

The impact of thermal history on thermal sensation in cooling conditions

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SUMMARY

This study explores how thermal history influences responses to identical air-conditioned environments. Conducted with 16 subjects in three thermal history conditions, results reveal that a warmer thermal history prolongs the time required to achieve thermal neutrality. Also, disparities between PMV predictions and thermal sensation with warmer thermal histories are demonstrated. The findings emphasize the inadequacy of relying solely on PMV for control logic, advocating for the inclusion of thermal history to enhance prediction precision and improve thermal comfort in air-conditioning systems.

KEYWORDS

Predicted Mean Vote, Thermal history, Thermal sensation, Air conditioning system

1 INTRODUCTION

Most of control logics of air conditioning systems are designed to provide optimal temperature and airflow based on predictions of thermal sensation derived mainly from the Predicted Mean Vote (PMV) model. The PMV model estimates an individual's thermal sensation by considering current environmental and personal factors. However, what has been largely overlooked is the influence of thermal history, encompassing past thermal experiences, which significantly shapes expectations for future thermal performance (Brager & De Dear, 1998). Even when the present environment and individual factors remain constant, differing thermal histories can lead to variations in current thermal sensations. Even though existing research has demonstrated the impact of thermal history on thermal sensation (Zhai et al., 2019; Ji et al., 2019; Wu & Wagner, 2023), there is a limited literature examining the influence of thermal history, specifically in the context of air conditioner operation. Therefore, this study aims to investigate how individuals respond to identical air-conditioned environments following diverse thermal histories.

2 METHODS

Chamber experiments were conducted with 16 subjects (in their 20-30s, wearing 0.3clo experimental clothes). As the study aimed to expose subjects to diverse thermal histories achieved through engaging in activities with varying metabolic demands, three distinct conditions were established: Condition 1: sitting (1 met (1 met=58.2 W/m²)), Condition 2: walking on a treadmill at 2 km/h (1.9 met), Condition 3: walking at 4 km/h (2.8 met).

Each experiment consisted of three sessions, encompassing one condition per session. Subjects initially stayed in the pre-conditioned room (chamber 1) for 20 minutes to stabilize their thermal state, which was set to a neutral environment (26.5°C, 50%). Subsequently, they moved to chamber 2 and performed one of the three conditions for 15 minutes under a hot environment (30°C, 50%). Through the activities in chamber 2, subjects had various thermal histories. After that, they proceeded to chamber 3, where they sat for 15 minutes while the air conditioning system was operated. The air conditioner was set to 26°C and medium speed, which was expected to create slightly cool (Thermal Sensation Vote (TSV) -1) environment according to PMV model. This 50-minute session was repeated three times consecutively, with a different activity condition performed in each session.

Throughout the experiment, air temperature, black bulb temperature, relative humidity, and air speed were measured in each chamber. Physiological responses were measured at regular intervals, including local skin temperature (forehead, cheeks, nose, forearm, hand, wrist, shin), heart rate, and electrodermal activity (EDA) to assess sweating. Additionally, subjects evaluated their thermal sensation, thermal comfort, subjective sweating, and thermal preference at regular intervals during the experiment.

3 RESULTS AND DISCUSSION

While the environmental conditions in chambers 1 and 2 were consistently maintained at the pre-set temperature and humidity levels, the conditions in chamber 3 underwent continuous changes from an initial state of 30°C and 50% due to the activation of the air conditioner. This resulted in a gradual decrease, reaching 25.7°C and 38.7%.

To investigate the impact of thermal history on thermal sensation in an air-conditioned environment, we categorized groups based on subjects' initial thermal sensations in chamber 3. The categorization included all data without sorting the experimental conditions. Following this categorization, we analyzed the changes in thermal sensation within each group under the air-conditioned environment. Out of the 48 responses, one subject reported TSV -2 (slightly cool), necessitating exclusion from the analysis. The remaining responses were then classified into four groups: Group 0 (TSV 0, neutral), Group 1 (TSV 1, slightly warm), Group 2 (TSV 2, warm), and Group 3 (TSV 3, hot), with sample sizes ranging from 8 to 19.

According to the PMV model, thermal sensation was estimated to decrease below thermal neutrality within 5 minutes of the air conditioner's operation. In the cases of Group 0 and Group 1, characterized by neutral and slightly warm thermal histories, respectively, the observed thermal sensation aligned with the PMV predictions. On average, their thermal sensation reached neutrality within 3 minutes of activating the air conditioner, stabilizing between TSV -1 (slightly cool) and 0 (neutral) after 6 minutes. Conversely, for groups with warmer thermal histories, thermal sensations changed differently. Group 2 exhibited an average neutral thermal sensation at 9 minutes, yet some subjects' sensations maintained above neutrality. In Group 3, the average thermal sensation reached neutrality after 12 minutes. However, despite continuous air conditioning, the thermal sensation consistently exceeded neutrality for the majority of subjects in this group.

4 CONCLUSIONS

The findings indicate that a warmer thermal history requires a longer time to achieve thermal neutrality and comfort. Moreover, the PMV predictions exhibit greater disparities in cases where thermal history was above warm. Particularly during the initial stages of air conditioner operation, errors attributable to thermal history are likely to escalate. Therefore, the implementation of customized control strategies tailored to diverse initial conditions is deemed essential for effective air conditioner operation.

5 REFERENCES

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