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Thermal comfort of adolescent children in classrooms: Some reflections on the state-of-the-art

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SUMMARY

Thermal comfort of adolescents (10-17 year olds) in school classrooms is an important but less explored topic. The classroom thermal environment impacts students comfort, learning, and health. Due to differences related to physiology and ability to influence their environments, children's thermal comfort needs and even their interpretation of thermal comfort differs from adults. Based on an overview of the current thermal comfort databases, we advocate that there is an urgent need for studies, spread across different climatic regions, examining classroom comfort for young children. The impact of climate change further drives this urgency.

KEYWORDS

thermal comfort; classrooms; adolescent children; thermal comfort zone; healthy classrooms

1 INTRODUCTION

Children are likely to spend 10-15% of the first 18 years of life in schools, primarily indoors, inside classrooms (Arya *et al.*, 2024). The indoor thermal environment of school classrooms has a crucial bearing on student's thermal comfort as well as their learning and task performance (Wargocki, Porras-Salazar and Contreras-Espinoza, 2019). Current thermal comfort standards are based on studies which examined the thermal comfort and behaviours of adults, primarily in office settings. There are several reasons why children would perceive the same thermal environment differently than adults. Due to their developmental stage, their breathing rates are higher than adults, their metabolic rates are also higher, their clothing patterns are different, a school day is generally more active than an office day, and classrooms have limited adaptive opportunities that young children can freely undertake.

There is a dearth of thermal comfort studies with adolescents as the participants. For example, in the ASHRAE Thermal Comfort Database II (Ličina *et al.*, 2018), nearly 5000 records correspond to studies conducted in classrooms, with age of respondents available. Only 356 of these correspond to the age group 10-17. In the current scenario, this becomes an even bigger concern as periods of unusual weather, leading to thermal discomfort, are on the rise due to climate change. Children are also more prone to adverse effects from exposure to extreme thermal environments due to their developmental stage.

2 ANALYSIS OF THE ASHRAE THERMAL COMFORT DATABASE II

For this work, we used the largest available thermal comfort surveys database, the ASHRAE Thermal Comfort Database II (ATCD2), to examine briefly the available data on thermal comfort in school classrooms. We compared the information available for the 10 to under 18 age group with the 18 to 22 age group. A summary of the thermal sensation data available in the database has been provided in Table 1. In the age group 10-17, most of the data available are for students 16-years-old or over. The 18-22 category has almost 10 times more responses than the younger ages. The linear fits in Figure 1, for the 10-17 vs the 18-22 age group from the ATCD2 provides a neutral temperature of 23.1 °C for the younger age group vs 24.5 °C for the 18–22-year-olds, which can lead to over 10% difference in air conditioning energy use.

Table 1: Summary of thermal sensation votes from ATCD2 for two age groups

Age group	Mean (s.d.)	Median (10^{th},90^{th} %ile)
10–17-year-olds (356 responses)		
Age	16.3 (1.2)	17 (14,17)
Air temperature	26.6 (2.6)	26.3 (23.6, 31.1)
18–22-year-olds (3592 responses)		
Age	19.8 (1.3)	20 (18,22)
Air temperature	26.4 (2.0)	25.9 (24.1,29.5)
Thermal sensation votes distribution (%)		
10–17-year-olds	Cold (0.6), Cool (4.5), Slightly cool (12.1), Neutral (43), Slightly warm (25.6), Warm (11.8), Hot (2.2)	
18–22-year-olds	Cold (0.3), Cool (1.9), Slightly cool (12.9), Neutral (50.7), Slightly warm (23.1), Warm (9.4), Hot (1.6)	

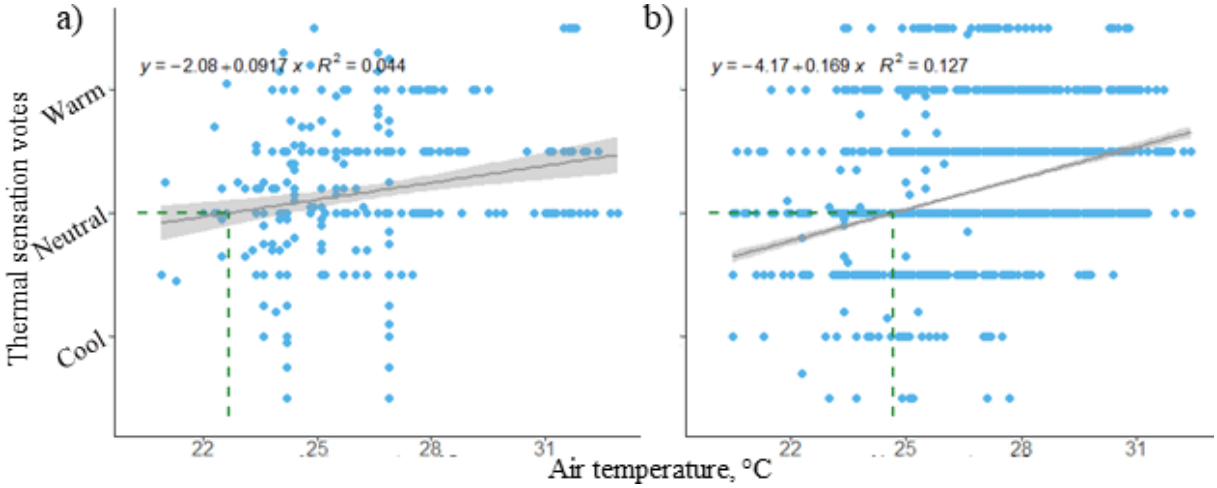

Figure 1: Thermal sensation votes and indoor air temperature in classrooms – linear regression fits for a) 10–17-year-olds and b) 18–22-year-olds

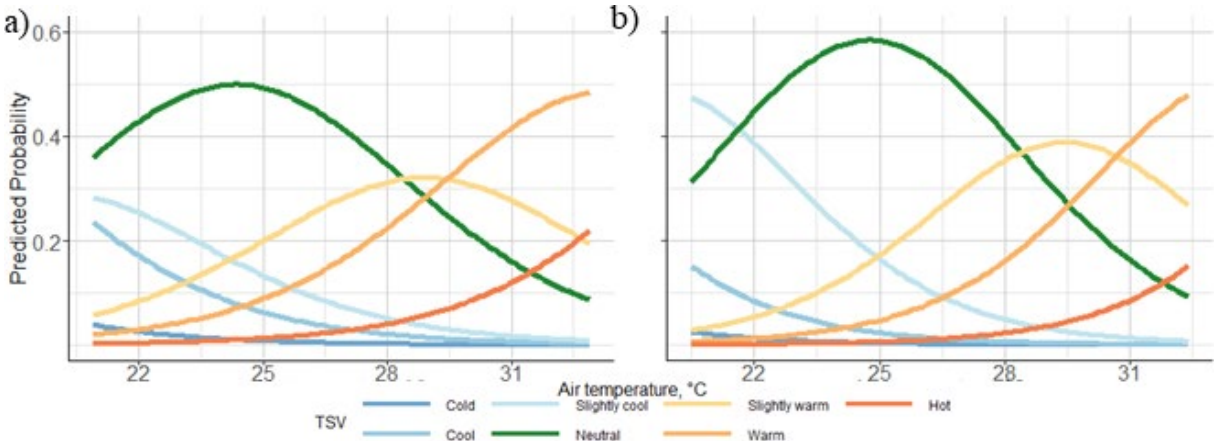

Figure 2: Ordinal regression model for thermal sensation votes and indoor air temperature in classrooms a) 10–17-year-olds and b) 18–22-year-olds

Similarly, an ordinal model (Figure 2) estimating the probability of votes under the different thermal categories are different for the two age groups. This highlights the need for more widespread studies in school classrooms, covering different stages of schooling, focusing on narrower age groups. The 10-17 vs 18-22 presents two very broad groupings, unsuitable for nuanced comparisons.

From a teaching-learning point of view, since different stages of education have different curriculum and learning objectives, the suitable thermal conditions for a learning environment would also depend on the stage of school. As has been observed, the thermal comfort needs for

primary, middle, and high school students tend to be different, with a linear relationship between age and neutral temperature (Torriani *et al.*, 2023).

3 MOVING FORWARD

The available evidence clearly demonstrates the distinct nature of children's thermal comfort. The relative dearth of studies also suggests the need for urgent and focused action, in different climatic and cultural contexts. The urgency is driven by the changing climate where warming classroom conditions will have a significant impact on learning, disproportionately impacting minorities and economically disadvantaged groups (Park *et al.*, 2020).

Chamber-based studies with children can be especially difficult with the issues related to transporting them to an unfamiliar thermal environment and the impact this may have on their responses. Also, as has been observed, thermal comfort questionnaire scales can be interpreted differently based on a number of factors (Schweiker *et al.*, 2020). For children to interpret the questionnaires, a more descriptive approach, involving suitable imagery, is desired (Aparicio-Ruiz *et al.*, 2021; Zapata-Lancaster *et al.*, 2023; Caporale *et al.*, 2024).

Additionally, ongoing and future studies of classroom thermal comfort need to pay due attention to its impact on children's health. While so far the focus has been on comfort and cognitive performance, this is a domain where architects and building engineers need to work in synchronization with public health experts. Due to the long duration children spend in classrooms, a healthy classroom thermal environment can be an important part of public health strategies, especially during acute situations, like a heatwave.

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