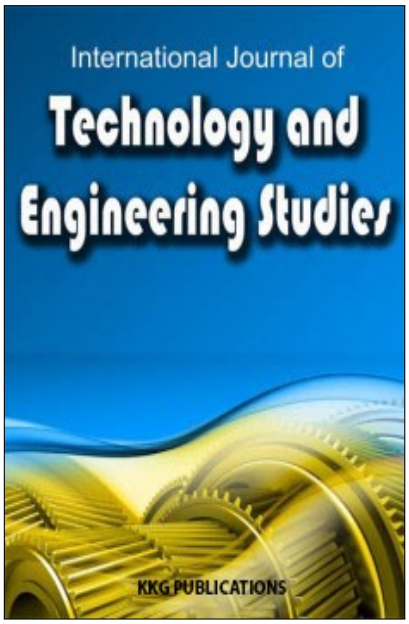

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THE STUDY ABOUT INDOOR TEMPERATURE EFFECT ON PRODUCTIVITY BY BRAINWAVE TYPE OF OCCUPANTS

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Abstract. This research seeks to find the optimal temperature where the occupant's comfortability and productivity according to brain wave type can be improved. In this study, EEG was compared and analyzed in the environmental test room by classifying subjects into two types: A and B. The condition of the environmental test room was in relative humidity 50 [RH%], air current speed 0.02[m/s] and illuminance 1000[lux] with setting up different temperatures from 19[°C] to 30[°C] at intervals of 3[°C]. At 25[°C] for A type and 22[°C] for B type, relative Mα wave, relative Mβ wave and SEF50 were revitalized. wave asymmetry index, stress index and fatigue degree of both types at the 25[°C] and 22[°C] were decreased. It was found that A type was more sensitive than B type about temperature, and also they have different preferences for productivity and concentration about temperature.

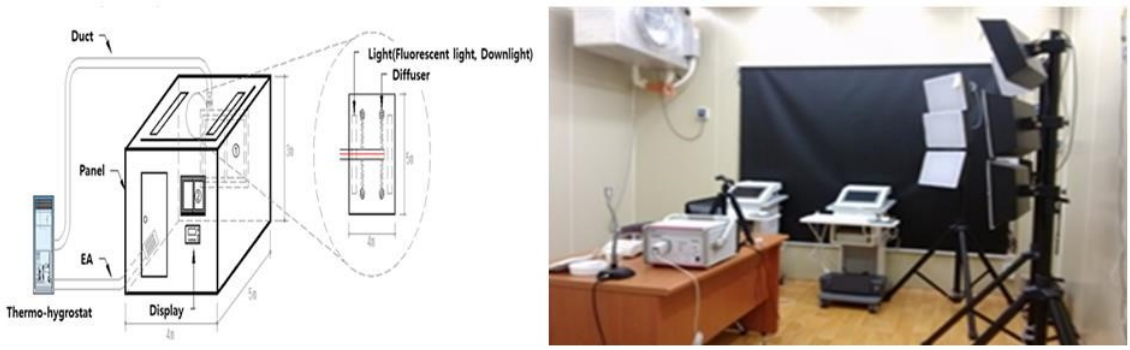
INTRODUCTION

Seeing the study results that indoor temperature, as a major factor influencing comfortability and psychobiological state, not only affects human's emotion the most[1] but also that the effective temperature male and female detect at equal neutral temperature is different [2], it is thought that the optimal temperature for improving productivity differs by brain wave type as well as by gender. Thus, this thesis, by observing concentration pattern through Learning Ability assessment and comparing and contrasting the human body's psychological and biological difference according to temperature change through assessing brain wave (EEG: Electroencephalography, collectively "EEG"), seeks to find the optimal temperature where the occupant's comfortability and productivity according to brain wave type can be improved.

EXPERIMENT METHOD

Conditions of Test Room

The structure of the environmental test room used in this thesis is as (a) in Figure 1, 4x5x3[m]. Its indoor appearance is as (b) in Figure 1, and its specification is as Table 1.



(a) Schematic Diagram (b) Interior Photograph

Fig. 1 . Structure of environmental test room

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TABLE 1
SPECIFICATION OF ENVIRONMENTAL TEST ROOM

Test Condition	Set Range and Error Range
Temperature	-10∼40[°C] 0.5[°C]
Humidity	20∼90[RH%] 3[RH%]
Illumination	0∼2000[lux] 3[lux]

Condition of Subject

This experiment, through examining health condition, selected 10 male university students experiencing no hinderance with physically acting as subjects and the physique condition of subject is as Table 2.

The subjects' activity quantity was set as 1met (metabolic rate: 1met = 58.2W/m^2), which is the activity quantity when sitting and relaxing at comfortable thermal state, and clothing quantity was standardized as approximately 0.7clo (long socks 0.10, panties 0.05, shirts 0.25, long pants for summer 0.28).[3]

TABLE 2
PHYSIQUE CONDITION OF SUBJECT

Subject	Age	Height[cm]	Weight[kg]
Male	25∼28	175∼185	65∼80

Classification Condition of Subject

The subjects were 10 healthy males as Table 3 and were classified into 5 A types and 5 B types based on average scholastic performance.

TABLE 3
CLASSIFICATION CONDITION OF SUBJECT

Subject	Subject Type	GPA
10 Males	5 A Types	Over 4.0 average
		Relative α wave activated in occipital lobe
	5 B Types	Under 2.5 average
		Relative α wave activated in frontal lobe

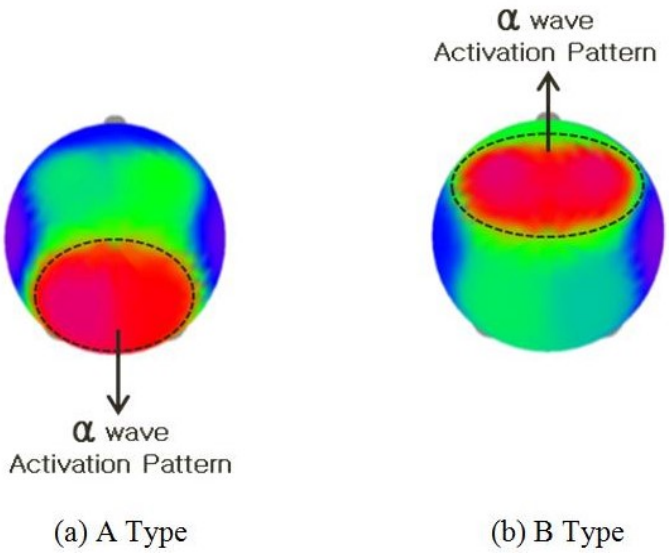

Fig. 2 . Brain mapping of A type and B type

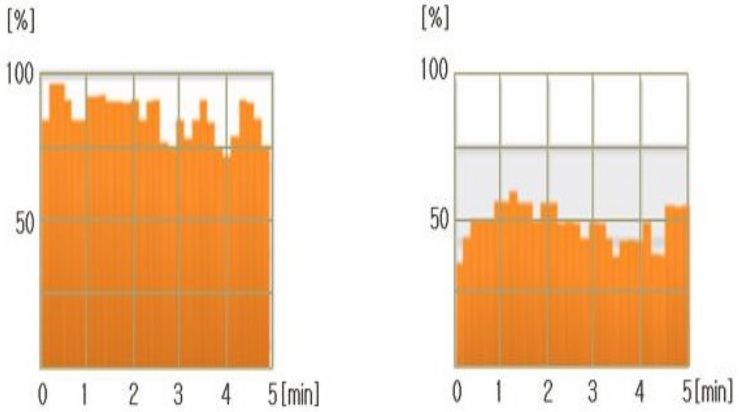

Fig. 3 . Concentration pattern of A type and B type

Using brain wave measurement instrument, the Brain Mapping of the two subject groups at fundamental wave with eyes closed was classified into A type as (a) in Figure 2, where the average GPA is over 4.0 and the Relative wave that brings mental stabilization and maximizes concentration is activated in the occipital lobe [4] and in B type as (b) in Figure 2, where the average GPA is under 2.5 and the Relative wave activation is high in the frontal lobe.

At the fundamental wave condition with eyes closed, A type with over 4.0 GPA average as (a) in Figure 3 seemed to maintain over 90% concentration level, however, B type with under 2.5 GPA average as (b) in Figure 3 could not exceed 50% concentration level. Accordingly, this thesis classifies the subjects into A type with high average GPA and high concentration level and high Relative wave activation level in the occipital lobe, and B type with low average GPA and low concentration level and high Relative wave activation level in the frontal lobe.

Condition and Method of Measuring the Reaction of Body

Condition of measuring the reaction of body

Under the same condition of relative humidity 50 [RH%], illumination 1,000[lux] and air current speed 0.02[m/sec][5], the comfortability and productivity change was observed through human body's brain wave change according to temperature change.

The temperature change in the test was varied from 19[°C] to 31[°C] at intervals of 3[°C], and each subject was measured for the EEG and HRV of the fundamental wave for five minutes with eyes closed and the learning ability was measured with eyes open for five minutes.

Brain Wave Measurement

It was measured for five minutes using PolyG-I (Laxtha Inc.), and compared andcontrasted the brain wave of 8 channels through International 10-20 System as Figure 4.[6]

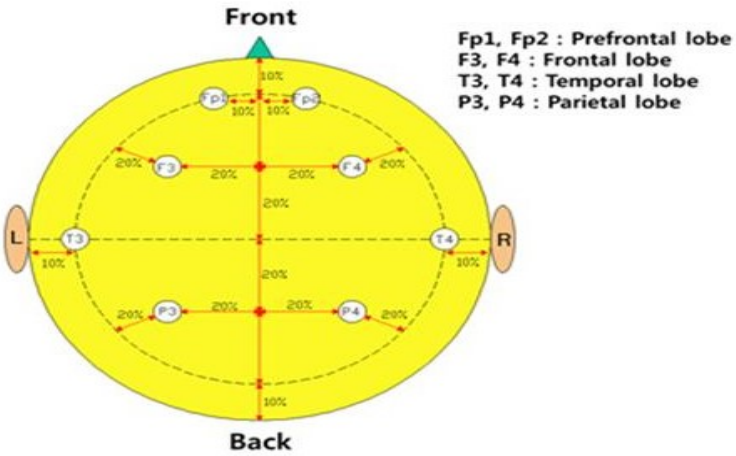

Fig. 4 . International 10-20 system

Learning Ability Measurement

The concentration pattern was observed for five minutes right after brain wave measurement under the same condition with brain wave measurement using LXSMD3-1 (Laxtha Inc.).

Stress, Fatigue and HRV Measurement

It was measured for five minutes using SA-6000 (Medicore Co. Ltd., Korea), which is automatic nervous system measuring instrument.

Statistics

The statistics used Analysis of Variance (collectively "ANOVA") which, when seeking to compare more than 2 groups, tests hypothesis by comparing the dispersion within a group or between groups.

RESULTS

Comfortability Change according to Temperature Change

The result of measuring asymmetry index A_2 and Relative Mα wave (10∼11.99[Hz]) according to temperature change is as Figure 5, 6.

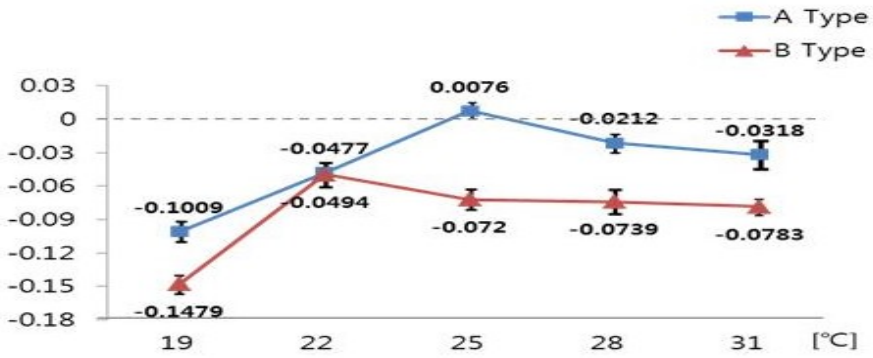

Fig. 5 . Variance of A_2 asymmetry index due to temperature variance

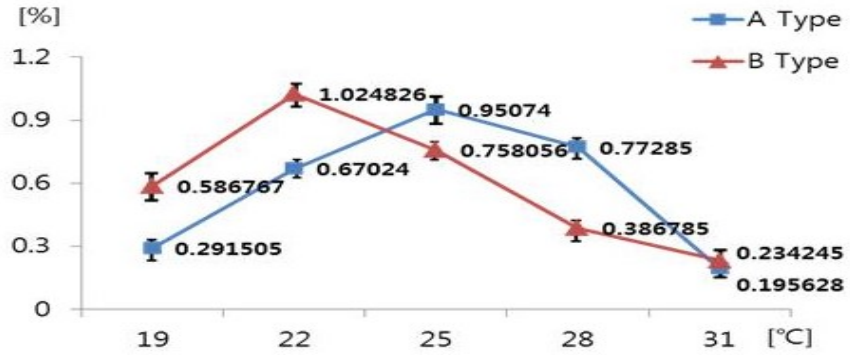

Fig. 6 . Activity variance of relative mα wave due to temperature variance

When the positive emotion and negative emotion come to a balance, the asymmetry index A_2 gets close to "0" and emotionally gets stabilized [7], and Relative Mα wave (10∼11.99[Hz]) occurs in deep meditation, mind concentration and stabilized state.[8] As in Figure 5, 6, as the temperature changes, the asymmetry index A_2 of A type and B type approaches "0" most closely at 25[°C] and at 22[°C], becoming 0.0076 and -0.0494 respectively and as of the Relative Mα wave, A type is most activated up to 0.95074[%] at 25[°C] and B type up to 1.024826[%] at 22[°C]. Thus it can be found that the A type at 25[°C] and B type at 22[°C] become most mentally and emotionally stabilized.

Since ANOVA statistics verification result of Relative M wave shows in Table 4 that the significance probability(P) of A type and B type is 0.028** and 0.007** respectively, which is smaller than 0.05, it can be noted as statistically significant.

TABLE 4
STATISTICAL ANALYSIS OF RELATIVE M WAVE

	A Type	B Type
Sum of Squares	0.116	0.346
DF	24	24
Mean Square	0.012	0.057
F Value	4.094	11.782
Pr >F	0.028**	0.007**

**$p<0.05$

Concentration Level Change according to Temperature Change

The result of measuring Relative Mβ wave (15∼19.99[Hz]) and SEF50(4∼50[Hz]) according to temperature change is as Figure 7, 8. Since as temperature changes, the Relative Mβ wave of A type becomes most activated up to 0.2953[%] at 25[°C] and of B type up to 0.3064[%] at 22[°C] respectively, and the SEF50 of A type becomes the highest at 25[°C] up to 78.4355[%] and of B type at 22[°C] up to 81.127[%], it is found that the concentration level and cognitive ability of A type and B type become the highest at 25[°C] and at 22[°C] respectively.[9]

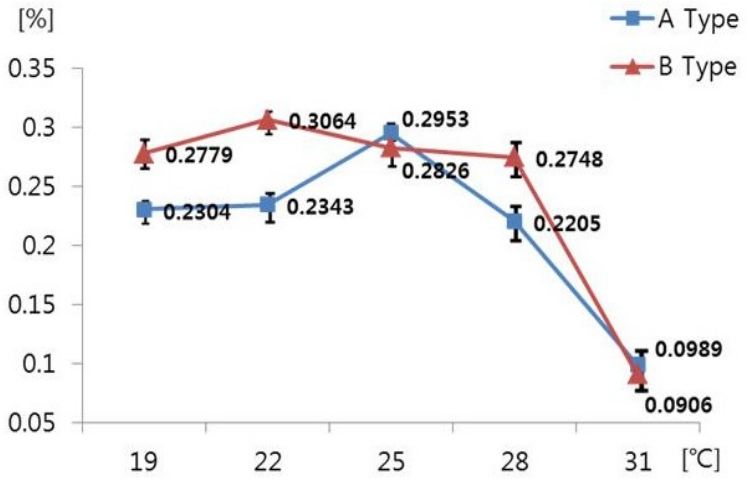

Fig. 7 . Activity variance of relative Mβ wave due to temperature variance

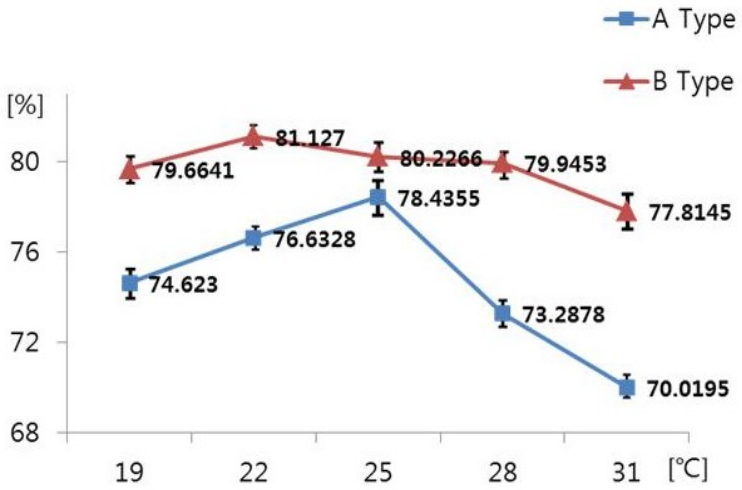

Fig. 8 . Variance of SEF50 due to temperature variance

Since ANOVA statistics verification result of Relative Mβ wave shows in Table 5 that the significance probability(p) of A type and B type is 0.006*, 0.003**, which is smaller than 0.1 and 0.05 respectively, it can be noted as statistically significant, and since ANOVA statistics verification result of SEF50 shows in Table 6 that the significance probability(p) of A type and B type is 0.045**, 0.053* respectively, which is smaller than 0.05 and 0.1, it can be noted as statistically significant.

TABLE 5
STATISTICAL ANALYSIS OF RELATIVE Mβ WAVE

	A Type	B Type
Sum of Squares	0.012	0.009
DF	24	24
Mean Square	0.002	0.001
F Value	6.731	8.052*
Pr >F	0.006*	0.003**

*p<0.1, **p<0.05

TABLE 6
STATISTICAL ANALYSIS OF SEF50 WAVE

	A Type	B Type
Sum of Squares	55.473	39.857
DF	24	24
Mean Square	8.571	4.501
F Value	5.796	3.356
Pr >F	0.045**	0.053*

*p<0.1, **p<0.05

Stress Change According to Temperature Change

The result of measuring stress and fatigue according to temperature change is as Figure 9, 10. Since as temperature changes, the stress index of A type decreases the most down to 91.5 at 25[°C] and of B type down to 92 at 22[°C] , and the fatigue of A type decreases the most down to 64[%] at 25[°C] and of B type down to 69[%] at 22[], it is found that the stress and fatigue of A type and B type become the lowest at 25[°C] and 22[°C] respectively [10].

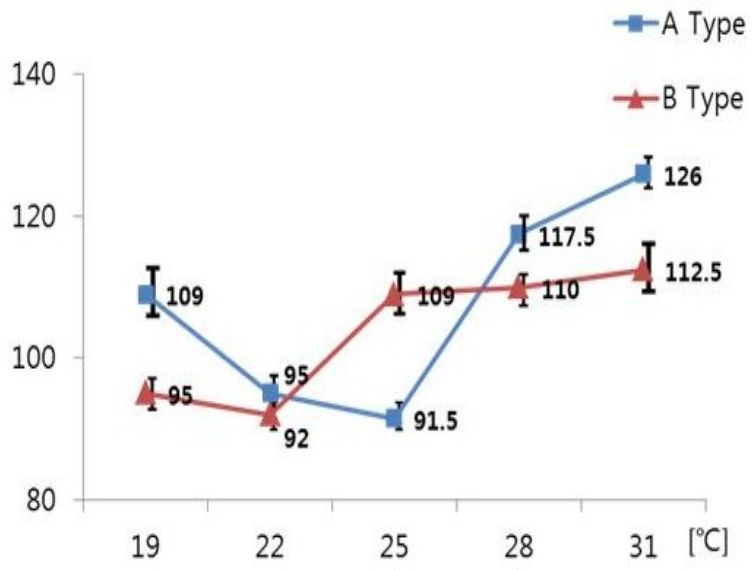

Fig. 9 . Variance of stress index due to temperature variance

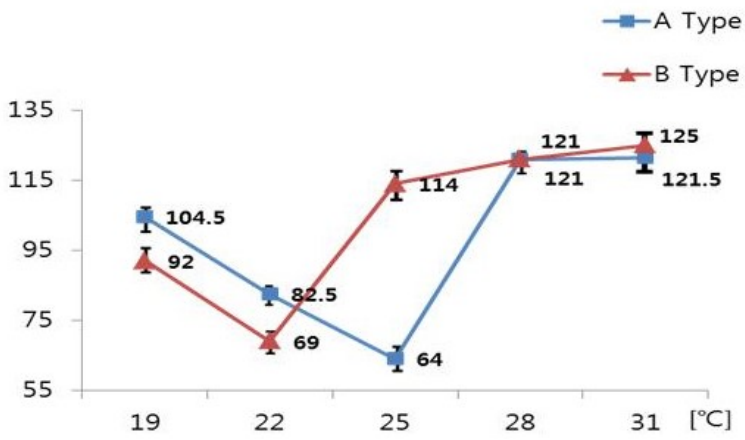

Fig. 10 . Variance of fatigue degree due to temperature variance

Body-index Analysis according to Temperature Change

As of A type at 31[°C] contrary to 25[°C] , Relative Mα wave showed 79% decrease, SEF50 11% decrease, Stress 38% decrease, and as of B type at 31[°C] contrary to 22[°C] , Relative Mα wave showed 69% decrease, SEF50 3% decrease and Stress 3% increase. Thus, contrasting the comfortable temperature and relatively uncomfortable temperature, it can be noted that the increase or decrease level of A type is bigger than that of B type, and through this result, it can be found that A type reacts more sensitively to temperature change.

CONCLUSION AND RECOMMENDATIONS

In the environmental test room with relative humidity 50 [RH%], illumination 1,000[lux] and air current speed 0.02[m/sec], under the condition of changing the temperature from 19[°C] to 31[°C] at intervals of 3[°C], subjects were classified into A type and B type and the brain wave, comfortability, concentration, and stress were measured and analyzed.

As a result of the measurement, A type at 25[°C] and B type at 22[°C] had the most activated level of Relative Mα wave and Relative M wave, and the left right brain asymmetry index, stress index and fatigue were most decreased.

It could be found that the preferred optimal temperature differs according to the brain wave type and that the type with developed Relative wave activation level in occipital lobe was more sensitive to temperature than the type with developed frontal lobe.

Declaration of Conflicting Interests

There are no conflicting interests in this study.

Acknowledgment

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