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Behavioral adjustment of Cool Chairs in Warm Offices

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Abstract: This paper reports the specifications for a Cool Chair in subjective experiments in an office environment in Japan during summer. Thermal conditions affect a worker's comfort, clothes, physical condition and activity level. Therefore, it is beneficial to allow workers to individually adjust their thermal environment. Recently, as a solution to this problem, 'Personal Air-conditioning Systems' have been developed. In particular, a chair which has a mounted thermal airflow generator with an environment adjustment function was developed. In this chair, named as 'Cool Chair', air is blown from its movable armrests and the seat. The airflow and wind direction in the armrest can be easily adjusted. The airflow around the Cool Chair is isothermal with the indoor temperature. Subjective experiments were conducted with 20 adult participants to examine the cooling effect of the Cool Chair, and the effect of its thermal adjustability on the psychology of its users was examined.

Keywords: Chair, Subjective experiment, Personal air conditioning system, Iso-thermal airflow, Thermal comfort,

1 Introduction

Thermal conditions affect a worker's comfort, clothes, physical condition, and activity level. Therefore, it is beneficial for workers to be able to individually adjust the thermal conditions in their personal space. The system presented in this study is called a 'Personal Air-conditioning System.' It was designed to improve the thermal comfort of office workers and has attracted significant attention from the perspective that it may reduce the number of potential injury claims in the office. Moreover office workers can adjust their thermal environments and can acquire the desired thermal environment.

An adaptive model that requires a voluntary, passive action was proposed by R.J. de Dear et al. [1]. The adaptive model involves three elements: behavioral adjustment, physiological adjustment and psychological adjustment. Although a psychological adjustment is considered to be most effective, it is difficult to evaluate it quantitatively. In this study, the cooling effect of the Cool Chair and the effect of the Cool Chair's thermal adjustability on a user's psychology were examined.

2 Function of the Cool Chair

In 2003, the authors developed a chair which has a mounted thermal airflow generator that has an environment adjustment function. This chair was named as the 'Cool Chair,' and is shown in Fig. 1. Air is blown from the armrests and seat of the chair; the armrests are movable, and hence, one can easily adjust the airflow and wind direction in the armrest (Fig. 2). This is powered by battery (Fig. 3). The airflow of the Cool Chair is isothermal with the indoor temperature. The armrest airflow can be adjusted to five phases with airflow-limiting control (Fig. 4). The combined maximum air volume which includes the armrest airflow volume and seat air volume is 40 m^3/h. The maximum sound pressure level is 47.0 dB when the indoor sound pressure level is 30 dB (Fig. 5). The chair consists of a seat switch; therefore, even if the user turns on the power and subsequently leaves the seat, the chair automatically switches off.

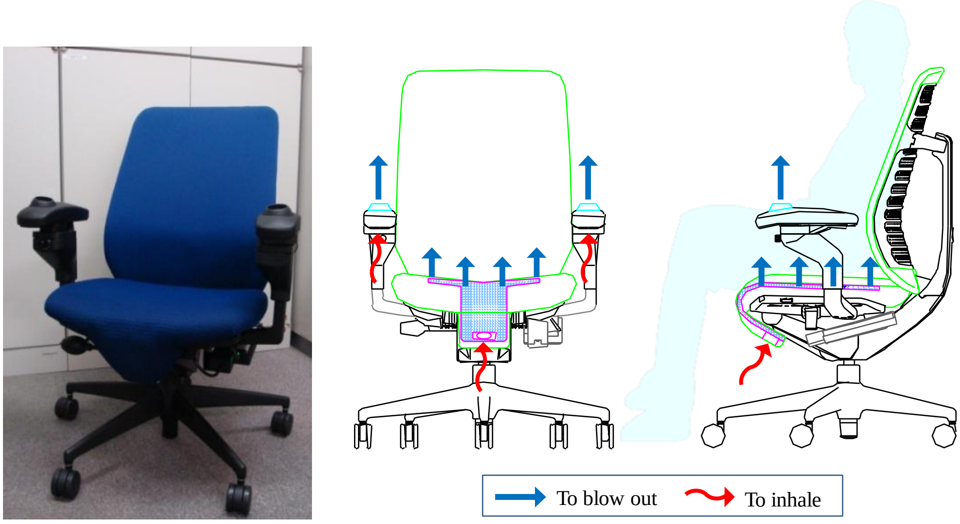

Fig. 1. External view of the Cool Chair

Fig. 2. (a) Airflow from the armrest and the seat; (b) Range of motion of the armrests

Fig. 3. Battery of the Cool Chair

Fig. 4. Airflow - limiting control

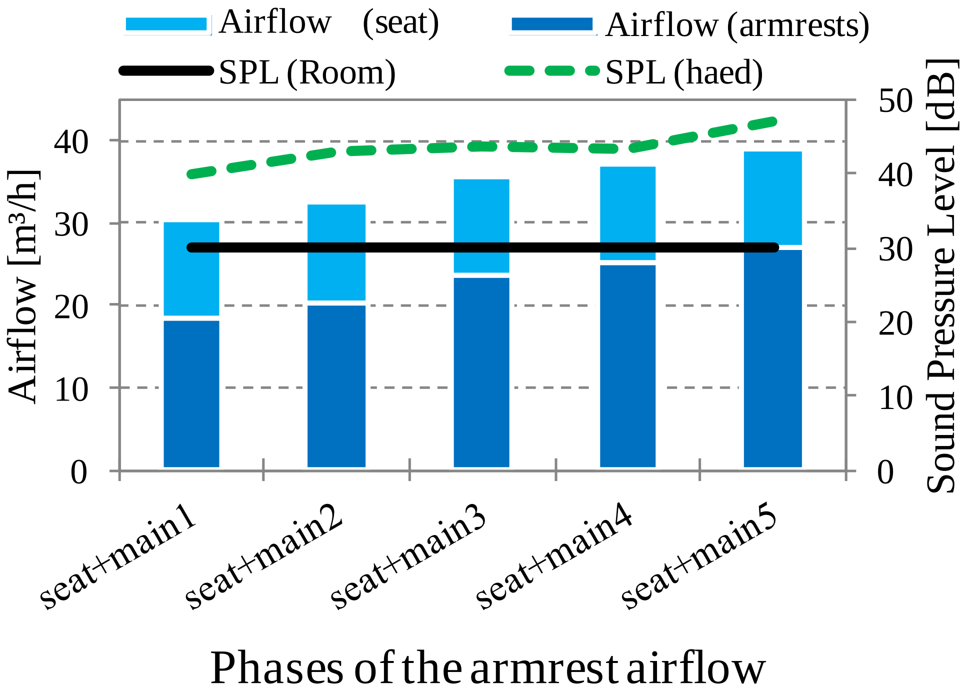

Fig. 5. Airflow volume and sound pressure level

Fig.6 shows a thermal mannequin. The equivalent temperature was calculated with the thermal mannequin with the Cool Chair and the general chair (Fig. 7). Fig. 8 shows the equivalent temperature owing to the cooling effect of the Cool Chair (relative to the temperature for a general chair) which is −4.5°C in the head. Then the temperature of the room was set at 28°C.

Fig. 6. Thermal Mannequin

Fig. 7. (a) The Cool Chair; (b) The general chair

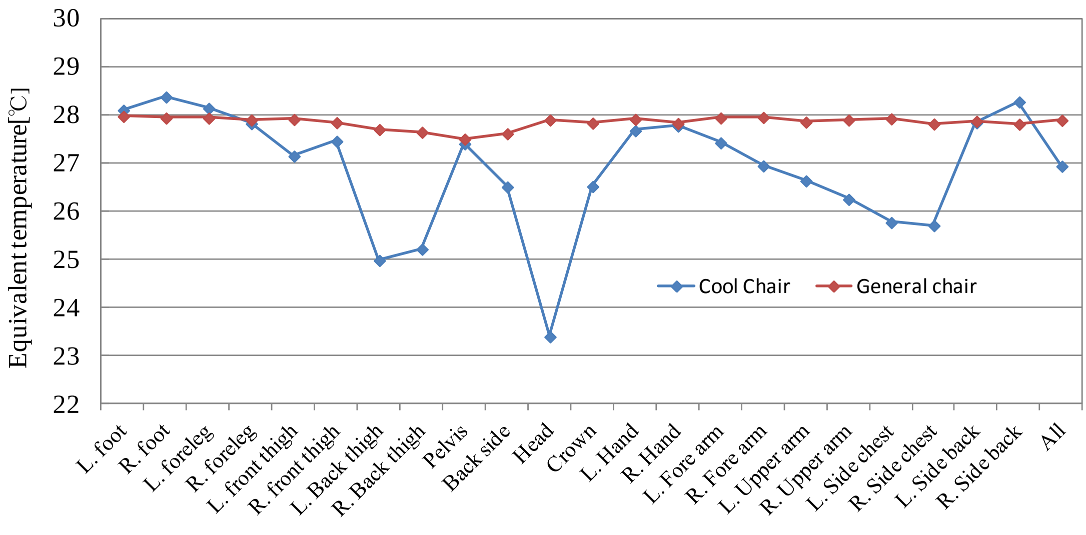

Fig. 8. Equivalent temperature caused by the cooling effect of the Cool Chair

3 Outline of subjective experiment

3.1 Experimental conditions

The experiments were conducted over the period November to December 2010. The experimental location was Kogakuin Twin Chamber (KTC) in Kogakuin University in Hachioji city in Tokyo. A schematic of the experimental room is shown in Figs. 9 and 10. Twelve male and eight female adults participated in the experiments. The men's clothes were 0.63 clo and the women's clothes were 0.51 clo. There were five groups of four same-sex pairs, and a two-day experiment was conducted for each group. The initial air temperature of chamber A was set to 36°C. This environment was the same as the outside environment in Tokyo during the summer. The temperature of chamber B was set at 28°C. On the second day, the temperature of chamber B was changed to 30°C. Table 1 summarizes the experimental conditions.

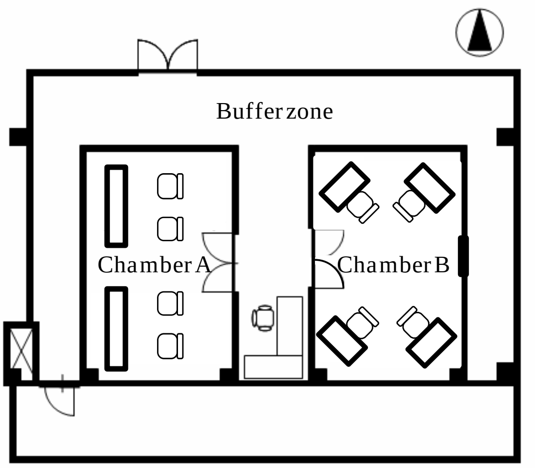

Fig.9. Plan of experimental room

Fig. 10. Experiment scenery

Table 1. Experiment conditions

		Chamber A	Chamber B
Air-conditioning method		Floor supply, sucking from the ceiling	
Room air temperature		35.9°C	28°C (First day)
			30°C (Second day)
Relative humidity		70%RH	50%RH
Mean radiant temperature		Equal to room temperature	
Room airflow		Mild	
Clothing insulation	Male	0.64 clo	
	Female	0.51 clo	
Metabolic rate		2.6 met (step exercise)	1.2 met (put together a jigsaw puzzle)

3.2 Outline of experiment

This experiment was performed to evaluate the performance of the Cool Chair by obtaining subjective perceptions of the subjects toward thermal comfort when using the Cool Chair in an actual office environment. Experiments were performed three times in a day, and in each case, the subjects performed tasks for 45 min.

Case 1) In chamber B, not all of the subjects used the chair during the experiment.

Case 2) In chamber B, all of the subjects were allowed to freely use the chair during the experiment.

Case 3) In chamber A, all of the subjects were given work with a metabolic rate of 2.6 met. Then, the subjects moved to chamber B, and as with Case 2, the subjects were allowed to freely use the chair during the experiment.

In all cases, the subjects made a thermal sensation vote (TSV), comfort sensation vote (CSV) and the state of sweat was recorded every 3 min. Fig. 11 shows the experimental schedule. Table 2 summarizes the estimation scales of TSV, CSV and the state of sweat.

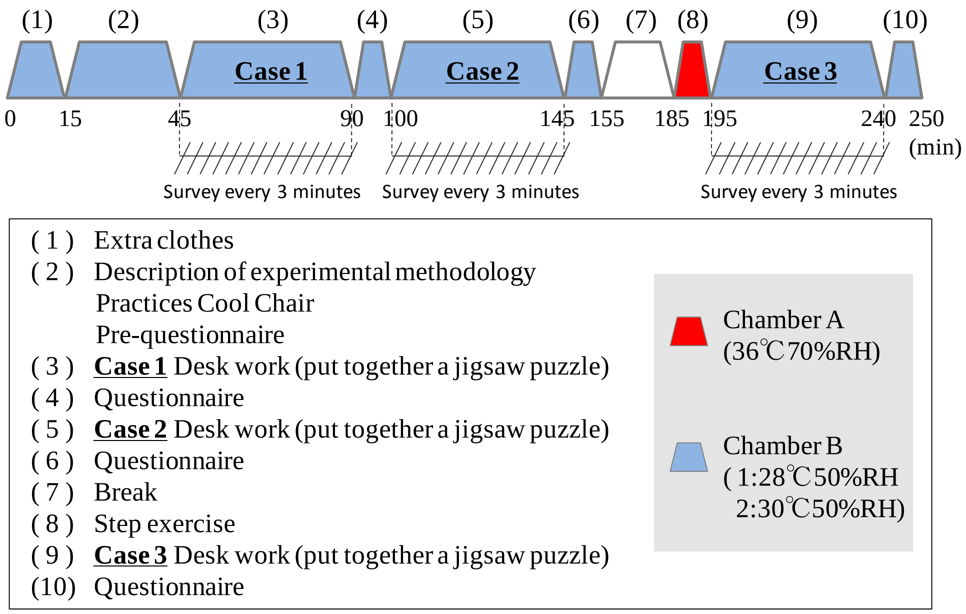

Fig. 11. Experimental schedule

Table 2. The estimation scales of TSV, CSV and the state of sweat

	TSV	CSV	State of sweat
3	Very Hot	Very Comfortable	Very Sweat
2	Hot	Comfortable	Sweat
1	Warm	Slightly Comfortable	Slightly Sweat
0	Neutral	Neutral	Neutral
-1	Cool	Slightly Uncomfortable	-
-2	Cold	Uncomfortable	-
-3	Very Cold	Very Uncomfortable	-

4 Results of subjective experiment

4.1 The results of the survey during the experiment

The mean values for both males and females during the experiment are shown in Fig 12. These results were obtained after the subjects sat in the chairs for 45 min. The TSV shifted to a more neutral value as male and female subjects compared Case 1 with Case 2 and Case 3 (using the Cool Chair). The CSV results indicated that the Cool Chair was more comfortable. It was confirmed that the TSV decreased with the use of the Cool Chair, while CSV increased. In addition, most subjects perspired in Case 3, and in this state, use of the Cool Chair caused the state of sweat graph to shift to a neutral value.

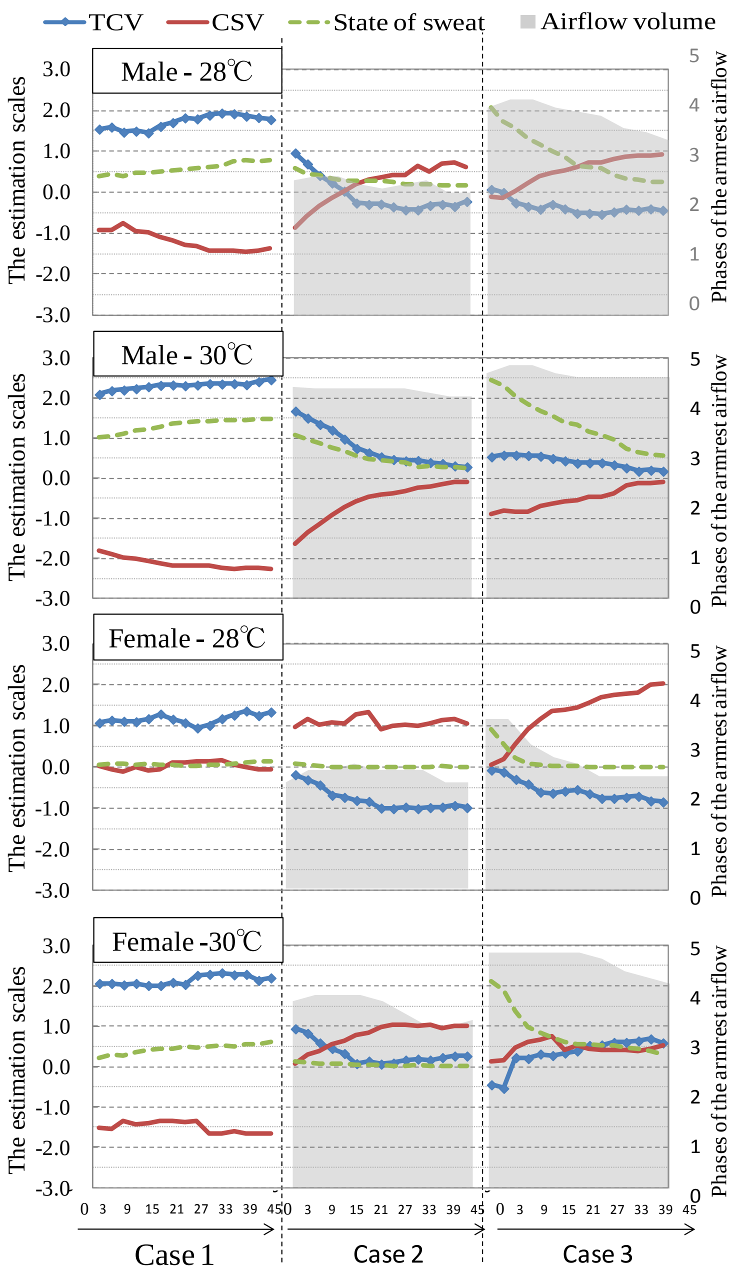

Fig. 12. Comparison of average values during the experiment

Fig. 13 shows the correlation between TSV and CSV. Most subjects were more comfortable when they felt cool. The correlation was observed to be higher for males, while there was greater variability among females. The results indicated that females were more comfortable than males.

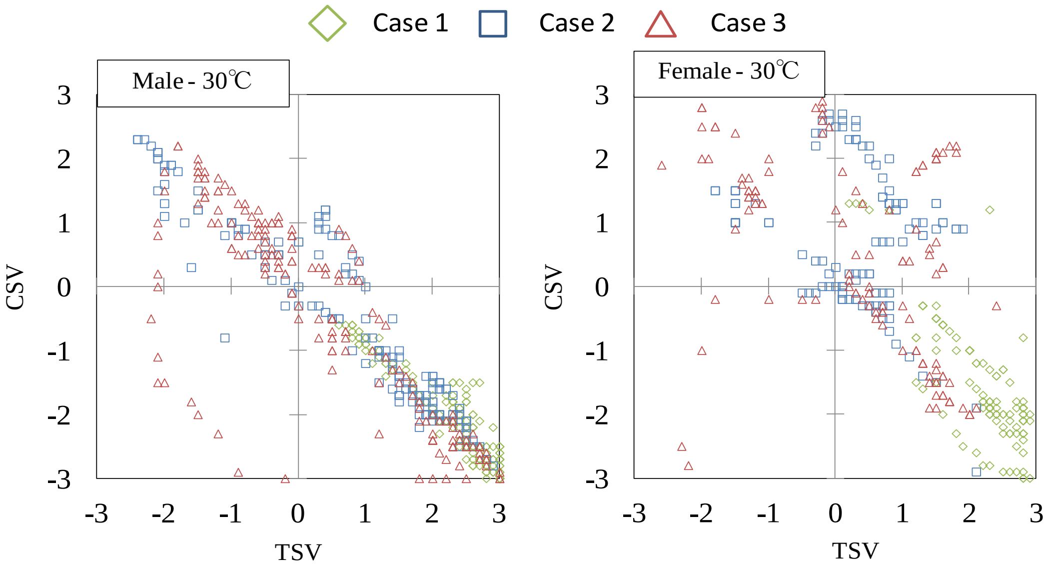

Fig. 13. Correlation between TSV and CSV

4.2 Wind direction when using the Cool Chair

Fig. 14 shows the wind direction in the armrest when using the Cool Chair. For the male subjects, the airflow was directed more to the upper body, while for female subjects, the airflow was directed more to the face and chest. Therefore, the speculation is that the airflow directed to the exposed face has the most significant cooling effect.

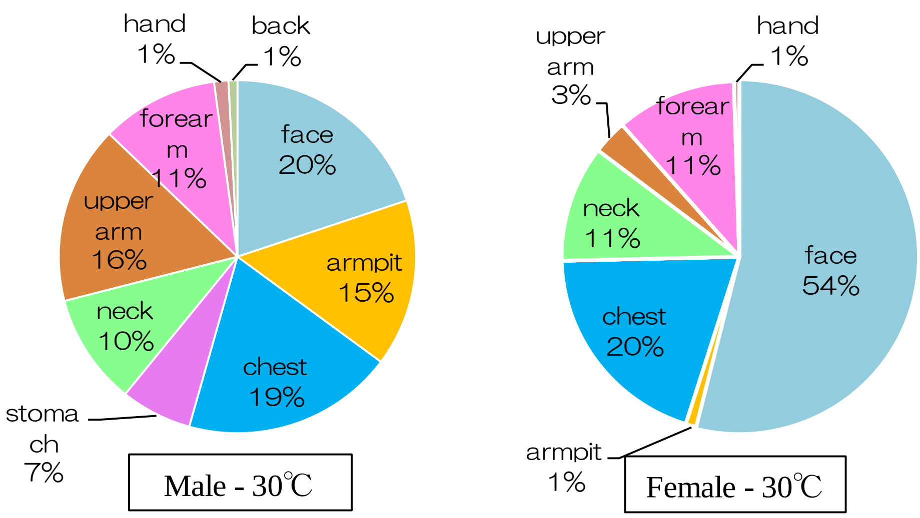

Fig. 14. Wind direction when using the Cool Chair

4.3 Acceptability of indoor thermal environment

Fig. 15 shows the findings of the thermal environment acceptability questionnaire after the end of each experiment. It was confirmed that the degree of acceptance of the Cool Chair improved for both males and females. Even if the initial air temperature is set at 30°C, approximately 60% of the males and 70% of the females responded that the indoor environment was acceptable. Although perspiration is considered to be a negative factor, the degree of acceptance did not decrease, but actually showed improvement in many subjects. Therefore, even if the indoor thermal environment is harsh, the significance of the Cool Chair was verified by our results.

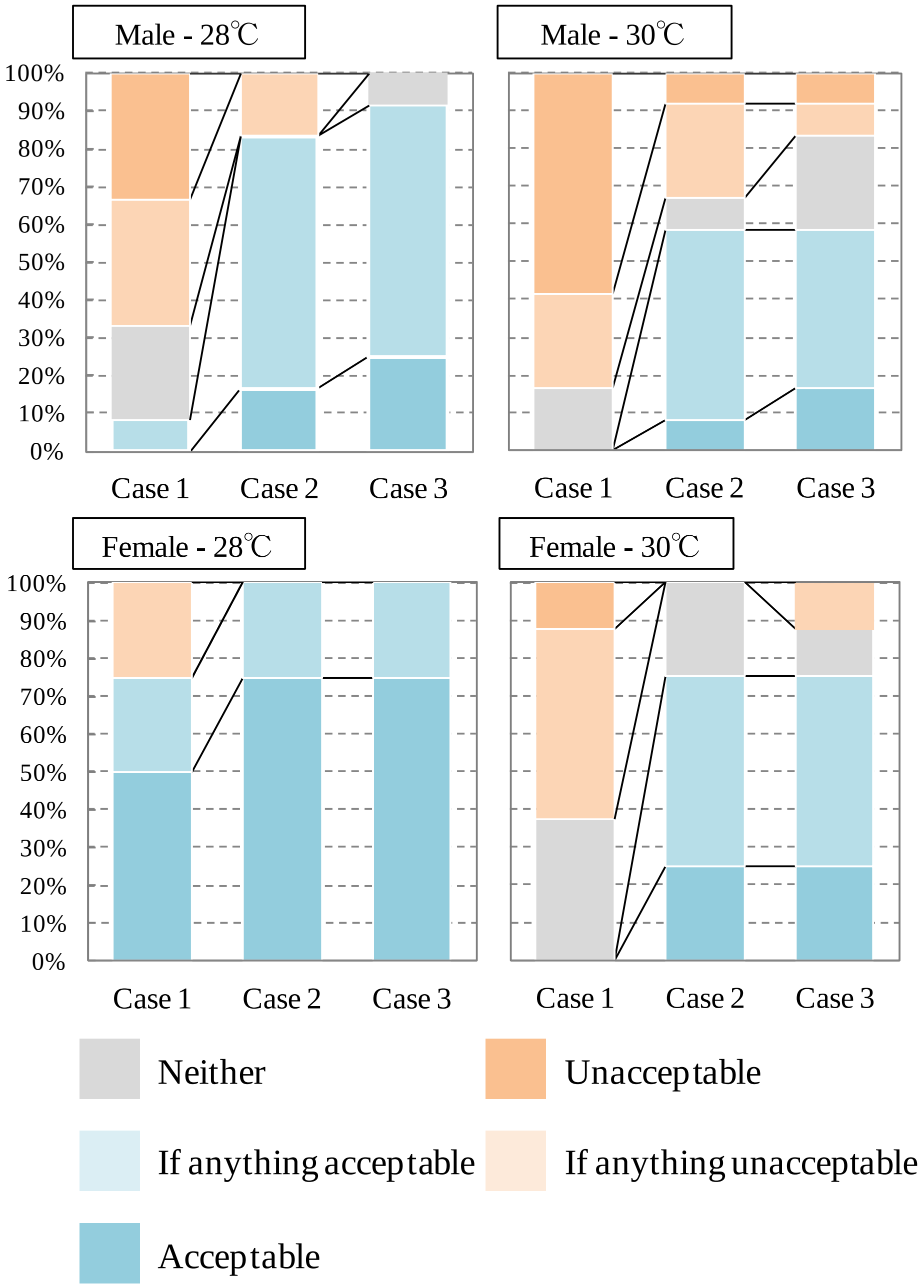

Fig. 15. Acceptability of indoor thermal environment

4.4 Correlation between sweating and acceptability

As indicated above, using the Cool Chair caused the state of sweat to shift to a more neutral value and also resulted in an improved degree of acceptance. Fig. 16 shows the correlation between the acceptance and sweating.

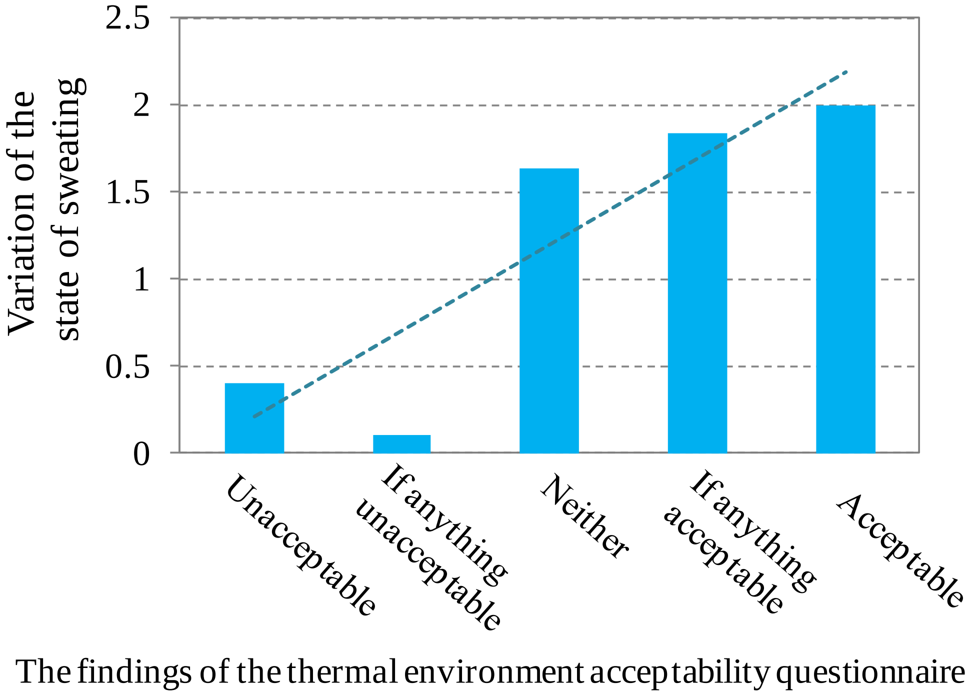

Fig. 16**.** Correlation between sweating and acceptability

The vertical axis shows the variation in the state of sweating during the experiment (from the start to the end of the experiment). The horizontal axis shows the findings of the thermal environment acceptability questionnaire at the end of each experiment. The graph shows a positive correlation between the state of sweating and the thermal environment acceptability.

It was deduced that the variation of the state of sweating was an important factor in determining the subjects' acceptance of the indoor thermal environment. In contrast, the subjects that did not accept the indoor thermal environment were those for whom the state of sweating was minor. It was confirmed that there is a correlation between the variation in the state of sweating and acceptability of the indoor thermal environment.

5 Conclusions

The objective of this study was to examine the cooling effect of the Cool Chair and to determine the effect of its thermal adjustability on a user's psychology. The results are as follows.

1） It was confirmed that the TSV decreased while the CSV increased when using the Cool Chair. It was also observed that when the subject became sweaty, using the Cool Chair also caused the state of sweat to become more tolerable.

2） It was confirmed that directing the airflow to an exposed face has the greatest cooling effect.

3） It was found that the skin moisture is not a barrier to comfort by use the Cool Chair. In Case 3, although perspiring is considered to be a negative factor, the degree of acceptance did not decrease, and actually was showed improvement in many subjects. Therefore, even if the indoor environment is harsh, the significance of the Cool Chair has been confirmed by these results.

4） It was confirmed that there is a correlation between the variation of the state of sweating and one's acceptance of the indoor thermal environment.

The Cool Chair with an isothermal airflow demonstrated adequate cooling performance. The Cool Chair requires action to achieve environment adjustability. The adaptive model indicated that use of the Cool Chair could further extend the upper temperature limit of what constitutes a comfortable environment. However, the Cool Chair must be fully used by the user for the maximum psychological adjustment to be realized. Future work is required to obtain detailed analysis of the psychological adjustment. This is expected to further improve the Cool Chair design.

6 Reference

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