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Thermal comfort expectations and adaptive behavioural characteristics of primary and secondary school students

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ABSTRACT

This study aims to better understand thermal comfort perception and related behavioural characteristics of school children. Statistical analyses were performed on the thermal comfort survey database consisting of 4866 responses collected from primary- and secondary school classrooms in Australia across two summer seasons. The students generally preferred 'cooler-than-neutral' sensations, with the preferred temperature being estimated to be 2–3 K below the neutrality predicted for adults under the same thermal environmental exposures. The students' 80% acceptability zone empirically derived from group mean thermal sensations, was significantly wider than the band of ± 0.85 thermal sensation votes assumed in the PMV-PPD model. The school children indicated air-conditioning as their favoured thermoregulatory method, among many other adaptive options including windows, fans, blinds or clothing adjustments. The results indicated that those students already placed in air-conditioning classrooms were more likely to prefer air-conditioning for the maintenance of their comfort, compared to those accommodated in classrooms without air-conditioning.

1. Introduction

Observational studies of indoor climate of school classrooms have been typically justified by pointing to adverse effects of unfavourable conditions such as warm temperatures and poor ventilation on students' comfort and academic performance (e.g. Refs. [1–4]). The policy urgency of the matter is emphasised as young school children are deemed to be more susceptible to environmental stimuli than adults [5]. Aside from physiological characteristics of young children that may influence their perception of comfort as pointed out in previous research [6–9], a study on school children should take into account distinctive contextual factors inherent in the classroom environment.

In the adaptive comfort theory occupants are deemed as an active agent in creating 'ideal' indoor thermal conditions, by adjusting their behaviours or modifying the surrounding environments [10]. In other words, a certain degree of freedom to behaviourally adjust or interact with the surrounding environments is regarded as prerequisites to the adaptive comfort model. An important implication from the adaptive hypothesis is that the adaptive opportunities can exert influence upon an occupant's comfort zone – the more the adaptive opportunities the wider the comfort zone becomes [11]. Hence the degree to which school children can practice adaptive behaviours in the classroom context is central to better understanding their perception of thermal comfort and attitudes towards classroom thermal environments.

There are adaptive opportunities available to school students in the Australian context, as school classrooms are typically equipped with various environmental control measures, e.g. operable windows, fans or mechanical cooling/heating systems. However researchers indicate that the ambient conditions inside the classroom largely depend on the teacher's preferences or habits, which may diverge from the expectations of children [12]. Therefore students tend to become passive recipients of environmental conditions selected by others, rather than exercising agency for their own comfort [13]. A study conducted in Brazil reports that school children rarely make modifications to the environment as they think they need permission before interfering [14]. It is typical for teachers to automatically assume responsibility for managing their classrooms' physical environments [8]. They would intuitively open or close windows, operate fans or air-conditioners, or adjust blinds in response to perceived or expected climatic conditions inside the classroom. Nevertheless, whether a teacher's environmental adjustments successfully reflect the requirements of the students is questionable. Less desirable environmental conditions of school classrooms discussed in the previous field studies (e.g. Refs. [15–18]) suggest that many teachers may not be well qualified to manage of the classroom environment.

Apart from the degrees of freedom conferred (or not) on students for modifying their classroom thermal environment, there are two other behavioural factors that can significantly affect their thermal comfort,

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namely activity levels and clothing insulation. Autonomy or agency for adjusting those two personal comfort seem somewhat limited as well in the Australian classroom context. Adding or removing a clothing garment represents an instant and effective attenuation of the body's heat-balance, but their freedom to do so is often curtailed by school uniform policies in schools [8,19]. Researchers also indicate that the opportunity of adjusting activity level is restricted during class hours, particularly if the class requires the students to be listening to the teacher's presentation in a seated posture [19].

Perhaps an even more fundamental adaptive comfort question in the context of school classrooms is whether students are even aware of environmental conditions to which they're exposed, and that they have any personal comfort agency whatsoever. An earlier study indicated that students tend to accept unpleasant environmental conditions rather than making changes to improve their own comfort level [20]; a state of "environmental numbness" in which the user rarely exercises any actions to mitigate unfavourable situations [20]. The polar opposite concept is the occupant who is highly aware of and engaged with their indoor climatic environment [21]. Researchers acknowledge the importance of students' environmental awareness and engagement, with a particular emphasis on the role of education in its heightening [14].

Defining comfortable indoor thermal environmental conditions has been the primary focus of thermal comfort research (e.g. Refs. [22–26]), but the overwhelming majority of existing research was based on adult subjects in office situations. Considering the distinctive characteristics of the school classroom environment, including high occupant density, teacher authority, limitations on adaptive opportunities and environmental agency during class hours, and rigid uniform policy, it cannot be assumed that previous findings from adult office-workers can legitimately be generalised to the school classroom context. Not surprisingly, earlier comfort studies carried out in school classroom settings have highlighted systematic discrepancies between the actual thermal perception reported by school children and the predicted by the current thermal comfort standards [8,27–32]. This implies that comfort requirements of school children are not adequately reflected in the current thermal comfort standards such as ASHRAE 55 [33] and ISO 7730 [34]. Thermal comfort of school populations has been understudied relative to office-based studies, therefore the current study aims to advance our knowledge by examining how school children respond to environmental stimuli in the classroom. Statistical analyses are performed on the thermal comfort dataset collected from primary- and secondary schools in Australia. The current study is subsequent to our earlier work in which the students' perception of classroom thermal environment was investigated in relation to adaptive comfort guidelines [27]. This paper addresses more specific research questions based on a larger classroom comfort survey dataset, addressing (1) differences in comfort expectations and requirements between younger and older groups of the students, (2) the students' attitudes towards different adaptation methods, and (3) the contextual factors associated with their adaptive comfort behaviours.

2. Material and methods

Our analyses utilise the database from two field survey campaigns carried out in primary (aged 10–15) and secondary (aged 16–18) schools during summer months of 2012 and 2013. The 2012 dataset comprises of 3356 survey samples collected from eleven schools, located across temperate and subtropical climate regions in New South Wales. Of the 11 schools, nine schools participated again in the 2013 survey, returning a total of 2850 responses. The results from the 2013 survey (n = 2850) have been published elsewhere [27]. The survey period varied from two to four weeks between the participating schools. Table 1 summarises the sample size, survey period, the number of participating schools. The monitored classrooms were with or without mechanical cooling systems. Using operable windows and ceiling fans was regarded as the primary method of space cooling even for those mixed-mode classrooms.

Table 1
Summary of sample size, survey periods and participating schools.

	2012 survey	2013 survey
Sample size	n = 3356	n = 2850
Survey period	2-4 weeks, March 2012	2-4 weeks, March 2013
Participating schools	6 primary schools 5 secondary schools	6 primary schools 3 secondary schools
Ventilation type of schools	4 naturally-ventilated 7 mixed-mode	3 naturally-ventilated 6 mixed-mode

The thermal comfort questionnaire included the standard "right-here-right-now" type questions, including: (1) thermal sensation; (2) thermal preference; (3) thermal acceptability; (4) activity just prior to the survey; (5) school uniform garment check-list; and (6) the preferred adaptive comfort strategies. Each completed questionnaire was time-and-date-stamped to enable *post hoc* matching with concurrent (1) physical indoor climate data collected from instruments installed in each classroom and (2) outdoor climate observations obtained from the nearest weather station (see Ref. [27] for more detailed description of methods).

In the 2012 survey, students rated their subjective warmth on the 5-point thermal sensation scale (Cold, Cool, Neutral, Warm, Hot), while the 2013 surveys used the standard ASHRAE 7-point scale (i.e. Cold −3, Cool −2, Slightly Cool −1, Neutral 0, Slightly Warm +1, Warm +2, Hot +3). To enable comparison between the two surveys, the 5-point scale was coded with both end points anchored at −3 and +3 to become numerically equivalent with the conventional 7-point scale. The assumptions underpinning this mapping process were supported with evidence from the relevant psychometric literature. Firstly, the number of points used in Likert-type scales (i.e. 5 and 7) does not change the data characteristics in terms of mean score, skewness and kurtosis [35]. Secondly, the description used on each point of the thermal sensation scale does not significantly change the numerical value of responses on such scales because of end-point effects. In comparing two different types of 7-point scales (i.e. the Bedford and ASHRAE scales), McIntyre [36] demonstrated there was no statistically significant difference between the numerical data from the two 7-point scales. McIntyre's [36] analysis indicated that the subjects' thermal sensation votes are more likely to be affected by each point's distance from the neutral (0) point on the scale rather than the adjectival descriptors attached to each point. Table 2 summarises the questionnaire, rating scales and corresponding coding used for our analyses.

It should be noted that sample size does not refer to the number of survey participants, since students were allowed to take multiple surveys during the 2–4 week survey period. However, tracking of each student was ruled out in our analysis because each participant was de-identified in the database. The database received careful quality verification by identifying and removing irrational or internally inconsistent responses. For the current analysis 'non-sedentary' subjects (i.e. who had been involved in vigorous activities including physical classes, dance or outdoor play) were excluded. Thus the results analysed in this paper are only based on a homogenous sample of 'sedentary' subjects – who had been sitting in the classroom for at least 30 min prior to completing the questionnaire (n = 4866). Detailed information about the sample demographics, gender, age, and anthropometrics of height and weight, were not collected during the survey. Nonetheless, considering that maturation-related physiological (metabolism) and morphological differences (mass, surface area, surface-to-mass ratio) could influence thermal responses, the individual responses were sorted into primary (n = 3545) and secondary school students (n = 1321) to represent the different age groups.