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Preferred Temperature in an Air-Conditioned Building: A Climate Chamber Experiment

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ABSTRACT

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PREFERRED TEMPERATURE IN AN AIR-CONDITIONED BUILDING: A CLIMATE CHAMBER EXPERIMENT

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Abstract

This paper documents the findings from series of climate chamber experiments on preferred temperatures gathered from 29 college-age participants from The University of Sydney, Australia. The analyses include monitoring of participant's core temperature, 7-point skin temperatures, participant's preferred temperature and thermal sensation throughout a total of 180 minute experiment duration. The mean individually determined preferred temperature from 29 participants was 25.1°C (± 1.2) and mean skin temperature of 33.7°C (± 0.6). The findings are compared with those of similar experiments conducted about 20 years ago, in warmer climatic zone and with different types of participants. Statistically insignificant differences suggest that occupants cannot be naturally adapted to prefer warmer ambient temperatures.

Keywords: Preferred Temperature; skin temperature; thermal sensation; thermal preference; climate chamber.

1. Introduction

There are concerns that the widespread use of air-conditioning may reduce the ability of a population to acclimatize to hot weather [1, 2]. In order to provide the thermal conditions suitable for building occupant's thermal comfort, many field measurements and controlled experiments were conducted to suggest the suitable preferred temperature across different metabolic rate, age groups and climate zones [3-8].

Given the 23 year gap in using climate chamber experiment to determine occupant's temperature preference, it is likely to investigate whether an invariant finding is still relevant. Therefore, this study repeats the experiment procedure from [7], in order to identify the current building occupant's preferred temperature.

2. Preferred Temperature Experiment

2.1 Participants

Participants in this experiment comprised of 29 college-age from The University of Sydney students, 12 male and 17 female, of whom 12 were South Americans, eight were Chinese, three were Anglo Saxons,

two were Indians, two were Middle Easterners and two were Europeans. They were exposed to adjustable indoor ambient temperatures under variable air valve (VAV) conditions in a climate chamber.

2.1.2 Instruments

Participant's core and skin temperatures were monitored throughout the three hour experimental period. Participants' core temperatures were detected using a CoreTemp® sensor ingested 8 hours before the scheduled session. The sensor's signal (of 262 kHz or 300 kHz) passes harmlessly through the body to the CorTemp® Data Recorder worn outside the body. The core temperature was recorded every 5 minutes.

Seven-point skin temperatures, at the forehead, left hand, left forearm, left abdomen, left anterior shin, left anterior thigh and left instep, were measured using wireless thermistors (i-Buttons). The digital thermometer measures temperatures from -55°C to +100°C, typically in 0.2 seconds with an accuracy of $\pm 0.5^\circ\text{C}$ within 0°C to +70°C. The skin temperatures were recorded every 5 minutes. Participants

were instructed to wear standard uniforms, which included a long-sleeved cotton twill shirt, denim long trousers, socks, covered shoes and their own underwear. The clothing insulation value of this light summer ensemble was 0.60 clo [9].

2.1.3 Preferred Temperature Experimental Procedure

Experiment sessions were conducted in the Indoor Environmental Quality Lab, The University of Sydney, Australia, using the facilities described in [10]. Set point adjustments and monitoring of the ambient temperature and relative humidity in the occupied zone of Chamber 1 were 0.6 m above the floor and were logged every 5 minutes by the Building Management and Control System (BMS) – Automated Logic. Chamber 1 was set to an operative temperature of 25.7°C. This temperature was obtained using Fanger's comfort equation in order to calculate a PMV value of zero with the specified clothing ensemble, activity level ($W/m^2 = 60$), relative humidity (30%) and air velocity (0.13 m/s) [4, 11]. An iPad® IEQ questionnaire application was developed to administer two psychometric scales on a fast 60-second turnaround. All selections were saved to the iPad® memory in a time-stamp comma separated file. After 30 minutes in Chamber 1, participants were asked to vote their thermal preference and thermal sensation every 10 minutes for the remaining 150 minutes of the experiment. The questions that assessed thermal preference and sensation were:

- i) Do you want a change of the air temperature? (Scale used: 1 = want warmer temperature; 0 = no change; -1 = want cooler temperature).
- ii) How would you rate your current thermal sensation? (Scale used: (-3 = cold; -2 = cool; -1 = slightly cool; 0 = neutral; 1 = slightly warm; 2 = warm; 3 = hot).

3. Discussion and Conclusion

Preferred temperatures (T_{Pref}) from 29 participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$) and there were no outliers in the data, as assessed by inspection of a boxplot. Mean T_{Pref} for three preferred temperature groups, namely Cool Group (25th percentile): 23.5°C (± 0.76), $n = 8$, $p < 0.001$; Middle Group (50th percentile): 25.1°C (± 0.37), $n = 12$, $p < 0.001$; and Warm Group (75th percentile): 26.2°C (± 0.69), $n = 9$, $p < 0.05$ were significantly different from the earlier T_{Pref} of 25.7°C reported by de Dear and co-workers [7]. The mean T_{Pref} did not differ significantly between male and female.

Mean skin temperature (T_{sk}), mean core temperature (T_c), mean body temperature (T_b) and mean thermal sensation vote (TSV) were averaged over the final 30 minutes of the experiment. The T_{pref} reported by de Dear et. al. [7] is slightly warmer compared to our current T_{pref} , with exception to nine participants who perceived 26°C as their T_{pref} (Table 1). Mean T_{sk} of the current sample at 33.7°C (± 0.6) was warmer but not significantly different from the 33.1°C (± 0.6) as reported by [7].

In this study, the preconditioned 25.7°C in Chamber 1 was perceived to be warm and almost 70% of the participants somewhat persistently wanted a cooler ambient temperature until they achieved their T_{pref} (i.e.: $< 25.7^\circ\text{C}$). The inverse relationship between outdoor and indoor temperature in thermal history investigation by Chun et. al. [12] was not fully evidenced in the current study, where eight participants perceived the pre-conditioned 25.7°C as warm and preferred a cooler ambient temperature. This response could be partly due to the fact that experiments were conducted when Sydney, Australia was experiencing the warmest winter on record. Nine warm days reaching at least 30°C, and no cold spells below 20°C, were

recorded from August until October in 2013 [13].

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