Field and Semi-Field Surveys on Thermal-Environment Experience and Its Associated Acquired Cognition by Family Members, Parents and Children

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ABSTRACT: This article describes the results of two surveys focused on thermal cognition of children and their parents. The first survey was to measure daily thermal environment as "field survey": we asked seven families, fourteen parents and eight children, to carry two small thermometers with data loggers. The second survey was a kind of subjective experiment as "semi-field survey" in which all of the participated families were asked to experience the same thermal environment in the experimental set-ups, and were requested to imagine and measure the physical quantities such as air temperature, relative humidity or surface temperature around them while we observed their behaviours. Through these two surveys, we have found some typical patterns of thermal cognition and thermal environment control behaviour. Since the children and their parents imagined the values of air temperature lower than those measured, they would feel comfortable even if the actual air temperature were higher than the air temperature value that they imagined comfortable. The survey method and its trials described in this article confirmed that this is a way to clarify the thermal cognition of children in relations to their parent's thermal cognitions. It is expected that further improvement and development of this method and the accumulation of data to be provided with similar surveys will bring us more knowledge and clear understanding about the acquiring process of both children's and parents' thermal cognition.
Keywords: Children, Acquired Thermal Cognition, Thermal Environment Monitoring, Imagined Comfortable Temperature

INTRODUCTION

It is important for occupants to build up their lifestyles for their well being without degrading their external environment. In this respect, passive technologies are more preferable to active technologies, but it does not necessarily mean that we have to go back again to the lifestyles of our ancestors. Instead, it is necessary to re-examine both the merits of passive technology and develop the consistent lifestyle, which can lead to maximizing the use of passive strategies while rationalizing the use of active strategies.

In general one's lifestyle starts to grow within family while he/she is a child. Over the last ten years or so, a variety of "built-environment" education programs has been developed and tried [1]. But so far, their development has been just by trials and errors and there is a lack of knowledge about what the lifestyles are, especially applicable to designing a house with much of passive strategies that can lead to healthy and comfortable "active" lifestyles. For this reason, we focused on "thermal environment of family members" in their houses here in this research.

One's lifestyle in relation to thermal environment must grow in "the cyclic process from sensation to behaviour" [2]; that is, he/she senses changes in the thermal environment through his/her sensory portals, then perceives and recognizes by his/her brain, and then if an adjustment is recognized to be necessary, he/she takes actions by moving muscles. The ability of thermal sensation is already set up as he/she is born, and it grows with various influential factors through his/her experience ever since then. We call it acquired thermal cognition [3]. According to previous researches regarding to thermal adjustment behaviour of occupants [4, 5], adaptive strategies such as cross ventilation, the use of small fans or air conditioning, and various behavioural patterns such as the choices of cooler paths approaching to the buildings and the change of clothes vary very much in the course of the continuous input of information from the thermal environment. The same is true for their associated thermal cognition.

In this study, two surveys focusing on the thermal cognition of children and their parents were set up. The purpose of this investigation is to have a better understanding of what kind of thermal environment they experience in their everyday life and whether there is a difference or a similarity in their thermal cognitions and behaviours.

METHODOLOGY

Field Survey The first survey was to measure daily thermal environment as field survey. Family members usually live in the same house, but each member may be surrounded by different thermal environments especially during daytime such as school for children, home or office for parents. Therefore, we asked seven family members to carry two small thermometers with data loggers, one for air temperature and relative humidity and the other with a gray-colored ball for radiant temperature. While carrying these sensors, they were asked to answer their thermal sensations, thermal cognitions in the nearest past. This was done for three times each day: in the morning around 7:00, at noon, and in the evening around 20:00. The subjects were asked to recall their exposed thermal environment during the previous 3 to 6 hours and marked their thermal cognitions for those hours on the charts we prepared. The parents helped their children. This series of survey together with the measurement of temperature and humidity were made for four days starting on Thursday and ending on Sunday in mid July 2008. Seven families participated in this survey. Table.1 shows the age of these participated families. All families have one child or two children, all under thirteen, and their parents are thirties or forties.

To analyse the subject's thermal cognition in detail, questionnaire sheets were prepared for the same subjects asking about their lifestyles, the general characteristics of their houses with respect to controlling the thermal environment in summer season, the usage of air-conditioning units, and the comfortable temperature that they imagine.

Semi-Field survey The second survey was a kind of subjective experiment as semi-field survey, in which all of the participated families were exposed to the same thermal environment. There are two purposes of this survey: to understand how the subjects recognize the thermal environment around them; and to investigate their thermal adjustment behaviours. This experiment was done by each family spending a half day either on 9th, 10th, 16th, or 17th of August 2008. The weather conditions for these four days were hot and humid and more or less the same.

Thermal cognition was investigated with three steps as follows: all subjects were exposed to feel the thermal environment, check their sensations on the scale, and measure the actual temperature values with thermometers and air velocity with an anemometer. Through these steps, the subjects evaluated the spaces set up for the survey shown in Table.2. Each family were separated into the parents and the children upon their arrival and asked to enter two rooms of the same thermal conditions in which there is air-conditioning unit. Then they were asked to adjust respective rooms with their own ways that they usually do. This is to know their adjustment behaviour in their daily life. In these rooms, they were allowed to open or close the windows, switch on or off

Table 1: Age of seven family members

Family	age			
	Father	Mother	Child	
	_F	_M	_C1	_C2
KA	40s	40s	6	——
AI	——	40s	10	8
NA	40s	40s	12	——
SH	30s	30s	4	——
KO	30s	30s	8	——
AS	30s	30s	8	——
SU	30s	30s	6	——

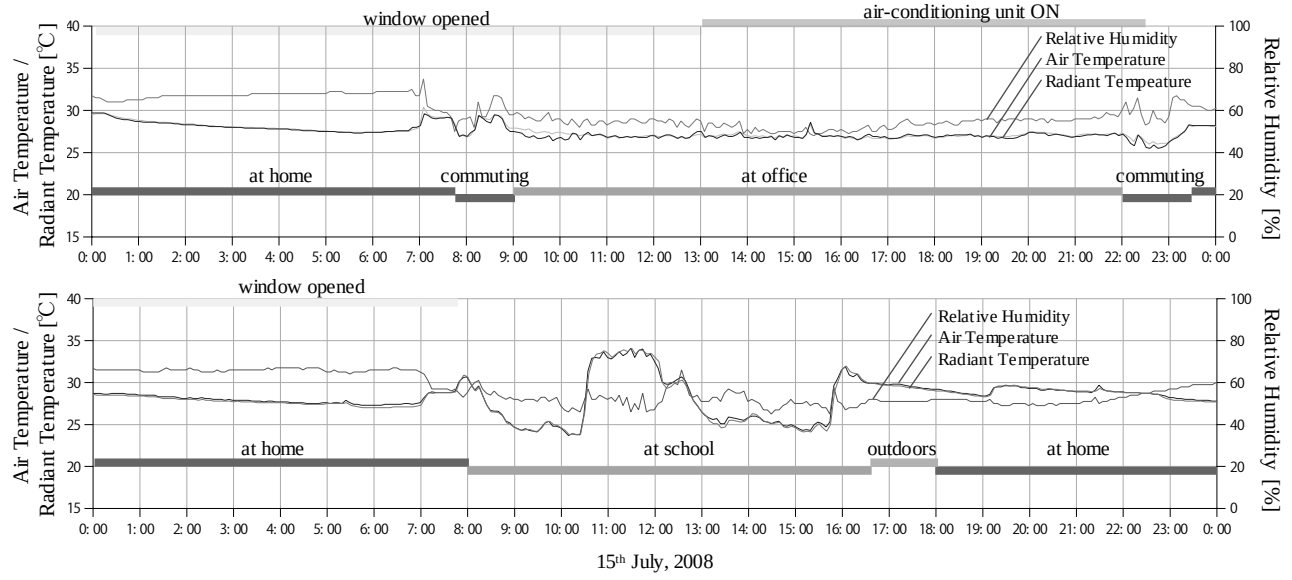

Figure 1: Variation of thermal environment in the case of "Family AS" (upper graph for father, lower for his child)

experienced two thermally different spaces: the other air-conditioned space with very low set-point temperature; and a corridor space surrounded by glass façades transmitting a lot of solar radiation. Finally, the parents and children entered together one of the two rooms they first experienced, and they adjusted the indoor thermal environmental conditions again as they were asked in the first space. During this course of experiment, we recorded the thermal adjustment behaviour of each family member in video films.

RESULTS AND DISCUSSIONS

Daily Thermal Environment Figure.1 shows the variation of thermal environment of "Family AS" as an example. The results show that the family members were exposed to a variety of thermal environment: for example, father working at his office stayed long in air-conditioned space with a rather stable temperature, while on the other hand, his child was forced to experience a sudden and large change in environmental temperature.

Figure.2 shows where the family members spend their time for one average weekday. Subjects were grouped into five characters, mother at home, mother at office, father at home, father at office, and children. This result indicates that all subjects spent approximately 80% or more of their time indoor space, and also about a half of their time at home. It means that thermal environment at home is influential to the development of thermal cognition.

Figure.3 shows the length of time that each of the subjects stayed in the air-conditioned indoor space during the four days of the field survey. Each vertical bar represents each subject. The members of SU and NA families were exposed to air-conditioned space for longer hours than others. Figure.3 also shows their imagined comfortable air temperature that each subject answered on the questionnaire sheet. The subjects who spent their

Table 2: Four spaces and their initial conditions

	1st	2nd	3rd	4th
Type of Space	lecture room	corridor	lecture room	lecture room
Air-conditioning system	off	off	on	off
window	closed	closed	closed	closed
parents and children	separated	together	together	together
adjustment of thermal environment	by subjects	-------	-------	by subjects

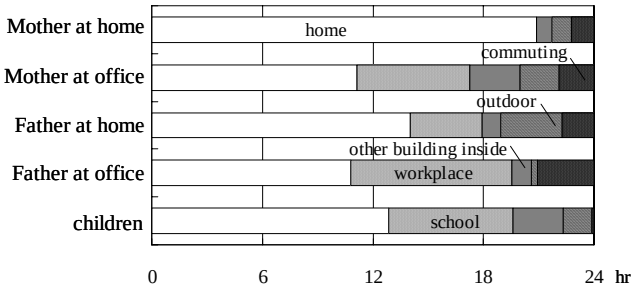

Figure 2: Space and time the participated family members spend on an average weekday

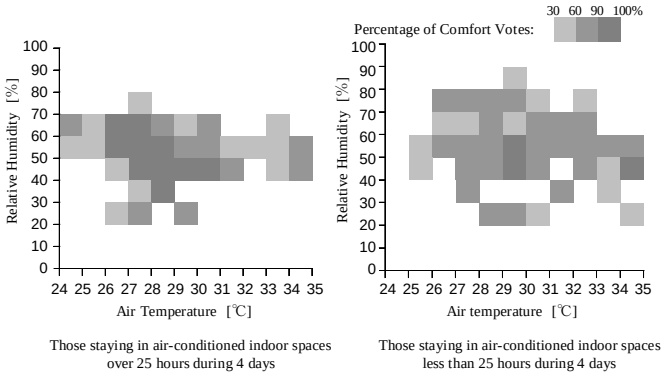

Figure 4: Percentage of comfortable votes

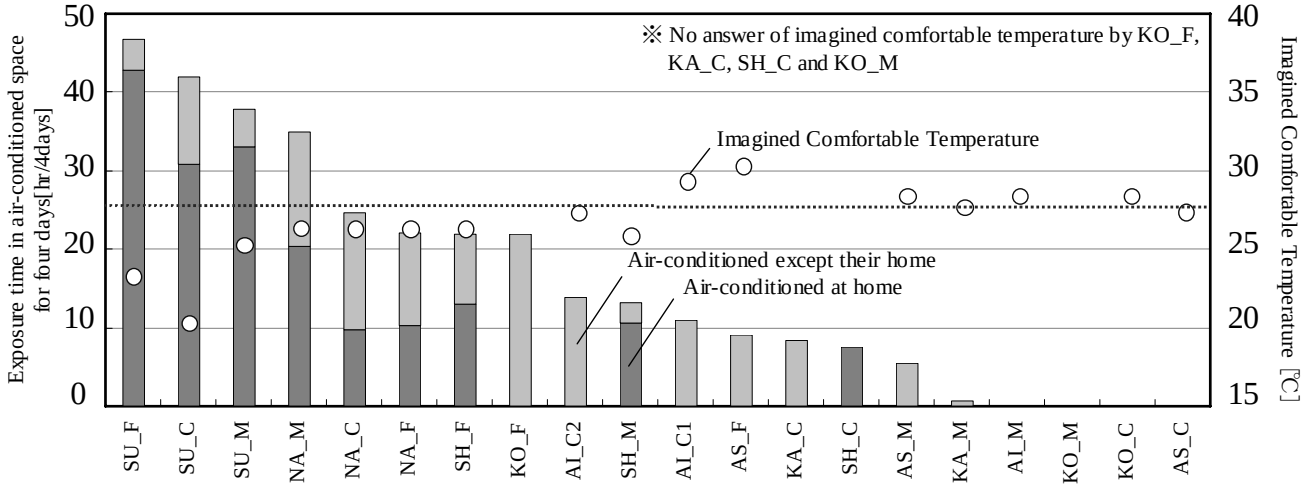

Figure 3: The length of time stayed in air-conditioned spaces ("_F" denotes Father, "_M" Mother, and "_C" Child)

time longer in air-conditioned space tend to answer their imagined comfortable temperature lower. This suggests that the thermal cognition has been developed through their everyday life. Since the parents decide how to control the thermal environment at home, their children are apt to feel comfortable just as exposed.

Percentage of Comfort Votes Figure.4 shows the percentage of comfort votes made by the parents through the four days of field survey for each of measured air temperature values of 1°C ranges and 10%rh ranges. Child subjects are excluded in Figure.4, since some of them were too young to answer. Parent subjects were divided into two groups: the left hand side of Figure.4 shows the result for the subjects staying in air-conditioned indoor spaces over 25 hours during the four-day field survey and the right hand side for the subjects staying less than 25 hours. The percentage of comfort votes for those staying in air-conditioned indoor space over 25 hours concentrates around the set point temperature and humidity. On the other hand, that of those less than 25 hours scatters in comparison with the former. This confirms that staying in air-conditioned space is influential to the subjects' thermal cognition.

The Pattern of Thermal Cognition Figure.5 shows the patterns of thermal cognition of two of the subjects, mother of AI family (AI_M) and father of NA family (NA_F). Upper graphs show the comfort-discomfort patterns and lower graphs the thermal sensations. AI_M represents one of the subjects staying in air-conditioned indoor spaces shorter than 25 hours, while on the other hand, NA_F one of the subjects staying in air-conditioned indoor spaces over 25 hours. AI_M who experienced high temperature and humidity, sometimes perceived comfortable with such conditions, even though she claimed hot or slightly hot. NA_F perceived comfortable for lower air temperature and lower humidity than AI_M did. He voted almost always neutral in such air-conditioned thermal environment. Comfort zone is presented as the percentage of dissatisfied in ASHRAE standard "ASHRAE 55-2004" [6], which was developed considering the thermal energy interactions between human body and indoor environment, its associated thermal comfort of occupants by subjective experiment. The standard assumes the occupants sitting on the chairs, so that it is not necessarily applicable to all of situations encountered by occupants' daily life. The thermal sensations and comfort levels can vary to a large extent from one thermal environment to another as he/she moves indoors and outdoors as shown in Figure.5. It is necessary for us to accumulate such pieces of information more in order to understand the human behaviours in relations to his/her thermal environment especially for aiming at the promotion of active lifestyles with a full use of passive strategies. Such knowledge must suffice the current standard of indoor thermal environment for mainly active heating and cooling systems.

Imagined and Measured Physical Quantities Figure.6 shows the relationship between imagined and measured air temperature, relative humidity, radiant temperature and air velocity. Closed circles indicate the answers of parents, and open circles those of children. Through all of four spaces shown in Table.2, both

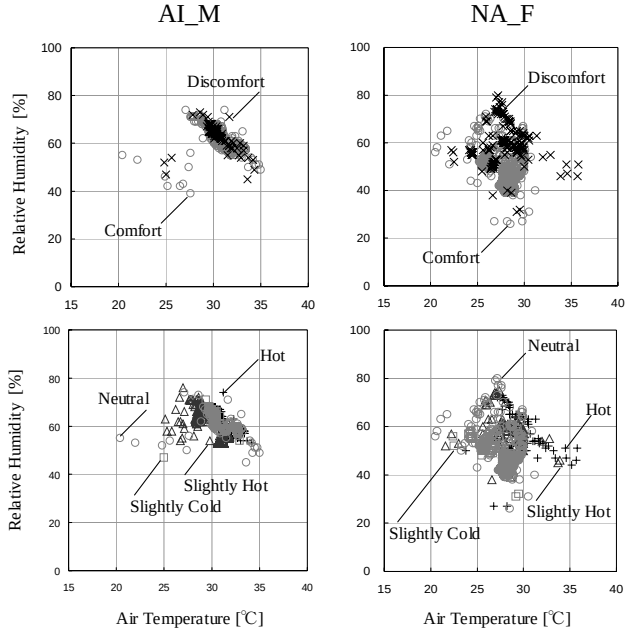

Figure 5: The distribution of comfort votes and thermal sensation votes

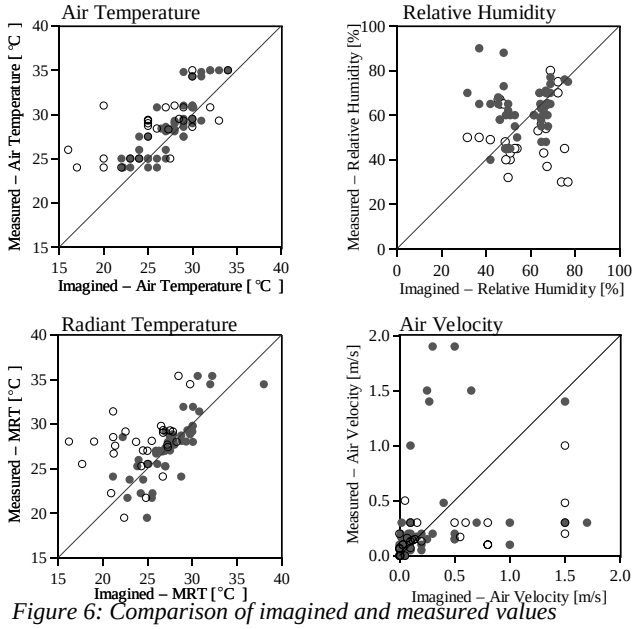

Figure 6: Comparison of imagined and measured values

parents and children tended to answer the imagined air temperature lower than the actual air temperature. This tendency seems to us that there is a possibility to create comfortable thermal environment for these subjects with actually higher air temperature than their believed comfortable air temperature. Mean radiant temperature tends to be imagined lower than actual values as air temperature does, but it seems harder to imagine the radiant temperature than air temperature. In the case of relative humidity and air velocity, it seems even harder to imagine. There was no tendency between imagined value and measured value.

Thermal Adjustment Behaviour Figure.7 shows the thermal adjustment behaviors of the subjects with SU Family and KO Family as two examples. The graphs shown in Figure.7 are a kind of radar charts, the left-side of which represents the means such as switching on mechanical devices and the right-side the means such as opening windows. There are three for the former and five for the latter. The members of SU Family were staying air-conditioned indoor spaces over 25 hours, and those of KO Family were staying air-conditioned indoor spaces less than 25 hours. According to the recorded films for the 1st and 4th room spaces, the subjects who stayed in air-conditioned indoor space shorter than 25 hours in the field survey opened the curtains, windows cross ventilation. Such thermal adjustment behaviour was found to be done by both parents and their children. In addition, some parents also opened the door to make cross ventilation more effective. On the other hand, the subjects who stayed air-conditioned indoor space over 25 hours did thermal adjustment behaviour just turning on the air-conditioning unit.

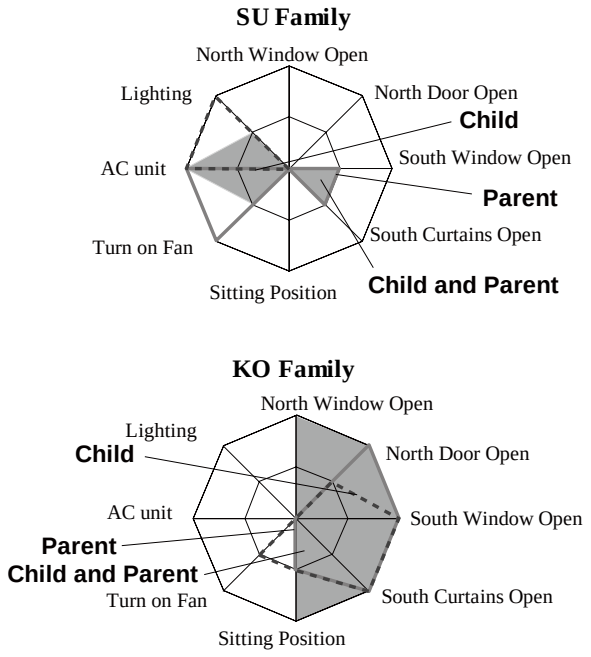

Figure 7: Thermal adjustment behaviours

CONCLUSION

In this study, two surveys were made: one in actual field and the other in a room with experimental set-ups as in semi-field. Through these two surveys, we have found the following with respect to thermal cognition and also thermal environment control behaviour.

1) Children and their parents had similar characteristics in the thermal cognition, especially in the case of families whose parents stayed air-conditioned indoor space over 25 hours during the period of the field survey. Those who are exposed much in mechanical cooling tend to answer the lower air temperature as their imagined comfortable temperature.
2) Those who stayed air-conditioned indoor space over 25 hours tend to switch just on the air-conditioning units rather than opening the windows when they were asked to adjust their thermal environment by any means given in the experimental room.
3) Since children and their parents imagined the values of air temperature lower than those measured, they could feel comfortable even if the air temperature value is higher than their imagined comfortable temperature.
4) The survey method and its trials described in this article confirmed that this is a way to clarify the thermal cognition of children in relations to their parent's thermal cognition. Further improvement and development of this method and the accumulation of data will provide us with more knowledge and clear understanding about the acquiring process of both children's and parent's thermal cognition.

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