Occupant thermal comfort in educational buildings.

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Abstract. The thermal environmental conditions in educational buildings, such as university libraries, affect the productivity and continuity of the students as well as their comfort and health. This paper will explore whether the thermal comfort standards and environmental management of educational buildings are sufficient for their occupants. A longitudinal study was conducted to investigate the thermal comfort of occupants in educational buildings. The Sydney Jones Library, at the University of Liverpool, was identified as an appropriate case study. For this study, users were asked to participate in an online survey that included questions to understand the factors affecting their thermal comfort and their views on the environmental conditions of the space. During the survey study, the temperature and relative humidity of the study area were recorded using data loggers. Statistical analysis of the results obtained from the survey revealed the effect of users' thermal perceptions and expectations on thermal comfort. The average indoor temperature varies between 19-20°C in winter, and 20-21°C in summer. This average temperature is below the recommended winter and summer comfort temperatures for library buildings in the UK. For this reason, the majority of the participants found the indoor temperature cool and wished it to be warmer.

Keywords. Thermal comfort, Climatic background, Education buildings, Comfort temperature

1. Introduction

Hawkes (2002) defined thermal comfort as “some intermediate point, when neither cold nor hot”. This point may differ from person to person, as people may feel differently in the same circumstances (Nicol et al., 2012). Since it is not always possible to know the precise end users and their expectations of a building, it is important for designers to consider thermal comfort standards when designing buildings in order to provide a thermally comfortable environment for building users (Nicol and Humphreys, 2002).

According to CIBSE Guide A (2015), educational buildings and computer rooms have the same comfort criteria, while library reading rooms have different comfort criteria. The temperature comfort ranges for computer rooms is 19-21°C in winter and 21-25°C in summer, while in library reading rooms these values are 22-23°C in winter and 24-25°C in summer (CIBSE Guide A, 2015). Study areas in many university libraries can be used for both reading and working with computers. In this case, it is important to question how the temperature will be determined and which standard will be used, as the comfort temperature value differs by up to 3°C if the space is considered as two separate areas. In such cases, various survey studies can be conducted to find out the building users' views on the indoor temperature, and the temperature range can be determined in line with the feedback.

However, besides the indoor temperature, there are various environmental and individual factors that affect the comfort of the users. These factors, which are frequently mentioned in previous studies, can be examined under three main headings: environmental (air temperature, humidity and air movement) (Olgyay, 1992; De Dear and Brager,2002; Auliciems and Szokolay,2007); personal (metabolic rate and clothing insulation) (De Dear and Brager, 2002, Auliciems and Szokolay, 2007) and contributing factors (age, gender and health condition) (Auliciems and Szokolay, 2007). In addition to these factors, Parson (2003) mentioned that the cultural and climatic background may affect the thermal perception of the users. Nicol et al. (2012) mentioned that people living in different climatic regions have different experiences.

It has been revealed that one of the factors affecting people's thermal experiences and expectations is long-term thermal memory, and the thermal histories of people in different regions vary according to their long-term thermal comfort memories (Knez et al., 2009). A study by Wang et al (2017) supports the hypothesis that long-term thermal history has an effect on thermal comfort. According to a study of the thermal comfort of students who have been in the UK for less than 3 years, the ideal acceptable temperature is 24°C for those with a warm climate background, compared to 22°C for those with a cold climate

background (a climate similar to the UK) (Jowkar et al., 2020).

According to HESA data (HESA, 2020), 22% of university students in the UK are international students and this number is increasing every year. It is debatable whether the comfort standards and environmental management of educational buildings, which are generally based on UK comfort criteria, offer equal comfort conditions for these international students coming from different climatic regions each year. Considering that one of the important factors affecting the productivity, attendance, comfort and health of students is thermal environmental conditions (Mendell and Heath 2005, Wang et al. 2018), it is to be expected that educational buildings would provide students with equal conditions in terms of thermal comfort as much as possible.

In the United Kingdom, there are limited studies examining the effect of student climatic background on thermal comfort in higher educational buildings. Therefore, in this study, it was decided to examine the comfort and temperature conditions in higher education buildings by considering the climatic backgrounds of the students.

2. Methods

This study was carried out at the Sydney Jones library at the University of Liverpool, located in Liverpool, England, between the 31st January 2022 and the 1st November 2022. A study room in the library was selected for this 9-month study, which included an online survey and the measurement of environmental conditions (Figure 1). Located on the ground floor of the library, and known as the computer room, this room consists of two sections. The first section has underfloor heating and a mechanical ventilation system, while the second section has radiators for heating and windows for ventilation. Figure 2 shows the plan of the study room and the location of where the environmental measuring devices were placed. Heating and cooling systems are controlled from a single centre, so the data of the case study area were taken from the University Facilities Management staff. The engineering and contract support manager of the University stated that the ventilation, heating and cooling systems operate 24/7, 365 days a year, and the room temperature is kept at 21°C ± 2°C.

Figure 1

Case study area

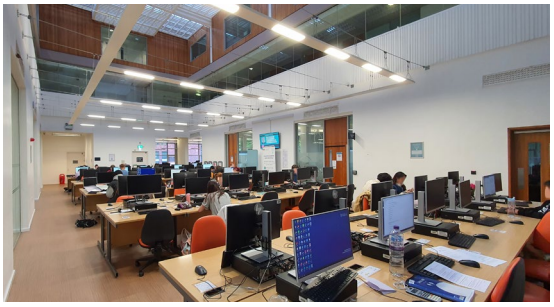
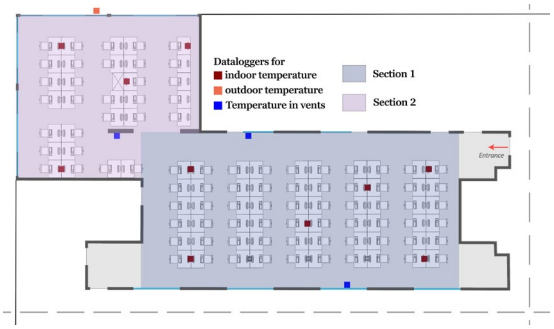


Figure 2

Plan of case study area

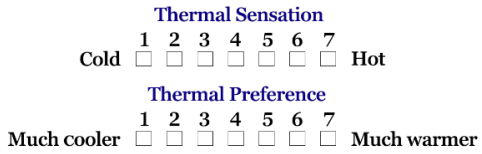


EasyLog EL-SIE-2+ dataloggers were placed on predetermined desks in the area to measure the air temperature and relative humidity at 15-minute intervals. Since it is suitable for outdoor conditions, the Lascar EL-GFX-2 data logger was placed in a shaded place on the exterior wall of the selected room to measure the outdoor temperature. An iButton and a Kestrel DROP D2 datalogger were placed on the ventilation units to identify when the ventilation was working and to know the temperature of the incoming air from the ventilation system.

University ethical approval was first obtained for the online survey, which included questions to understand the climatic history of the users and their thoughts on the thermal conditions of their environment. The 7-point scale, an example of which is shown in Figure 3, was used to understand the thermal sensations and thermal preferences of the participants. In addition, small posters containing the QR code of the questionnaire were placed on all desks. A total of 271 people participated in the survey. Survey data were analysed using the IBM® SPSS® program (IBM®, 2022).

Figure 3

7-point scale

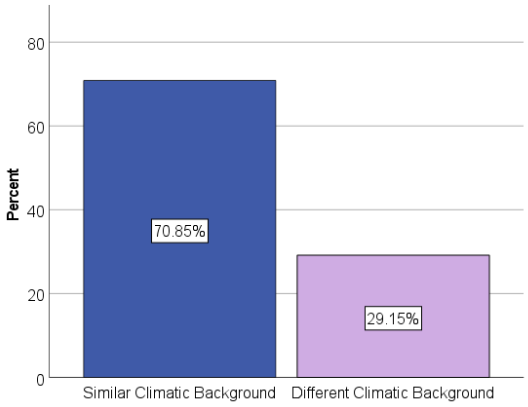


3. Results

A total of 271 people from 33 different nationalities participated in the survey, of which 84% were under the age of 26. In addition, 65% of the participants defined themselves as female, 34% as male and 1% as non-binary. 66% of the participants were British students and 34% were international students. The participants were divided into two groups according to their climatic background as either those from a climatic background similar to Liverpool and those from a different climatic background, and the survey results were compared accordingly. As seen in Figure 4, the percentage of people from a similar climatic background was 70.85%, while the percentage of people from a different climatic background was 29.15%. People coming from warmer or cooler climate regions were examined together, however the majority came from a warmer climate.

Figure 4

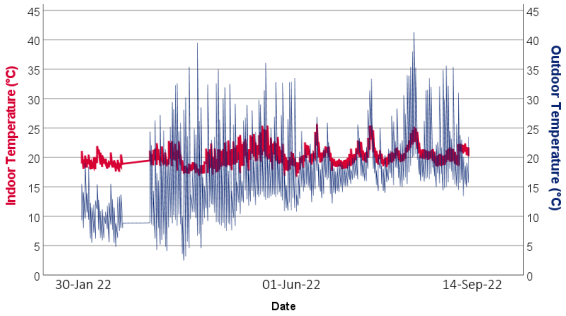
Percentage of climatic backgrounds of respondents



The graph in Figure 5 was created using indoor and outdoor temperature data obtained from dataloggers in the case study area, from 30th January 2022 to 14th September 2022. The minimum indoor temperature was 16.7°C, while the maximum indoor temperature was 25.7°C. While the monthly average indoor temperature varied between 19-20°C in winter, it was 20-21°C in summer. While the average outdoor temperature was 12°C in winter, it was 18°C in summer.

Figure 5

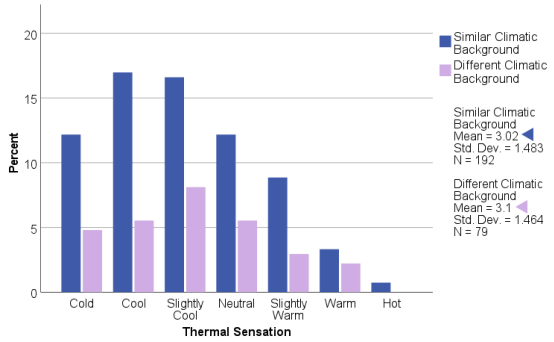
Indoor and outdoor temperatures during the study



The histogram in Figure 6 shows the comparison of the thermal sensations of the participants according to their climatic background. The mean value of the thermal sensations of the participants from a similar climatic background to Liverpool was 3.02, '*slightly cool*', and for those from a different climatic background 3.1 it was '*slightly cool*'. It was observed that the thermal sensation responses of the majority of the participants in the two groups were closer to the cold part of the scale. It was seen that the frequency of those who felt warm was less.

Figure 6

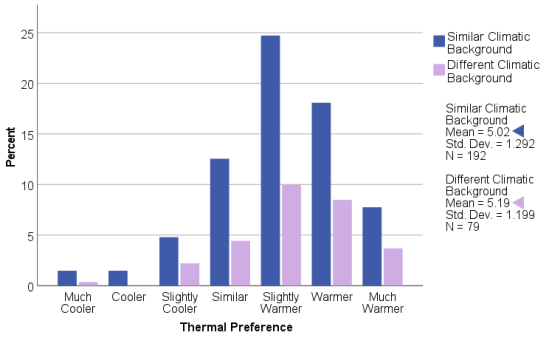
Percentage of thermal sensation votes by climatic backgrounds



The thermal preferences of the participants were compared in Figure 7. It was clearly seen that the majority of the participants wanted the environment to be warmer. The mean value of the thermal preferences of the participants who have a similar climatic background to Liverpool and a different climatic background were also very close to each other, and this value, which can be defined as a `*slightly warmer*`, was 5.02 and 5.19, respectively.

Figure 7

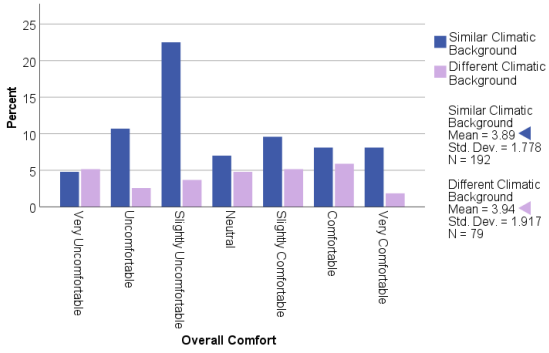
Percentage of thermal preference votes by climatic backgrounds



The overall comfort responses of the participants were compared with the histogram in Figure 8. The mean comfort value of participants from a similar climatic background to Liverpool was 3.89, between `*slightly uncomfortable*` and `*neutral*`, and the mean value of participants from a different climatic background was 3.94, between `*slightly uncomfortable*` and `*neutral*`. Although the distribution of the responses differed in both groups, it was seen that the number of those who felt slightly uncomfortable, especially among the participants from a similar climatic background to Liverpool, was high.

Figure 8

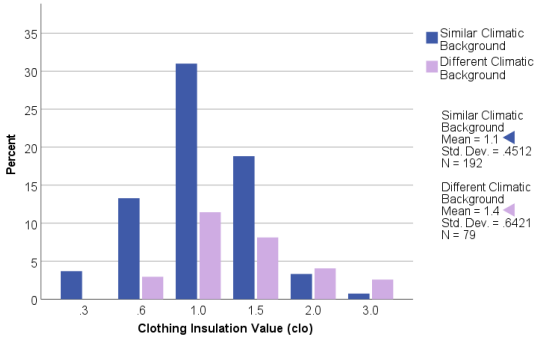
Percentage of overall comfort votes by climatic backgrounds



In Figure 9, the clothing insulation (clo) values of the participants were compared. While the mean value for participants from a similar climatic background was 1.1 clo, it was 1.4 clo for participants from a different climatic background. For participants from a similar climatic background, the minimum clothing insulation value was 0.3 clo, while the maximum value was 3.0 clo, but the frequency of people wearing clothing at this level was quite low. The minimum clothing insulation value of the participants from a different climatic background was 0.6 clo.

Figure 9

Percentage of clothing insulation value by climatic backgrounds



4. Discussion

When the team responsible for central heating and cooling and the team performing the restoration of the area where the study was conducted were interviewed, it was learned that the comfort temperature range set for this area was 21°C ± 2°C. Since the area is mostly used as a computer room, the temperatures were determined as 19-21°C in the winter and 21-25°C in the summer, and the CIBSE Guide A (2015) may have been considered for these reference temperatures. However, when assessing the activity levels determined for these areas in the CIBSE Guide A (2015), this value was determined as 1.4 met for computer rooms. However, the results of the survey showed that the activity level of most of the participants was 1-1.1 met. This showed that the standards for a library in CIBSE Guide A (2015), where the activity level is specified as 1.1 met, would be more appropriate. According to these standards, the winter comfort temperature of the library should be 22-23°C and the summer comfort temperature should be 24-25°C. However, when the measurements made in the case study area were considered, it is seen that the average temperatures in winter were 19-20°C, while they were 20-21°C in summer.

Considering Jowkar et al.'s (2020) study, the ideal temperature value according to climatic backgrounds was stated as 24°C and 22°C for those who came from a warm climate region and those who came from a similar climate region with England, respectively. However, the average temperature ranges measured for this study remained below these values. It is possible that the reason why thermal sensation, thermal preference and overall comfort mean values of the majority of participants were similar is due to the fact that the indoor temperature was low for the majority, regardless of whether they were born in England or in a different country. Looking at the notes added by the participants at the end of the survey, it was seen that they thought that the environment was cold and that the air conditioner was working even in

winter. In addition, according to the notes, some library users observed that they had to leave earlier than they planned, and that they did not want to use the same environment again.

The clothing level specified for a library in CIBSE Guide A (2015) is 1 clo in winter and 0.6 clo in summer, but the results of the survey show that the clothing level of the students was 1.3 clo in winter and 1 clo in summer. In addition, when the clothing level of the students was considered according to their climatic background, it was seen that the clothing insulation values of people born and raised in Liverpool or in a similar climate region were lower than the clothing insulation values of students from other climatic regions. When the clothing level data were disaggregated, however, somewhat counterintuitively the clothing level for people from a warmer climate region was 1.4 clo, and 1.6 clo for those coming from a cooler climate region. This clothing situation is an example of behavioural adjustment, which is one of the thermal adaptation methods mentioned in the studies of de Dear and Brager (1998).

It has not been clarified whether the climatic history has a direct effect on thermal perception, due to the small number of participants with different climatic backgrounds and the differences in environmental conditions at the time they participated in the survey. In addition, considering the results, it is thought that the participants did not consider only thermal environmental conditions when making general comfort assessments. Conducting a survey in which participants are surveyed at the same time in a more controlled environment, with less potential for adaptive behaviour, may reveal clearer results in future studies.

5. Conclusion

In this study, which was carried out in the library of a university located in Liverpool, England, the monthly average temperature of the study area was measured as 19-20°C in winter and 20-21°C in summer, but these temperature values are below the summer and winter comfort temperatures specified for the library in CIBSE Guide A (2015). Therefore, the majority of the participants from similar and different climates evaluated the study area as cool and wanted it to be warmer. It was also observed that the climatic background of the participants affected their clothing level and the majority of the participants, especially from different climatic backgrounds, preferred clothing with a thickness above the standard in order to adapt to the ambient conditions.

6. Acknowledgements

The authors would like to thank the Turkish government and the Republic of Türkiye Ministry of National Education for supporting this study.

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