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A Study on the Evaluation Tendency of Thermal Sensation in Tropical Region - Targeting short time residents -

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Abstract. Climate change is getting more and more serious issue in the world. This is known as caused by the increase of carbon dioxide. To stop the increase, many countries agreed to the Paris Agreement in 2015. When to discuss the climate change, temperature drop and increase are focused more often. The big change of the temperature, especially the rise of the temperature, causes the more usage of air conditioning system, and it also causes more energy consumption. In addition, the usage of the air conditioning system is affected by both indoor and outdoor thermal environment. The temperature setting of air conditioning system tends to be lower in the countries situated in tropical region than the countries in the other region. This happens because the thermal sensation of human is easily affected by the outdoor environment. For that reason, to grasp the tendency of thermal sensation in outdoor space is important. In addition, the tendency of short time residence is necessary to wipe out the influence of the thermal environment adjustment by long time living. For that reason, this research targeted the thermal evaluation tendency of short time residents in Bangkok and carried out subject experiments in outdoor spaces to develop landscape design method. As the result of analysis, a different tendency was grasped at one of the measuring points with open sky.

1. Introduction

According to the global climate change, many countries are facing serious problems, especially in the countries suffering the rise of the temperature such as Japan. The rise of temperature causes more deaths by heat stroke in summer in both indoor and outdoor. Furthermore, it also causes more energy consumption and causes the exhaustion of more carbon dioxide.

The death by the heat stroke is caused by losing the balance of body temperature. In addition, the balance of body temperature of human is mainly affected by the heat transfer between human body and the air. However, the thermal sensation of human is also an important factor.

For instance, when the thermal sensation reaches to hot, the human body starts to sweat to control the body temperature, then the body temperature is to be adjusted. For that reason to estimate the thermal sensation is important. However, the thermal sensation is affected by both physical and psychological factors.

There have been many researches targeted physical thermal factors. On the contrary, there are not many research targeting the psychological factors.

Matsubara et al. [1] focused on sight sense as psychological effect and had experiment on hue-heat and clarified that the effect of visual stimulus causes 0.3 degree centigrade difference.
Kurazumi et al. [2] studied the effect of artificial and non artificial visual stimulus on human thermal sensation, and mentioned the effect on human's neutral temperature.
Ohno et al. [3] had research on the composite environment of thermal and hue-heat impression, and grasped the interaction on the subject.
Ahmed [4] studied the thermal comfort for the tropical urban environments and showed the importance of development of outdoor comfort model.
According to those researches, it is important to clarify the evaluation tendency on outdoor thermal environment from the psychological aspect, human thermal sensation.
For that reason, the purpose of this research is to clarify the psychological effect on human thermal sensation in outdoor space in tropical region by targeting short time residence to wipe out the influence of environment history.

2. Experiment overview

The research was carried out in Bangkok in rain season. The measurement points were selected in the university premises. 4 points were chosen by considering surrounding environment such as surface ground condition and sky factors. The details of measuring points are shown in Figure 1, 2 and Table 1.

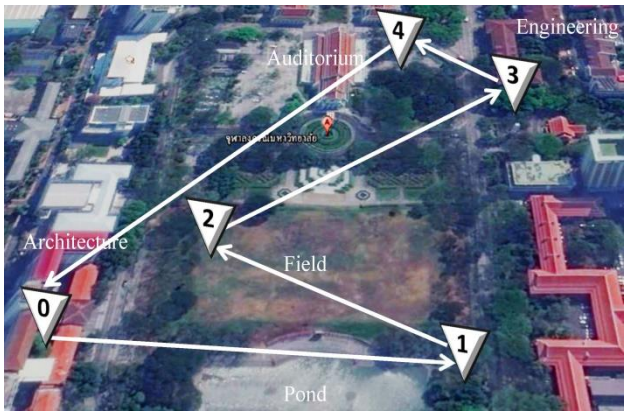

Figure 1. Measuring points

Table 1. Ratio of sky factors

Measuring Point \ Sky Factor	Sky	Non Sky	Green
⓪Building court	0.14	0.52	0.34
①Pond side	0.25	0.09	0.66
②North playfield	0.88	0.03	0.09
③Engineering bldg side	0.16	0.28	0.56
④Auditorium plaza	0.42	0.22	0.36

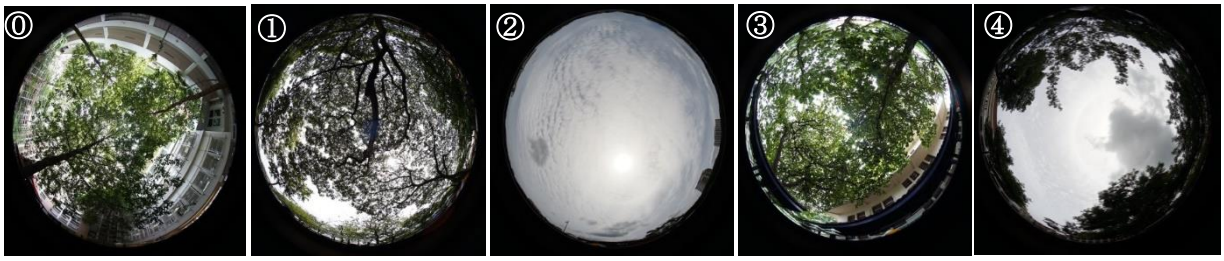

Figure 2. Sky photos of the measuring points

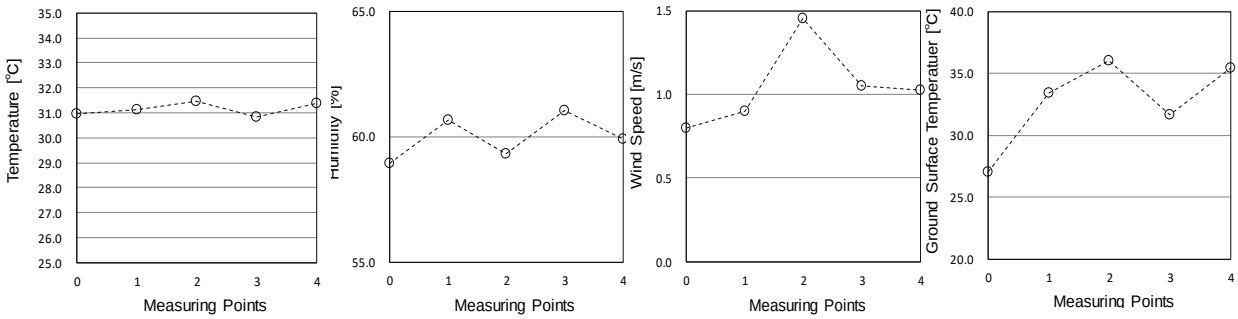

Figure 3. Average thermal environment of each measuring point

The experiment was carried out 4 days with the total subjects of 64 by using declaration vote.
To grasp the thermal conditions of each measuring point, consecutively measured thermal data of 2014 in the same season was used.
The averaged value of temperature, humidity, wind speed, and surface ground temperature is shown in Figure 3. According to the figure, it is clear that there is not big difference of the thermal condition among the measuring points.

3. Details of the declaration vote

The declaration vote was taken for this experiment. The vote is composed of image evaluation part using SD method and thermal sensation part. SD method part contains 30 adjective pairs with 7 level rating scales, by giving the score of +3 to -3. The thermal sensation part is by line rating scale.

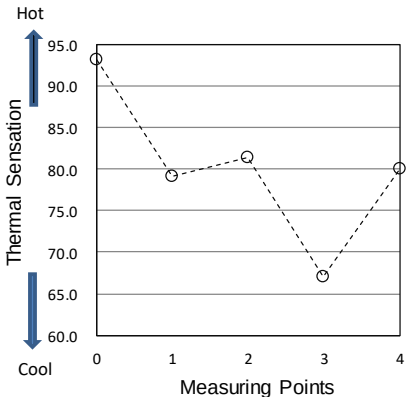

Figure 4. Thermal sensation vote

4. Experiment results

The result of the experiment is shown in Figure 4 and 5. Figure 4 shows the averaged value of thermal sensation in each measuring point, and Figure 5 shows the averaged value of image evaluation result in each measuring point.
As can be seen from Figure 4, the measuring point “0” showed the highest value, then “2”. The point “3” showed the lowest value. The measuring point 0 which showed the smallest ratio of sky factor, and the point 3 showed the largest value of green factor as shown in Table 1.
By looking at Figure 5, it can be seen that measuring points “2” and “3” shows different tendency compared to the other points

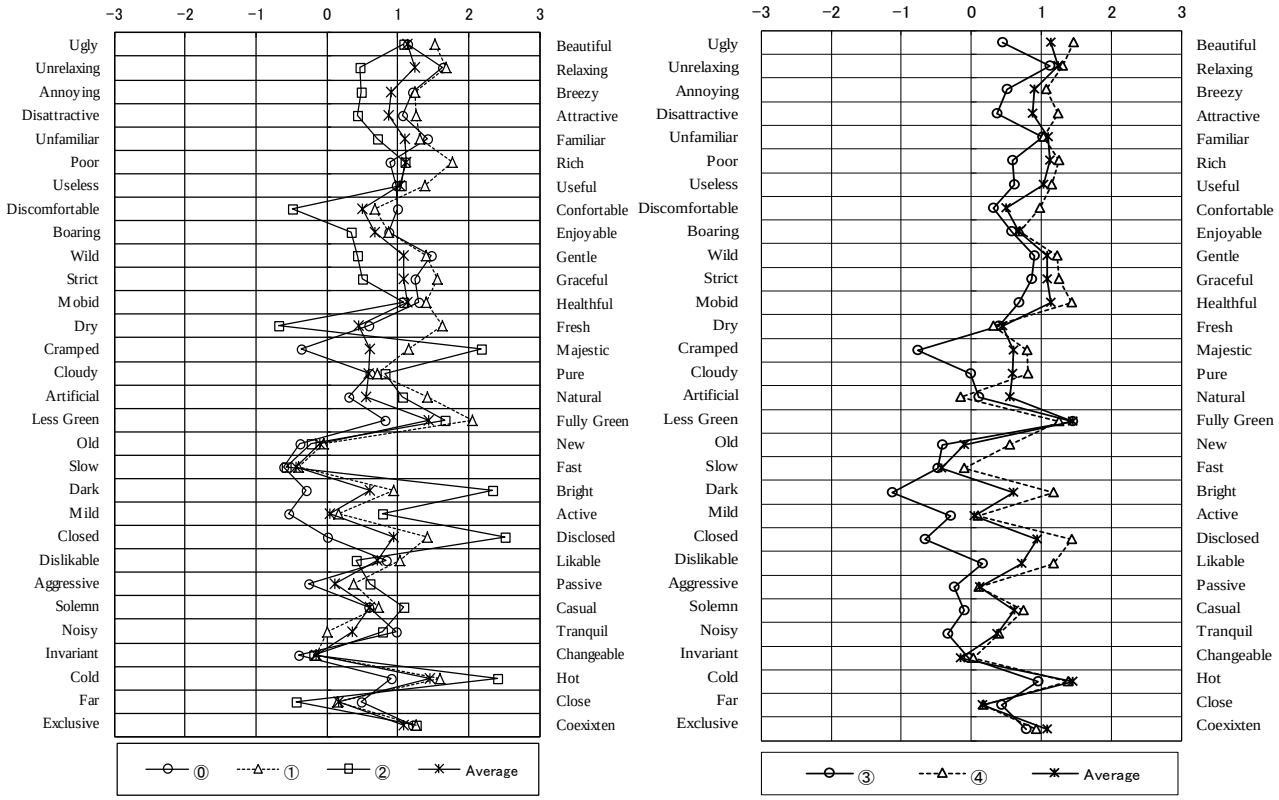

Figure 5. Results of image evaluation

Table 2. Factor loading matrix

Adjective Pairs \ Factor	1st Comfort	2nd Sensation	3rd Impression
Unattractive - Attractive	0.83	0.18	0.23
Strict - Graceful	0.76	0.10	−0.02
Unrelaxing-Relaxing	0.72	−0.12	0.19
Annoying - Breezy	0.72	0.06	0.24
Unfamiliar - Familiar	0.72	0.12	0.19
Ugly - Beautiful	0.71	0.30	0.07
Poor - Rich	0.71	0.31	0.00
Wild - Gentle	0.70	−0.09	−0.17
Dislikable - Likable	0.68	0.25	0.20
Mobid - Healthful	0.67	0.30	−0.06
Discomfortable - Confortable	0.67	−0.10	0.29
Boaring - Enjoyable	0.63	0.19	0.29
Useless - Useful	0.55	0.39	0.19
Cloudy - Pure	0.51	0.40	0.07
Dry - Fresh	0.50	−0.03	0.08
Exclusive - Coexistent	0.42	0.36	0.19
Old - New	0.36	0.20	0.29
Noisy - Tranquil	0.35	0.07	−0.19
Dark - Bright	0.06	0.85	0.10
Closed - Disclosed	0.09	0.84	0.00
Cramped - Majestic	0.17	0.82	−0.12
Mild - Active	−0.05	0.54	0.41
Aggressive - Passive	0.25	0.51	0.36
Cold - Hot	−0.03	0.51	0.00
Solemn - Casual	0.40	0.49	0.15
Less Green - Fully Green	0.37	0.39	−0.24
Slow - Fast	0.16	0.17	0.53
Invariant - Changeable	0.14	0.11	0.46
Far - Close	0.23	−0.23	0.38
Artificial - Natural	0.22	0.30	−0.37

* Factor scores of higher than 0.35 are highlighted.

5. Analysis of the image evaluation structure

To analyse the tendency of the image evaluation results by the subjects, factor analysis was taken. For the factor analysis, varimax rotation method was taken. The most interpret result was obtained when the factor number is set as 3. The result of setting the factor number as 3 is shown in Table 3. The factor score of more than 0.35 are highlighted.

Focusing on the items marked high factor, the first factor is named as “Familiarity” because the items which are relating to comfort, such as “Unattractive - Attractive”, “Strict - Graceful” and “Unrelaxing - Relaxing”, are categorized.

The second factor is named as “Sensation” because the selected it ems, such as “Dark - Bright”, “Closed – Disclosed” and “Cramped -Majestic” which emphasize human sensation are relating.

The third factor is named as “Impression” because the items such as “Aggressive - Passive” “Slow – Fast”, and “Invariant – Changeable” are related.

To analyse the tendency of given factor score in each measuring points, the averaged 3 factor scores are plotted in Figure 6.
Looking at the 1st factor, it can be seen that the measuring point "0" and "1" marked high score. In the score of the 2nd factor, measuring point "2" marked the highest, and "3" marked the lowest. In the score of 3rd factor, there is not a big difference among all the measuring points.

6. ANALYSIS ON THE CORRELATION OF THE IMAGE EVALUATION FACOTRS AND THE SKY FACTORS

The result of Pearson's correlation analysis between the image evaluation factors and the sky factors is shown in Table 3.
Only the 1st and the 2nd factor showed the advantage of either 1% or 5% level. The correlation coefficient of the 3rd factor is low comparing with the other factors. In addition, the 2nd factor showed the highest value of correlation coefficient among the 3 factors toward the sky factors.
Focusing on the 1st factor, "Non sky" and "Green" showed the positive value. The 2nd factor, on the other hand, only "Sky" showed the positive value.

7. ANALYSIS ON DEFINITE FACTOR BY MULTIPLE LINEAR REGRESSION

To analyse the definite factor of outdoor thermal sensation, multiple linear regression analysis was taken. For the analysis, factor score was separated to each measuring point and analysed. The result is shown in Figure 7.
Focusing on the multiple correlation coefficient, measuring point 3 showed the highest value and then measuring point "2". The measuring point "4" showed the lowest value.
Focusing on the tendency of standard regression coefficient, only measuring point 2 showed the obviously different tendency. The standard regression coefficient of 2nd factor "Sensation" is negative

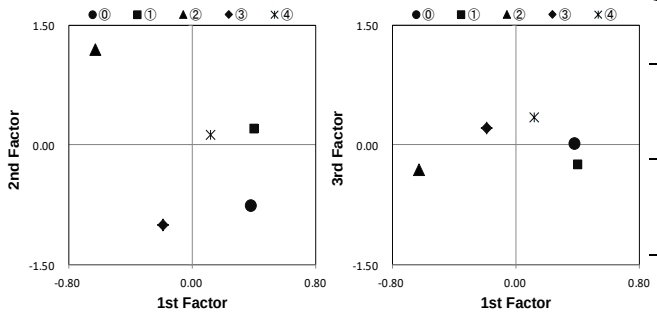

Figure 6. Averaged factor score

Table 3. Result of correlation analysis

Obtained Factors \ Sky Factor		Sky	Non Sky	Green
1st Factor Comfort	Correlation Coefficient	-0.29 **	0.18 **	0.25 **
	Sample Number	296	296	296
2nd Factor Sensation	Correlation Coefficient	0.68 **	-0.60 **	-0.44 **
	Sample Number	296	296	296
3rd Factor Impression	Correlation Coefficient	-0.11	0.12 *	0.04
	Sample Number	296	296	296

**shows advantage at 1% level ** shows Advantage at 5% level

	Measuring Points ⓪	①	②	③	④
Multiple Correlation Coefficient	0.45	0.41	0.49	***0.55***	0.29
Comfort	0.30	0.33	0.29	***0.41***	0.16
Sensation	0.29	0.06	***-0.43***	0.18	0.17
Impression	0.13	-0.17	0.10	***0.19***	0.06

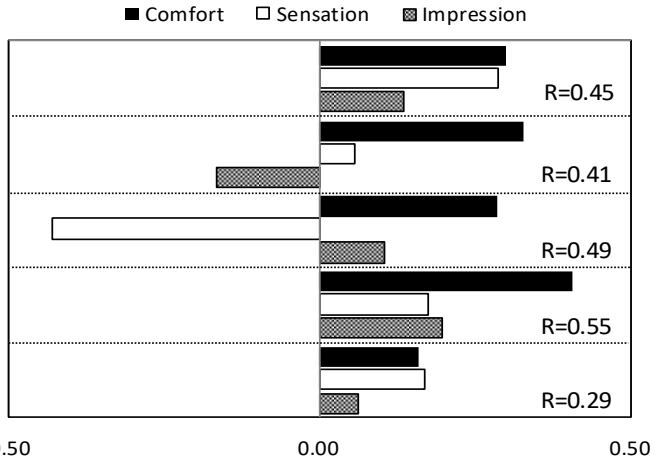

Figure 7. Result of multiple linier regression analysis

value to the thermal sensation. The factor "Sensation" is composed of the items including "Dark - Bright", "Cold - Hot". For that reason, this factor is can be taken as most likely affecting the thermal sensation. In addition, measuring point "2" is with the highest percentage of sky factor which means with more sunlight than the others.

By the deeper analysis of this result, it can be said that the subjects declare the thermal sensation lower than the actual condition of the thermal environment at measuring point "2" where is with larger sky factor and more sunlight.

8. CONCLUSION

In this study, short time resident was targeted to clarify the evaluation tendency of thermal environment. The obtained results are as below.

1) Comparing the results of image evaluation of each measuring point, point "2" showed obviously different tendency.

2) By the factor analysis, 3 factors were obtained. In addition, the averaged factor scores of each measuring point, the measuring point "2" showed the highest value in the 2nd factor. Furthermore, the measuring point showed the lowest value in the 2nd factor.

3) By the correlation analysis between the obtained 3 factors and the sky factors, the 2nd factor showed the highest value of correlation coefficients on all the sky factors.

4) To analyse the definite factor, multiple regression analysis was taken. As the result, the 2nd factor showed the possibility of lower the thermal sensation at the measuring point "2".

In summary of the above results, it is confirmed that by raising the 2nd factor has the effect of alleviating thermal sensation of the short time residents in a space with a high sky factor.

This result can be applied for designing outdoor space targeting short time resident.

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REFERENCES

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

[2] 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

[3] 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

[4] 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

[5] 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

[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