES

[1] C.Ohkubo, K.Miyazaki and Y.Osada, Bull. Inst. Publ. Health Jpn. 25, 1 (1976)
[2] G.Jansen, G.Notbohm and S.Schwarze, J. Acoust. Soc. Jpn.(E) 14, 3 (1993)
[3] S.Sugimoto, J. Illum. Engng. Inst. Jpn. 65, 4 (1981)
[4] H.Iwashige, H.Ogawa and M.Ohta, Proc. of International Congress on Sound and Vibration, No.253 (2005)
[5] S.S.Stevens, Psychophysics (Transaction Books, New Brunswick, 1986)
[6] H.Iwashige, H.Ogawa and M.Ohta, Proc. of International Congress on Sound and Vibration, 3843-3850 (2003)
[7] H.Iwashige and M.Ohta, Proc. of International Congress on Sound and Vibration, 1389-1392 (1996)
[8] H.Iwashige and M.Ohta, Proc. of Noise-Con.94, 735-738 (1994)
[9] H.Iwashige and M.Ohta, Proc. of Inter-Noise, 1119-1122 (1992)