

Development of the multi-sensory augmented DDC (Direct Digital Control) to improve the cognitive Characteristic of the Nursery Facilities

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Abstract

In this study, EEG and Vibra image are compared and analyzed in the environmental test room due to the multi-sensory stimulation of sound fluctuation of 4 types, sound volume of 3 types, color temperature of 3 types and aroma of 3 types. The paper aims to find optimal multi-sensory stimulation and to develop the multi-sensory augmented DDC to increase the cognitive characteristic of the nursery facilities. The condition of the environmental test room was in temperature 25[°C], relative humidity 50[RH%], air current speed 0.02[m/s] and illumination 1000[lux]. The result of this study, at sound fluctuation a=2.1968 music, color temperature 2,700[K], and Lavender scent, relative M β wave and SMR/ θ were increased, and vibra image of tension/anxiety were decreased. Therefore multi-sensory stimulation of sound fluctuation a=2.1968 music, color temperature 2,700[K], and Lavender scent effects to increase the cognitive characteristic. This paper researched to find optimal multi-sensory stimulation and to develop the multi-sensory augmented DDC to increase the cognitive characteristic of the nursery facilities.

Keywords: Cognitive characteristic, DDC, EEG, Multi-sensory stimulation, Vibra image.

Introduction

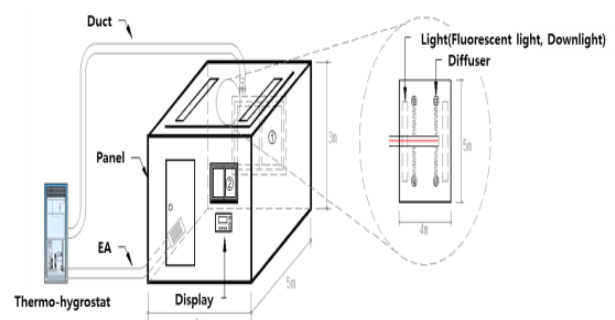
Nowadays, comfort range of the indoor air conditioning and heating is evaluated by amount of human activity, amount of clothing and four factors of thermal environment (temperature, mean radiant temperature, air velocity, humidity).[1] This method evaluates the amenity of indoor thermal environment, and controlling the indoor environment.[2] Human is an organic composite having five senses which are touch, visual, auditory, olfactory, and taste. However, current building in the world is using temperature and humidity sensors in place of human sense for building control. Therefore, multi-sensory augmented DDC(Direct Digital Control) that can stimulate the five senses of humans is developed to increase the amenity, productivity, concentration, and to decrease the energy consumption. Hence, this study conducted single-sensory stimulation by variation of sound fluctuation, color, temperature, and aroma scent in the steady temperature and humidity room with the same conditions in temperature 25[°C], relative humidity

50[RH%], illumination 1,000[lux] and air velocity 0.02[m/sec], which satisfies the comfort zone, by ASHRAE(American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.).

Method

Condition of the environmental test room

The inside image of air-conditioned room in this study is shown in figure 1. Data in the steady temperature and humidity room include temperature -10~40[°C](error range ± 0.5 [°C]), humidity 20~90[RH%](error range ± 3 [RH%]) and illuminance 0~2,000[Lux](error range ± 3 [Lux]).



(a) Schematic diagram



(b) Interior Photograph

Figure 1: Structure fo Environmental Test Room

Condition selection of sense stimulus

In this study, auditory stimulus conditions are selected by sound fluctuation a index(a=2.1968, a=3.1109, a=2.2805 and a=2.9293), and visual stimulus conditions are selected by color temperature(2,700[°K], 5,000[°K] and 6,800[°K])[3], and olfactory stimulus conditions are selected by aroma scent(Lemon, Rosemary and Lavender).[4]

Measurement and analysis of physiologic signal

The subjects in this experiment were 6 selected kindergarten students at the ages of 6. The subjects' activity level was set to be 1met(metabolic rate: 1met=58.2 W/m²) as the active mass when taking rest by being seated on a chair in the comfortable thermal condition. The clothing-weight state was unified with about 0.65clo.[5] The measurement of brain wave was utilized PolyG-I(Laxtha Inc.), which is the specialized bio-signal measuring equipment. To analyze quantitative brain wave, the measurement was made for 5 minutes per 1 time based on the analytical unit. The measurement of vibra image was utilized Vibra image 7 program(Vibra system Inc.), which is measured and analyzed three parameters of tension & anxiety, stress, and balance by webcam.[6]

Result of experiment

Variation of the cognitive characteristic according to sound fluctuation

The outcome of measuring relative Mβ, SMR/θ in EEG and tension & anxiety in vibra image according to variation of sound fluctuation is as Fig. 2. Relative Mβ was increased average 14.45% and SMR/θ was increased average 7% in fluctuation a=2.1968 sound source compared to being exposed to sound fluctuation. Tension & anxiety was also decreased average 8.26%. The result of ANOVA statistical verification on relative Mβ and SMR/θ is as Table 1. The value of significance probability(P) stands at 0.071 and 0.044, respectively, thereby being able to be known to be statistically significant.

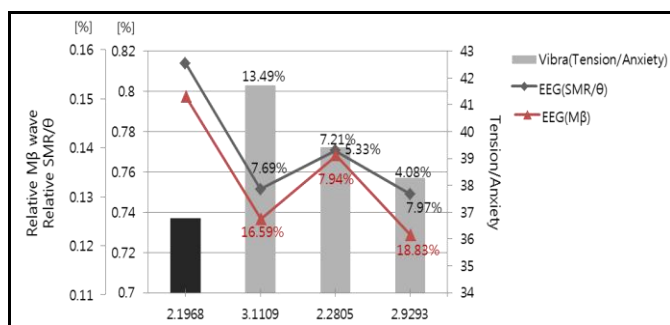


Figure 2: Variation of relative Mβ, SMR/θ, and Tension & Anxiety due to sound fluctuation

Table 1: Statistical analysis of relative Mβ and SMR/θ

	Sum of Squares	DF	Mean Square	F Value	Pr>F
Relative Mβ	0.003	23	0.001	18.133	0.071*
SMR/θ	0.084	23	0.008	6.281	0.044**

Variation of the cognitive characteristic according to sound volume

The outcome of measuring relative Mβ, SMR/θ in EEG and tension & anxiety in vibra image according to variation of sound volume is as Fig. 3. Relative Mβ was increased average 27.93% and SMR/θ was increased average 11.23% in sound volume 30[dB] compared to being exposed to sound volume. Tension & Anxiety was also decreased average 13.11%. The result of ANOVA statistical verification on relative Mβ and SMR/θ is as Table 2. The value of significance probability(P) stands at 0.028 and 0.018, respectively, thereby being able to be known to be statistically significant.

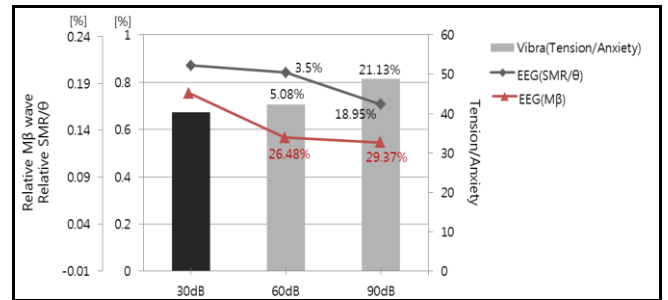


Figure 3: Variation of relative Mβ, SMR/θ, and Tension & Anxiety due to sound volume

Table 2: Statistical analysis of relative Mβ and SMR/θ

	Sum of Squares	DF	Mean Square	F Value	Pr>F
Relative Mβ	0.002	17	0.001	14.307	0.028*
SMR/θ	0.126	17	0.030	7.456	0.018*

Variation of the cognitive characteristic according to color temperature

The outcome of measuring relative Mβ, SMR/θ in EEG and tension & anxiety in vibra image according to variation of color temperature is shown in Fig. 4. Relative Mβ wave was increased average 23.54% and SMR/θ was increased average 21.67% in color temperature 2,700[°K] compared to being exposed to color temperature. Tension & Anxiety was also decreased average 8.54%. The result of ANOVA statistical verification on relative Mβ and SMR/θ is shown in Table 3. The value of significance probability(P) stands at 0.08 and 0.082, respectively, thereby being able to be known to be statistically significant.

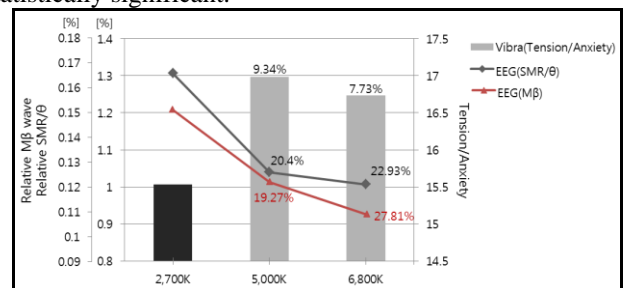


Figure 4: Variation of relative Mβ, SMR/θ, and Tension & Anxiety due to color temperature

Table 3: Statistical analysis of relative M β and SMR/ θ

	Sum of Squares	DF	Mean Square	F Value	Pr>F
Relative M β	0.001	17	0.003	7.723	0.080*
SMR/ θ	0.053	17	0.011	6.002	0.082*

Variation of the cognitive characteristic according to aroma scent

The outcome of measuring relative M β , SMR/ θ in EEG and tension/anxiety in vibra image according to variation of aroma scent as shown in Fig. 5. Relative M β was increased average 17.59% and SMR/ θ was increased average 16.66% in lavender scent compared to being exposed to aroma scent. Tension & anxiety was also decreased average 11.11%. The result of ANOVA statistical verification on relative M β and SMR/ θ is shown in Table 4. The value of significance probability(P) stands at 0.023 and 0.012, respectively, thereby being able to be known to be statistically significant

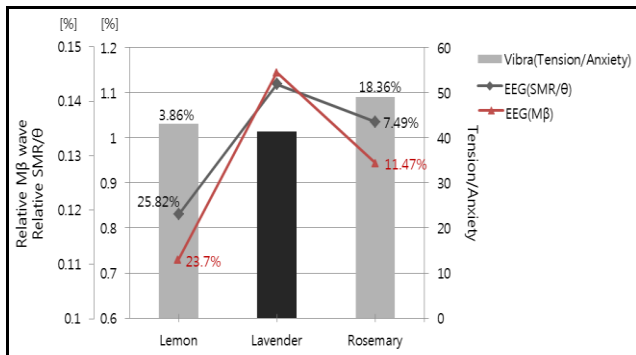


Figure 5: Variation of relative M β , SMR/ θ , and Tension & Anxiety due to aroma scent

Table 4: Statistical analysis of relative M β and SMR/ θ

	Sum of Squares	DF	Mean Square	F Value	Pr>F
Relative M β	0.003	17	0.001	26.265	0.023*
SMR/ θ	0.088	17	0.020	12.581	0.012*

Development of the multi-sensory augmented DDC(Ditect Digital Control)

The multi-sensory augmented DDC which is using temperature, humidity, illumination and noise sensor measured indoor condition. Also, the multi-sensory augmented DDC connected to a controlling algorithm based on personal computer with ModBUS protocol. It controlled cooling, heating, humidity, illumination, color temperature, sound source, sound volume, aroma scent and video. Controlling algorithm condition of the multi-sensory augmented DDC was created by experiment of single-sensory stimulation. The multi-sensory augmented DDC connection diagram is as Fig. 6.

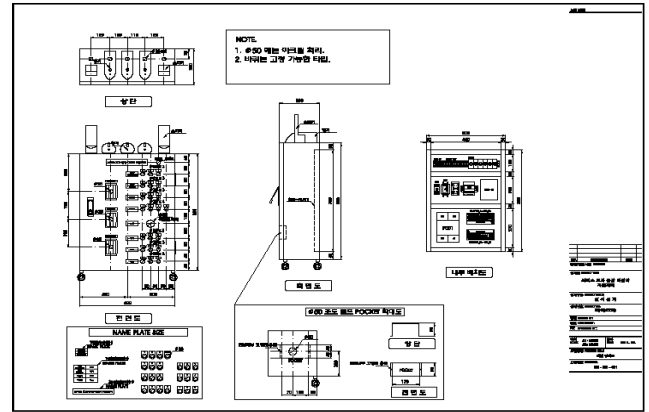


Figure 6: Multi-sensory augmented DDC connection diagram

Conclusion

As a result of the experiment, the condition of sound fluctuation $a=2.1968$, color temperature $2,700[^\circ K]$ and lavender scent is effective to increase concentration and cognitive characteristic, and to decrease tension & anxiety. The multi-sensory augmented DDC and demo simulator to improve the cognitive characteristic of the nursery facilities are developed by the result. Current building in the world is using temperature and humidity sensors in place of human sense for building control. However, in the future, it is expected that cognitive characteristic, such as amenity, concentration, and productivity, and energy saving is increased by the building automatic control system which can stimulate five senses of human.

This study selected 4 sound sources according to sound fluctuation, 3 sound volumes, 3 lightings according to color temperature and 3 aroma scents to improve amenity, concentration and productivity of human. However, given being performed a research and a consideration by using more various stimulation conditions, the optimal multi-sensory stimulation condition is judged to be possibly found in consideration of an occupant's mental state along with the objective of space.

Acknowledge

This work is supported by the National Strategic R&D Program for Industrial Technology(10044828, Development of augmenting multisensory technology for enhancing significant effect on service industry), funded by the Ministry of Trade, Industry and Energy(MOTIE).

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