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# A Study on the Effect of Environment Sound on Human Thermal Sensation

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**Abstract**. In recent years, there have been several devastations caused by the global climate change. Global climate change is considered as relating to the global warming and is becoming a serious problem. Global warming is related to the increase of carbon dioxide. The increase of the carbon dioxide is caused by the energy consumption increase. In addition, air conditioning dominates the large ratio of the energy consumption. Furthermore, according to the huge earthquake happened on March 11, 2011 in Japan, the country's energy policy is facing a turning point, which is to establish less harmful and less energy based society than ever. For that reason, to decrease the energy consumption, how to reduce the energy consumption by the air-conditioning is an important issue. There have been several research relating to the topic. However, those researches did not study on the effect of the environment sound on the human thermal sensation. For that reason, the purpose of this research is to clarify the effect of environment sound on human thermal sensation. As the result of this study, the environment sounds, such as "Rain" "Stream" "Water Bamboo" showed the effect to lower the human thermal sensation.

## 1. Introduction

Climate change is getting more and more serious issue in the world. The change is known as caused by increase of GW gasses, such as carbon dioxide which is the largest exhaust by human activity relating to the energy consumption in the world. In addition, the energy usage of buildings shows the largest ratio in the consumption.

According to the fact that most of energy consumption is caused by the buildings equipment, it is important to reconsider the equipment.

Focusing on the building equipment, air conditioning shows the large ratio. For that reason, it is important to reduce the energy consumption by air conditioning system.

To reduce the energy consumption, there are many research targeted the effect of water surface, hue-heat, and floor cooling system as followings.

Fukagawa et al. [1] carried out a research targeting the effect of irrigation pond on surrounding thermal environment by long term outdoor measurement of thermal environment. This research grasped the effect of irrigation pond to lower the surrounding temperature, about 1.5 degree centigrade as the maximum.

In addition, Matsubara et al [2] carried out a research targeting hue-heat by experiments and clarified that the effect of visual stimulus causes 0.3 degree centigrade difference. Furthermore, to clarify the effect of artificial and non-artificial factors as visual stimulus on human thermal sensation, Kurazumi et al [3] had an experiment and grasped the tendency.
There are also the researches on the composite environment of thermal and hue-heat impression in the several room temperatures. Ohno et al [4] tried to grasp the interaction of the subject by experiment.
Fukagawa et al. showed that the effect of water on the temperature is smaller than how the human feels and detects. In addition, the result of Matsubara et al. showed that the human's thermal sensation can be affected by the visual stimulus, such as color. Furthermore, Kurazumi et al. clarified the difference of the effect by artificial and non-artificial visual stimulus on human's neutral temperature.
Hishida et al. and Ohno et al. grasped the interaction of the composite environment. According to the results, there might be some possibilities that the effect of water landscape can be not only as physical effect on surrounding temperature but also as the effect on human's thermal sensation.
For that reason, the purpose of this research is to clarify the effect of sound on human thermal sensation.

## 2. Experiment overview

This research is studied by a subject experiment. The experiment was carried out in the artificial weather chamber in Kyushu Sangyo University in Japan, in summer in 2014. For the experiment 6 male students were selected as subject. They were age of 20 and 21, and were asked to wear prepared unified clothes, which are short sleeve T-shirt and short pants made of 100% cotton.
During the experiment, subjects were asked to sit on a chair calmly and asked to fill in the declaration vote after environment sound was played for approximately 5 minutes. Then asked to fill in the declaration vote which is composed of SD method part and thermal sensation part.
Totally of 9 different sound conditions, including no environment sound, were set for this experiment. The details of sounds including the sound level is shown in Table 1. The 30 adjective pairs used for SD method is shown in Table 2.
This experiment targeted slightly uncomfortable thermal condition. For that reason, temperatures set for the experiment were 28 and 30 degree centigrade. The moisture was controlled to be between 50 to 60%.
The results of the evaluations are averaged in each temperature setting and the sound type, such as water-related and non- water related sound, are shown in Fig.1 and 2.
By looking at Fig. 1, which is the result of 30 degree centigrade setting, it is obvious that the water-related environment sounds marked higher than the other non-related sounds. In addition, the items which are "Fresh - Dry" and "Cool - Hot" showed big differences.
By looking at Fig.3, which is the result of 28 degree centigrade setting, there is not obvious tendency

Table 1. Utilized Environment Sounds

| Type of Environment Sound | Inndication | dB |
|---|---|---|
| Background Noise | (BG) | - |
| Water Filled Bamboo | (WB) | 66.0 |
| Stream | (ST) | 60.0 |
| Rain | (RA) | 59.0 |
| Big Wave | (BW) | 68.0 |
| Water Fall | (WF) | 60.0 |
| Tree Sound | (TS) | 55.0 |
| Tayphoon | (TY) | 61.0 |
| Crow Cry | (CC) | 58.0 |

Table 2. Adjective Pairs for SD Method

| | | | | | |
|---|---|---|---|---|---|
| Enjoyable | – | Boaring | Attractive | – | Dis-attractive |
| Crisp | – | Gloomy | Fast | – | Slow |
| Beautiful | – | Ugly | Airy | – | Heavy |
| Open | – | Closed | Active | – | Inactive |
| Bright | – | Dark | New | – | Old |
| Pure | – | Cloudy | Cold | – | Hot |
| Near | – | Far | Changeable | – | Fixed |
| Necessary | – | Unnecessary | Natural | – | Artificial |
| Rich | – | Poor | Healthy | – | Ill |
| Energetic | – | Docile | Noble | – | Cramped |
| Gentle | – | Tight | Calm | – | Rough |
| Comfortable | – | Discomfortable | coexistensive | – | Exclusive |
| Big | – | Small | Fresh | – | Dry |
| Familiar | – | Unfamiliar | Quiet | – | Bustling |
| Likable | – | Dislikable | Masculine | – | Feminine |

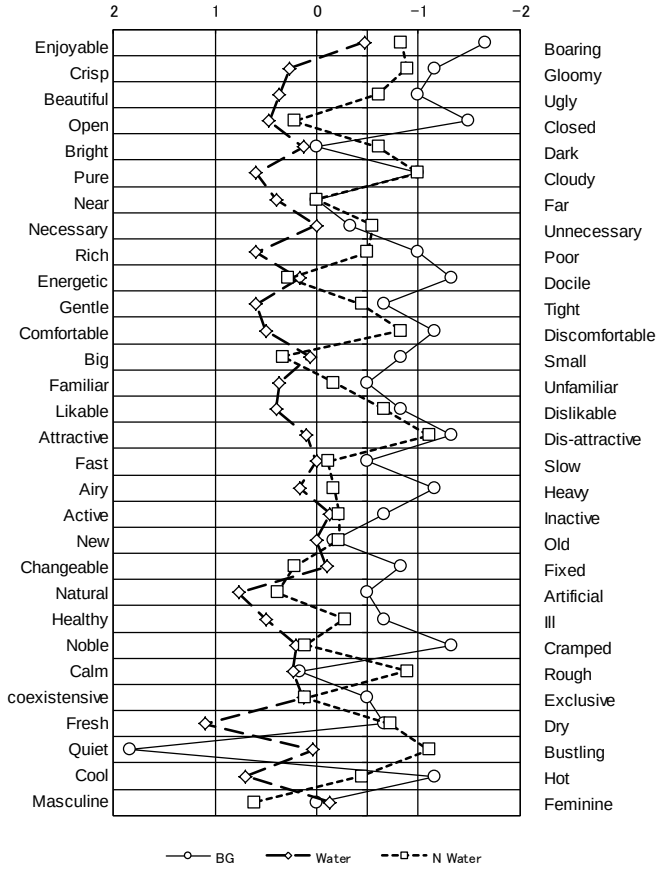


Figure 1. Average Score of Image Evaluation at 30 degree centigrade

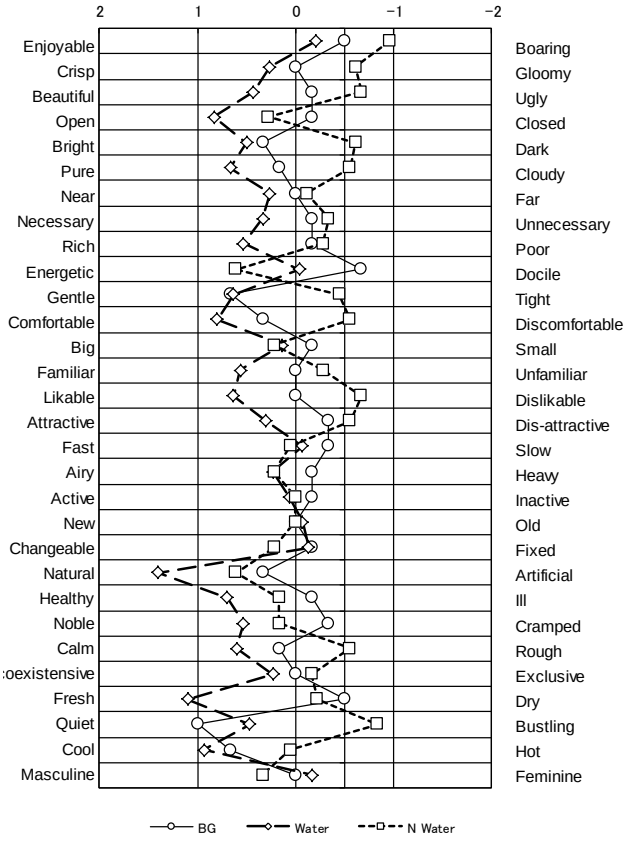


Figure 2. Average Score of Image Evaluation at 28 degree centigrade

as 30 degree setting. However, the items which are “Fresh - Dry” and “Cool - Hot” showed little bigger differences than the other items.

## 3. Analysis of evaluation structure

To analyze the evaluation structure of the subjects, factor analysis was taken. “Bartlet method” was utilized for the analysis.

For this analysis, the results of all the environment sounds and all the temperature settings were combined and were analyzed. The result of the analysis, the factor loading matrix, is shown in Table 3.

First, the analysis was done by setting the eigenvalue as more than 1.0 and obtained 5 factors which could not clearly be identified. Then changed the setting of factor number down from 5 to 2. When the factor number is set as 3, clearly identified factors were obtained.

The first factor is named as “Emotion” because the items such as “Pure”, “Comfortable” and “Crisp” which are relating to human emotion.

The second factor is named as “Movement” because the items, such as “Fast”, “Energetic” and “Active” are categorized.

The third factor is named as “Space” because the items such as “Open” “Coexistence”, and “Noble” are categorized.

## 4. Analysis of average factor score

The point diagrams of average factor score in each environment sound differed in each temperature setting are shown in Fig. 3 and 4.

Table 3. Result of Factor Analysis

| Factor / Adjective | 1st Factor Emotion | 2nd Factor Movement | 3rd Factor Space |
|---|---|---|---|
| Pure | 0.881 | -0.172 | 0.214 |
| Comfortable | 0.873 | -0.136 | 0.239 |
| Crisp | 0.857 | -0.110 | 0.174 |
| Beautiful | 0.854 | -0.114 | 0.212 |
| Gentle | 0.839 | -0.261 | 0.047 |
| Likable | 0.816 | -0.071 | 0.268 |
| Necessary | 0.744 | 0.080 | 0.141 |
| Attractive | 0.742 | -0.037 | 0.299 |
| Cool | 0.740 | 0.165 | 0.076 |
| Calm | 0.728 | -0.436 | 0.174 |
| Bright | 0.705 | -0.028 | 0.116 |
| Fresh | 0.675 | 0.014 | 0.199 |
| Quiet | 0.670 | -0.569 | -0.100 |
| Healthy | 0.670 | 0.086 | 0.525 |
| Masculine | -0.665 | 0.130 | 0.094 |
| Rich | 0.661 | 0.097 | 0.356 |
| Enjoyable | 0.588 | 0.265 | 0.169 |
| Airy | 0.563 | 0.236 | 0.059 |
| Familiar | 0.533 | -0.090 | 0.457 |
| Natural | 0.524 | 0.281 | 0.374 |
| Near | 0.155 | 0.078 | 0.018 |
| Fast | 0.017 | 0.684 | -0.357 |
| Energetic | -0.353 | 0.671 | 0.171 |
| Big | -0.200 | 0.665 | 0.064 |
| Active | 0.125 | 0.582 | 0.134 |
| New | 0.184 | 0.282 | 0.009 |
| Open | 0.460 | 0.090 | 0.671 |
| Coexistensive | 0.326 | -0.175 | 0.624 |
| Noble | 0.392 | 0.372 | 0.539 |
| Changeable | -0.108 | 0.091 | 0.488 |

Looking at Fig. 3 which is 30 degree centigrade setting, by focusing on the 1st factor, 4 of the 5 water related sounds marked positive score. Non-water related sounds, on the other hand, marked negative score. Beside the 1st factor, on the 2nd and the 3rd factor, there was no clear tendency.
Looking at Fig. 4 which is 28 degree centigrade setting, by focusing on the 1st, all the water related sounds showed the positive score. However, no sound also showed the positive score, which is close to water fall sound. Furthermore, the 2nd factor and the 3rd factor did not show the obvious tendency as the 1st factor.
By the analysis of the average factor score in each sound, some tendencies are confirmed on the 1st and the 2nd factor.

## 5. Analysis on the correlation of the factors and thermal sensation vote

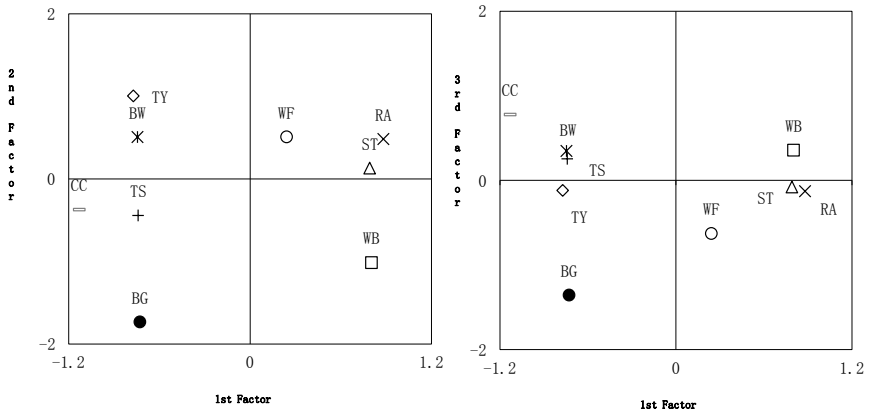


Figure 3. Point Diagrams of Average Factor Score at 30 degree

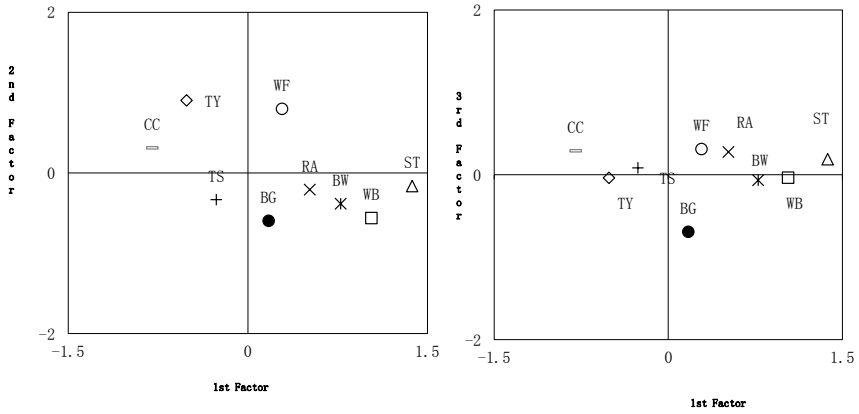


Figure 4. Point Diagrams of Average Factor Score at 28 degree

Table 4. Correlation of the Factors and Thermal Sensation Vote

| | | 1st Factor Emotion | 2nd Factor Movement | 3rd Factor Space |
|---|---|---|---|---|
| Thermal Sensation | Correlation Coefficient | -.397** | -.315** | -.048 |
| | Significance Probability | .000 | .001 | .623 |
| | Number | 108 | 108 | 108 |

** shows the 1% significance coefficient of correlation

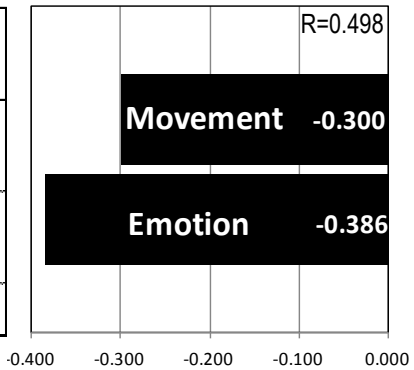


Figure 5. Result of Multiple Linear Regression Analysis

To analyse the correlation among the 3 factors and thermal sensation vote, Pearson's correlation analysis was taken. The result is shown in Table 4.

By focusing on thermal sensation vote, “Emotion” and “Movement” showed significance coefficient of correlation of 1%. In addition, “Emotion” showed the bigger value than “Movement”.

According to the results of the previous chapters, it is possible to say that the essences which are evaluated as “Emotion” by the subjects affect the thermal sensation of the humans. Furthermore, the effect appears both in summer and winter.

## 6. Definite factor analysis on thermal sensation vote

To analyze the definite factor on thermal sensation vote, multiple linear regression analysis was taken. For this analysis, 2 factors, which showed the 1% significance coefficient of correlation by the Pearson's correlation analysis, were utilized.

The score of the thermal sensation was set as dependent variable. The scores of the 2 factors were set as independent variables. The result of multiple linear regression analysis is shown in Figure 6.

The multiple correlation coefficients by the analysis showed 0.498 which can be taken as high reliability by considering the fact that the thermal sensation is in step scale.

The both factors showed negative correlation to the thermal sensation. This means when the factor score increases, the subjects feel that the thermal condition is cooler.

## 7. CONCLUSION

By this research, it can be said that the environment sounds which mark high score in the 1st factor affect the thermal sensation more than the other sounds. In addition, the 3rd factor does not clearly affect the thermal sensation.

The obtained 4 results are as follows.

1. By the factor analysis 3 factors were obtained from the environment sounds.
2. 2 of the 3 factors showed negative affect with the significant coefficient correlation on the thermal sensation and the 1st factor showed the largest ratio. This tendency is more obvious under 30 degree centigrade setting than 28.
3. Among all the environment sounds, “Rain” “Stream” “Water Bamboo” marked the large score on the 1st factor
4. The sounds mentioned above have possibility to lower the human thermal sensation and increase the thermal comfort. However, the tendency is more obvious at 30 degree centigrade which means that the sound is more effective on the slightly hot thermal condition.

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**References**

[1] K.Fukagawa et al. Hiroshima International University, *Architectural Institute of Japan Refereed Journal* Vol. 605 pp.91-98, A study on the differences on the formation of the temperature among urban area, rural area and around irrigation ponds in a developing city, 2005

[2] N.Matsubara et al., Kyoto Prefecture University, *The Japanese Psychological Association Conference* pp.570-571, 2004,

[3] Y.Kurazumi et al., Sugiyama Jogakuen University, *Japanese society of Biometeorology Refereed Journal* Vol.48-4 pp.129-144, Psychological effects of the environmental stimuli on thermal sense in outdoor spaces, 2011

[4] H.Ohno H et al., Nagoyaeiyou college, *Architectural Institute of Japan Refereed Journal* No.374 pp.8-18, The Interactions between Thermal Sensation and Hue-Heat Impression Under Various Thermal Conditions, 1987

[5] K.Ahmed, University of Engineering and Technology of Dhaka, *Energy and Buildings* Vol 35, Issue 1, pp.103-110, Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments, 2003

[6] K.Fukagawa et al. Kyushu Sangyo University, Ecology Environment & Conservation International Journal Vol 23, Suppl. Issue pp. S31-S36, A study on the effect of visual stimuli on human thermal sensation – targeting water landscape, 2017