

Robust e-Voting Composition

Cooke, R. & Anane, R.

Author post-print (accepted) deposited by Coventry University's Repository

Original citation & hyperlink:

Cooke, R & Anane, R 2011, Robust e-Voting Composition. in IEEE 17th International Conference on Parallel and Distributed Systems (ICPADS). IEEE, Taiwan, pp. 676-683, IEEE 17th International Conference on Parallel and Distributed Systems, Tainan, Taiwan, Province of China, 7/12/11.

<https://dx.doi.org/10.1109/ICPADS.2011.109>

DOI 10.1109/ICPADS.2011.109

ISSN 1521-9097

ISBN 978-0-7695-4576-9

Publisher: IEEE

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Comfort temperature and preferred adaptive behaviour in various classroom types in the UK higher learning environments

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Abstract

Maintaining the thermal comfort of occupants along with minimising the related energy consumption is necessary in educational buildings in the UK. Thermal comfort is particularly important in this context as it affects how well students learn in the classroom. This study aims to identify comfort temperature ranges in different classroom types, lecture rooms, studios and PC labs in UK higher learning environments. Overall, more than 3,000 university students in Coventry and Edinburgh were observed and surveyed simultaneously with the monitoring of environmental measurements under free-running, cooling and heating modes, in October and November 2017 and January to March 2018. Thermal comfort zones and comfort temperatures were identified in each classroom type under these three operation modes. The thermal comfort zone was shown to be significantly dependent on the operative temperature in the studios and PC labs. In terms of the students' priorities for adaptive behaviour inside the classrooms, students in the lecture rooms and PC labs with lower levels of freedom, preferred to restore their thermal comfort through personal adaptive behaviour. However, environmental behaviour was shown to be preferred in the studios where the occupants have a greater freedom level. Results indicate a higher level of physiological and psychological thermal adaptation for the occupants of the studios and PC labs compared to those in the lecture rooms. Consequently, the type of classroom and the students' freedom levels should be considered in environmental design of higher education buildings.

Key words: Thermal comfort, Higher education buildings, Lecture room, Studio, Comfort temperature, Adaptive behaviour.

1. Introduction

Trying to find an effective energy efficiency strategy is the basis of recent research in many developed and developing countries. The UK's commitment to reduce its greenhouse gas (GHG) emissions by 2050 [1] highlights the importance of reducing energy consumption in this country. Considering the 5.2 billion kWh of energy consumed annually by UK higher educational buildings [2], studying thermal comfort in such spaces that influence energy consumption plays an important role in saving energy and reducing the related GHG emissions. However, potential energy gains should not be achieved at the cost of reduced thermal comfort in educational buildings as thermal comfort is shown to be one of the influential parameters on students' intellectual performances [3,4]. It is confirmed in a number of studies that thermal discomfort creates dissatisfactory conditions which consequently causes distraction and reduction of the students' learning performance and mental tasks [2–6]. Both higher and lower temperatures than the comfort zone tend to reduce students' performance and their ability to grasp instructions. Warm environments affect students' productivity and cold temperatures reduce manual dexterity and speed [7,8].

Given the importance of thermal comfort in educational buildings, along with the influence of thermal environment on energy consumption and related emissions, this topic has attracted substantial attention among researchers in the recent years. So far, studies have been conducted on thermal comfort in educational buildings in *primary schools* in the UK [8–10], Italy [11], the Netherlands [6,8] and Taiwan [12], *secondary schools* in Italy [13,14], Portugal [15] and Cyprus [16] and *university buildings* in Italy [4,17], the Netherlands [18], Japan [19,20], Brazil [21], India [22,23] and UK [24–26]. Vargas [25,26] conducted two studies at Sheffield University in the UK that evaluated the impact of HVAC technologies on environmental diversity along with examining the role of transitional lobby spaces on occupants' thermal comfort. Lawrence and Keime [24] also examined how active and passive

building design strategies provide comfortable and energy efficient workspaces at Sheffield University, UK.

Existing guidelines such as CIBSE [27] ASHRAE [28] and EN ISO 7730 [29] recommend general environmental criteria for classrooms or educational buildings with no discrimination based on educational level. This suggests applying the same environmental criteria for school buildings to universities and colleges without considering the potential differences between the occupants in each level. However, students in higher learning environments vary in terms of age, gender, thermal background, subjects studied, and the class type that they are exposed to. Therefore, the environmental standards recommended for primary to high school cannot be applied to such multidisciplinary environments. This shows the necessity of having a correct understanding about the occupants' thermal comfort requirements in university buildings in order to provide them with the thermal environment close to their comfort perceptions.

In a thermally uncomfortable setting, occupants tend to react to the 'discomfort sources' in order to restore their personal thermal comfort either unconsciously (by sweating, shivering, etc.) or consciously (via environmental or personal adaptive behaviours) [30]. Conscious behaviours may be through *environmental* or *personal* adjustments [30,31]. People's priorities for adaptive behaviours tend to vary according to their levels of control over the environment [32–34]. Students in higher learning environments are typically from different disciplines and studying various topics [35]. They are exposed to different classroom types with variable occupancy periods and different levels of freedom for adaptive behaviours. For example, students in art-based subjects may spend four or five hours in studios. They have great freedom for adaptive behaviour in the classrooms. Meanwhile, students in science-based subjects spend one to two hours in lecture rooms or PC labs with low or medium levels of freedom to control indoor environment.

Given the influence of occupancy period and thermal adaptation, and control over a space on thermal comfort, different thermal perceptions are expected for students in each classroom type. Therefore, applying similar comfort criteria in all class types may not thermally satisfy students in diverse disciplines.

The lack of an environmental standard for such spaces in the existing guidelines as well as limited studies in field of thermal comfort and energy efficiency to determine thermal comfort range in higher learning environments show the need for more investigations, in this regard.

This study aims to identify:

1. The comfort temperature ranges for students in different classroom types in higher learning environments (sections 3.3 and 3.4).
2. Students' priorities for adaptive behaviour in each classroom type and its influence on their thermal comfort perceptions (section 3.5).

2. Methods

Field experiments were conducted through simultaneous environmental measurements, questionnaire surveys, and observations in eight mixed-mode university buildings in Coventry (52.4068° N, 1.5197° W), England, and Edinburgh (55.9533° N, 3.1883° W), Scotland, in the United Kingdom (UK). The mean annual temperature in Coventry and Edinburgh is 12°C and 10°C, respectively [36]. Relative humidity is similar in both locations, at around 85%. The mean annual air velocity is 2 m/s higher in Edinburgh than Coventry. The locations were selected to represent two different climatic conditions in the north and south of the UK. Data collection took place between October and November 2017 in Coventry and between January and April 2018 in both Coventry and Edinburgh, during the first and second academic semesters when students attended the classrooms.

2.1. Case-study buildings

Experiments were conducted in eight different buildings (B1 to B4 in Coventry and B5 to B8 in Edinburgh). Classrooms were selected based on the availability of the lecturers' consent, classroom types and the number of students. Both morning and afternoon sessions were selected to cover outdoor temperature changes during the day and the impact on students' thermal comfort.

All classrooms were equipped with HVAC systems and operated on changeover or concurrent mixed-mode [37]. Space heating was provided through a square ceiling diffuser in all buildings, and radiators in some cases. Space cooling was provided through ceiling ducts in all buildings except B3, which were equipped with floor cooling outlets. Based on the indoor ambient environment, free-running (FR, neither heating nor cooling), cooling (CL) or heating (HT) modes were preferred by the occupants in these spaces. Ventilation was achieved through operable windows and fresh air supplier ducts controlled manually (except B3) or automatically and manually (B3). However, due to presence of top hung windows and the small extent of window openings because of safety issues, natural ventilation through the windows was not efficient enough. Overall, curtain and window status (open or closed), the number of windows, existing opportunities for adaptive behaviours, HVAC operation mode and ventilation type in each room were also registered.

2.2. Thermal environmental measurement

Field measurements included the recording of four parameters in each classroom: indoor air temperature (T_{in}), relative humidity (RH), air velocity (V_i) and mean radiant temperature (T_{mr}). Relative humidity, air velocity and mean radiant temperature were recorded using the Multi-purpose SWEMA 3000 [38] instrument, working based on ISO 7730 with a time interval of 5 minutes (Table 1

Description of the instruments

Measured parameter	Resolution	Range	Accuracy
Mean radiant temperature	0.1°C	0 - 50°C	±0.1°C
Air velocity	0.03m/s	0.05 - 3m/s	±0.04m/s
Relative humidity	0.8%	0 - 100%	±0.8%
Air temperature	0.1°C	-40 - 70°C	±1.0°C

As shown in Figure 1 (b), the thermometer was placed 1.1 m above the floor level, as recommended by EN ISO 7726 [39] and the anemometer and humidity probe were placed above and below the thermometer. The SWEMA kit and one temperature and RH logger were placed in the middle of the room, away from heating or cooling sources. The rooms were divided into 4 or 5 zones, based on their physical shape (Figure 1 (a)). Each temperature and RH logger was placed in each zone to gain the nearest environmental data on the students' sensations.

The majority of cases, measurements started from the beginning to the end of the class to register all the changes of the environmental variables during each session. However, for the data analysis, averages of the recorded points in the last 15 minutes of each class (when the students were filling in the questionnaires) were considered. The operative temperature, which is generally worked with in this study, was calculated as the mean of the radiant temperature and indoor air temperature for air velocity below 0.2 m/s and through the following formula for higher air velocity [40].

$$T_{op} = A \cdot T_{air} + (1 - A)T_{mr} \quad (1)$$

Where T_{op} is operative temperature, A is the constant value introduced as 0.6 [40] and T_{mr} is mean radiant temperature.

Outdoor air temperature data was obtained from the UK meteorological office [36]. The weather station which represented ambient temperatures in the vicinity of the university was less than 5 km from the study site.

). The probes included in the SWEMA kit were positioned at the occupants' head heights on a vertical stand to reflect all the subjects' thermal sensations.

Table 1
Description of the instruments

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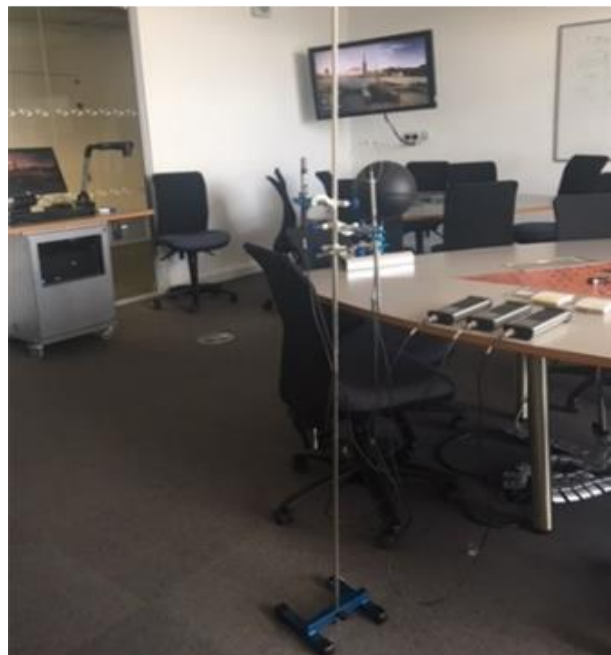
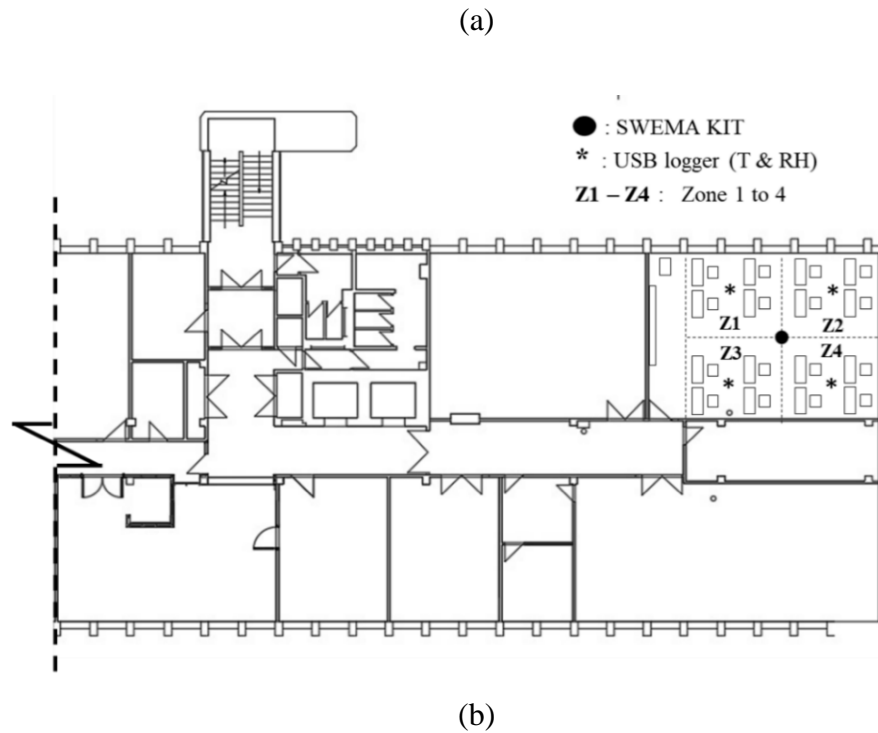


Figure 1. Location of instruments in one of the lecture rooms. a: architectural plan, b: photo of instruments

2.3. Questionnaire survey and participants

Cross-sectional questionnaire surveys were conducted with students in both art- and science-based subjects in studios, PC labs and lecture rooms. The average area of the classrooms, occupancy density, the number of surveys and the number of participants in each room are summarized in Table 2. In Coventry, the survey was repeated 31 times in eleven lecture rooms, 12 times in nine studios and 17 times in nine PC labs and in Edinburgh, 31 times in eight lecture rooms.

Students in the lecture rooms and PC labs were involved in sedentary activities such as listening to the lecturer, and computer modelling during the measurements. However, in the studios, they were involved in activities such as creating mock ups, drawing and computer modelling. According to the classrooms' timetable at both universities and author's observation, the duration of each lecture was around 1 or 2 hours, including a fifteen-minute break in between, while, studio sessions took almost half a day with a couple of breaks in between. Metabolic rate was assumed to be 1.1 met [40] for the students in all classroom types based on their activity levels. Clothing values were evaluated using a checklist (provided in the questionnaire) including upper- and lower-body underwear and outwear items. Participants were asked to select the worn clothes at the survey time. The insulation value for each worn item was obtained from the introduced clo values in EN ISO 7730 [41], sum of which were considered as the total clothing insulation for each subject. The HVAC mode was selected based on the running mode within the survey period, (when students were filling in the questionnaires), regardless of the outdoor air temperature. In some cases, HVAC mode was changed by the occupants before the survey. For instance, HT mode was running at the beginning of the lecture while it changed to FR (or CL) in the middle or at the end of the lecture, (before the survey started); therefore, FR (or CL) mode was registered.

Table 2
Summary of the investigated buildings

Location	Building	No. of participants	Classroom type	Mode	Average area (m ²)	No. of surveyed rooms	No. of survey repeat	Average occupancy density (m ² /person)
Coventry	B1	293	Lecture room	FR	100	2	2	2.5
			Studio	FR	150	4	4	5.0
	B2	707	Lecture room	CL, HT	120	1	8	1.2
			Studio	FR	130	1	3	3.0
			PC lab	CL, FR	90	3	7	3.5
	B3	900	Lecture room	CL, FR, HT	100	8	21	2.0
			PC lab	CL, FR	80	6	10	3.0
	B4	147	Studio	HT	150	4	5	5.0
Edinburgh	B5	382	Lecture room	HT	80	3	8	1.2
	B6	155	Lecture room	HT, FR	80	1	4	1.2
	B7	200	Lecture room	HT	120	1	4	1.2
	B8	728	Lecture room	HT, FR	120	3	15	1.2

FR: Free-running mode, HT: Heating mode, CL: Cooling mode

The thermal sensation votes (TSV) were examined based on the ASHRAE 7-point thermal sensation scale. A similar 7-point scale was used for thermal preferences (TP). Thermal acceptability and overall comfort were also assessed on 4 point scale, as Zhang's study [42] (Table 3).

Hard copy versions of the questionnaires were distributed in the last 15 minutes of each class, after the students had sat in the classrooms for at least 1 hour. It is mentioned in the previous studies that 15 minutes was enough to eliminate the influence of metabolism on the thermal sensation votes [10,43]. However, in this study, 1 hour is considered for the safe margins of a settled metabolic rate and to minimise the disturbance of the class activity. All participants were asked to complete the questionnaires at the same time to make sure the recorded environmental variables corresponded to all the collected thermal sensation votes. Almost 10% of the students did not provide responses, but overall, 3,511 students (1,247 in lecture rooms, 408 in studios and 391 in PC labs) participated in Coventry. 1,406 questionnaires were collected in lecture rooms in Edinburgh. Participants in both locations were of both genders with an average age of 22 years old.

Table 3
Thermal sensation, preference, comfort and acceptability scales

Scale	-3	-2	-1	0	1	2	3	4
Thermal sensation (TSV)	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot	
Thermal preference (TP)	Much warmer	Warmer	Slightly warmer	No change	Slightly cooler	Cooler	Much cooler	
Thermal acceptability (TA)					Clearly acceptable	Just acceptable	Just unacceptable	Clearly unacceptable
Overall comfort (OC)					Comfortable	Slightly uncomfortable	Uncomfortable	Very uncomfortable

2.4. Data analysis

Collected data were statistically analysed to estimate the comfort temperature in which the majority of students were thermally satisfied.

As suggested by Humphreys et al. [30,44] and ASHRAE standard [40] thermal comfort zone was assumed as the range within which a subject feel thermally comfortable or satisfied, which was taken as the three central categories on the ASHRAE sensation scale. Thermal acceptable zone was considered as the temperature range in which 80% of the occupants voted for thermal sensations between -1 to 1 [30,44]. To identify the students' thermal comfort zone under each operation mode, Probit regression analysis was applied to the thermal sensation votes and operative temperatures. Probit analysis deals with binary responses to a variable. In the case of thermal sensation votes, the two responses are arranged as: 1) TSV between -1 to 1 (on the subjective ASHRAE seven-point scale) which is considered as "comfort zone" [30,40,45]; and 2) TSVs beyond the comfort zone (TSV= ± 2 and ± 3). This analysis was conducted by applying Probit regression as a link function and operative temperature as covariate [46]. To complete the process, all the equations were transformed to proportions in the CDF.NORMAL function using SPSS, statistical software package.

$$\text{Probability} = \text{CDF.NORMAL}(\text{quant}, \text{mean}, \text{SD}) \quad (2)$$

Where CDF.NORMAL is the cumulative distribution function, quant is the operative temperature (°C). Mean were calculated by dividing the constant value by the Probit regression coefficient; and standard deviation (SD) is the inverse of the regression coefficient in each equation [46].

Griffiths' method was applied to estimate comfort temperature in each classroom type under FR, CL and HT modes. This approach can calculate the comfort temperature for each single thermal sensation vote and temperature. It is useful for small temperature ranges where linear regression is unreliable [30]. Griffiths' method uses a standard value for the linear relationship between comfort vote and operative temperature: 'Griffiths slope' which is equivalent to the regression coefficient. This method assumes a constant rate of comfort temperature change per variation of thermal sensation scale by considering the sensation vote of 'neutral' as comfortable [30].

The comfort temperature was calculated using the following equation [47–49];

$$T_c = T_{op} + (0 - \text{TSV}) / \alpha \quad (3)$$

Where T_c is comfort temperature by Griffiths' method (°C), T_{op} is operative temperature (°C), TSV is thermal sensation vote and α is Griffiths' constant (K^{-1}). Therefore, if the participants' thermal sensation vote is 0 (neutral), the comfort temperature would be the same as the operative temperature. Similar to previous studies conducted by Nicol et al. [48], Rijal et al. [50] and Mustapa et al. [20], three values for the Griffiths' constant (0.25, 0.33 and 0.50) were adopted to find the most reasonable comfort temperature.

3. Results and discussion

In the following sections, an overview of the indoor and outdoor environmental data and results from subjective evaluations are illustrated.

3.1. Outdoor and indoor environments

Figure 2 shows the outdoor air fluctuations in 2017 - 2018, and within the survey period in Coventry and Edinburgh. There is a higher temperature difference between these two locations during the summer compared to the winter months. Regarding the survey period, there is a minimum, average and maximum air temperature of 1°C, 7°C and 15°C in Coventry and 2°C, 6°C and 13°C in Edinburgh, respectively.

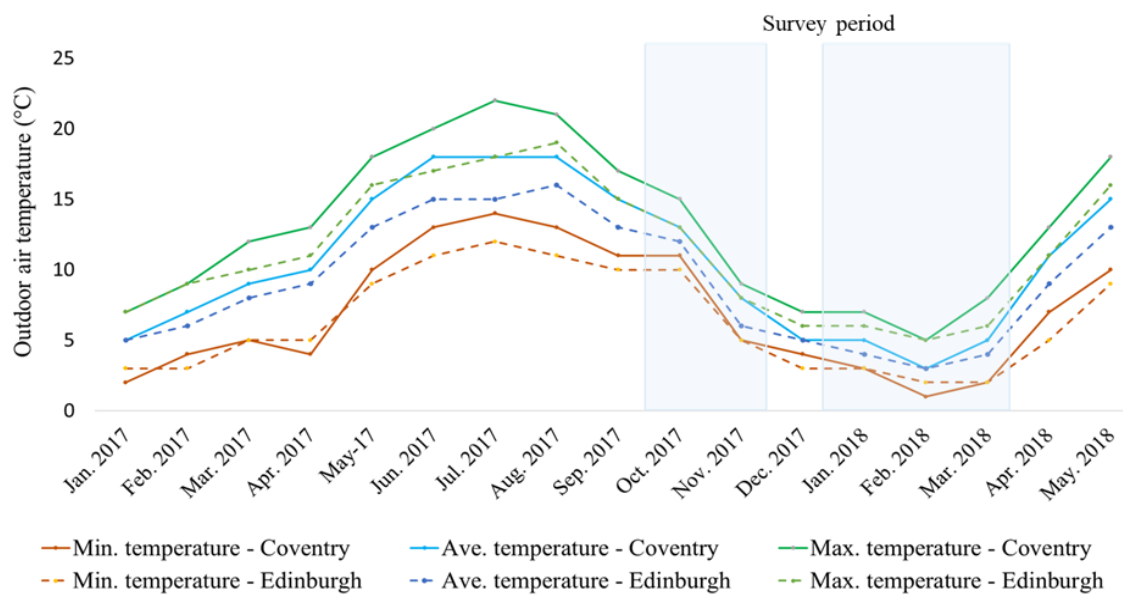


Figure 2. Monthly mean outdoor air temperature in Coventry and Edinburgh, (source: [36])

Results for the indoor and outdoor environmental parameters are presented in Table 4. Mean indoor air temperature, mean radiant temperature and operative temperature (in the survey period) were approximately equal to 22.9°C, 22.6°C and 22.8°C in Coventry, respectively. These values (averaged over January to April 2018) changed to 21.7°C, 22.2°C and 22.0°C in Edinburgh.

Table 4
Summary of the indoor and outdoor environmental parameters

Classroom type	Mode	Item	T_{out} (°C)		T_{air} (°C)		T_{mr} (°C)		T_{op} (°C)		V_i (m/s)		RH_{in} (%)		CO_2 (ppm)	
			Cov.	Edi.	Cov.	Edi.	Cov.	Edi.	Cov.	Edi.	Cov.	Edi.	Cov.	Edi.	Cov.	Edi.
Lecture room	FR	Mean	12.7	6.5	22.6	24.3	22.7	23.7	22.6	24.1	0.08	0.03	51	27	1359	1022
		SD	2.6	1.2	1.3	1.1	1.4	0.9	1.3	1.0	0.35	0.02	9	3	725	275
	CL	Mean	10.3	-	22.7	-	22.0	-	22.4	-	0.07	-	38	-	951	-
		SD	4.8	-	2.1	-	1.7	-	1.9	-	0.24	-	9	-	157	-
	HT	Mean	3.8	5.6	21.2	23.8	20.3	23.4	20.8	23.7	0.06	0.04	24	31	779	1020
SD	2.7	2.1	1.5	1.3	1.2	0.9	1.2	1.1	0.29	0.03	5	6	34	263		
Studio	FR	Mean	14.0	-	24.0	-	23.8	-	23.9	-	0.07	-	60	-	2624	-
		SD	2.2	-	1.0	-	1.1	-	0.9	-	0.04	-	7	-	1367	-
	HT	Mean	9.0	-	23.3	-	23.2	-	23.2	-	0.03	-	41	-	1847	-
		SD	0.0	-	0.6	-	0.7	-	0.6	-	0.01	-	4	-	327	-
PC lab	FR	Mean	11.3	-	23.3	-	23.5	-	23.4	-	0.03	-	44	-	1322	-
		SD	2.0	-	0.9	-	0.8	-	0.8	-	0.02	-	7	-	327	-
	CL	Mean	13.1	-	23.5	-	23.1	-	23.3	-	0.08	-	49	-	1651	-
		SD	1.8	-	0.5	-	0.7	-	0.6	-	0.05	-	5	-	771	-

T_{out} : Outdoor air temperature (°C), T_{air} : Indoor air temperature (°C), T_{mr} : Indoor mean radiant temperature (°C), T_{op} : Operative temperature (°C), V_i : Indoor air velocity (m/s), -: no data available, SD: standard deviation

According to Table 4, the mean outdoor air temperature for FR mode in Coventry was higher than Edinburgh within the survey period. However, the indoor operative temperature in all the classroom types and operation modes in Edinburgh were higher than Coventry. The air velocity was low in both locations in all operation modes. The mean indoor relative humidity was 24% higher in Coventry than Edinburgh under free running mode, but it is almost in a similar range in both locations under HT mode.

Considering the classroom types and HVAC operation modes in Coventry, the mean operative temperature in the studios was 1°C higher than the lecture rooms under FR mode and 2°C under HT mode. In the PC labs, it was 1°C higher than the lecture rooms under both FR and CL modes. The operative temperature in all the classroom types was higher in Edinburgh than Coventry.

3.2. Subjective evaluation

Figure 3 indicates the relation between the clothing insulation values, and thermal sensation votes vs operative temperature binned at 0.5°C intervals in Coventry and Edinburgh. Very

similar trend can be observed for mean TSVs and mean clothing insulation values in both locations.

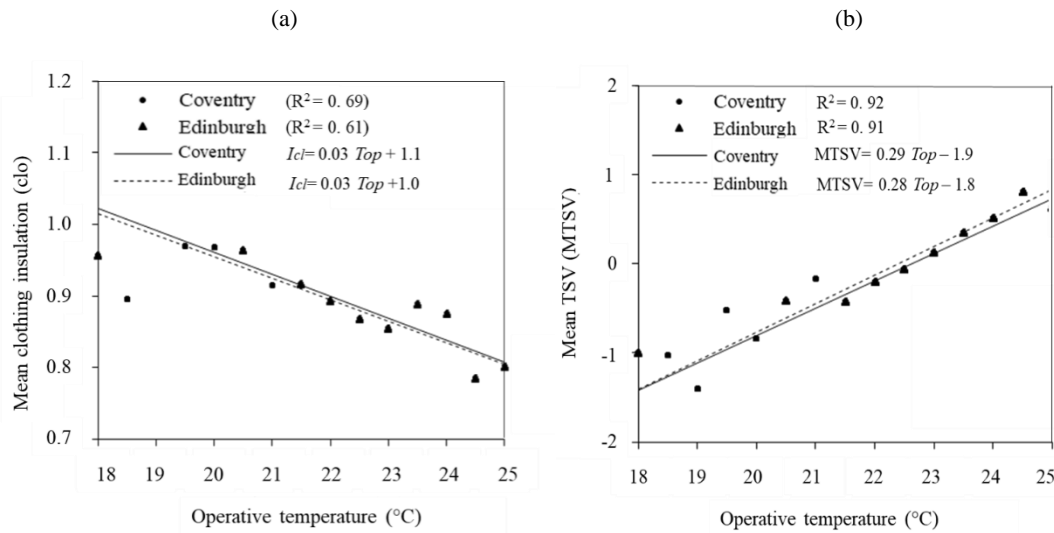


Figure 3. Relation between: (a) mean clothing insulation and operative temperature, and (b) mean TSV and operative temperature

Table 5 presents a summary of the mean value of the subjective parameters collected during the survey. The mean thermal sensation votes (MTSVs) in all classroom types in both locations tend to fall between ± 0.5 . The negative value of MTSV in the lecture rooms in Coventry (-0.26) indicates the cold thermal sensation of students in such spaces. However, the MTSV in the studios and PC labs were equal to 0.20 and 0.12, respectively showing that students felt warmer than neutral in these environments.

Considering all the modes, the mean values of the thermal preference votes in Coventry were approximately equal to 0.14, -0.2 and -0.05 in the lecture rooms, studios and PC labs, respectively. This shows the occupants' preferences towards a warmer thermal environment in lecture rooms and a cooler environment in studios and PC labs, which is consistent with their thermal sensation votes. The mean clothing value for all participants in all classroom types was in the range of 0.85 to 0.91 clo.

Table 5.
Summary of subjective evaluations

Classroom type	Mode	Item	TSV		TP		Clothing (clo)		Overall comfort		Thermal acceptability	
			Coventry	Edinburgh	Coventry	Edinburgh	Coventry	Edinburgh	Coventry	Edinburgh	Coventry	Edinburgh
Lecture room	FR	Mean	-0.20	0.49	0.13	-0.38	0.87	0.84	1.54	1.53	1.86	1.83
		SD	1.22	1.22	1.11	1.12	0.32	0.32	0.80	0.75	0.67	0.74
	CL	Mean	-0.23		0.11	-	0.85	-	1.56	-	1.83	-
		SD	1.20		1.12	-	0.31	-	0.78	-	0.67	-
	HT	Mean	-0.54	0.50	0.32	-0.39	0.96	0.85	1.45	1.48	1.75	1.8
		SD	1.17	1.10	1.14	1.03	0.32	0.31	0.68	0.70	0.64	0.78
Studio	FR	Mean	0.18	-	-0.19	-	0.90	-	1.56	-	1.90	-
		SD	1.15	-	1.13	-	0.29	-	0.76	-	0.64	-
	CL	Mean	-	-	-	-	-	-	-	-	-	-
		SD	-	-	-	-	-	-	-	-	-	-
	HT	Mean	0.27	-	-0.12	-	0.87	-	1.49	-	1.82	-
		SD	1.14	-	1.05	-	0.30	-	0.73	-	0.66	-
PC lab	FR	Mean	0.19	-	-0.17	-	0.86	-	1.43	-	1.77	-
		SD	1.09	-	0.99	-	0.31	-	0.71	-	0.72	-
	CL	Mean	0.05	-	0.06	-	0.87	-	1.43	-	1.68	-
		SD	1.21	-	1.03	-	0.32	-	0.74	-	0.62	-
	HT	Mean	-	-	-	-	-	-	-	-	-	-
		SD	-	-	-	-	-	-	-	-	-	-

- : No data available, SD: standard deviation

Figure 4 shows the distribution of thermal sensation and thermal preference votes in Coventry and Edinburgh. TSVs are normally distributed centred in ‘neutral’ with a negligible shift toward colder votes in Coventry. However, there is a tendency towards the warmer side in Edinburgh, showing students’ warmer than neutral thermal sensations. As suggested by Fanger [45], Humphreys and Nicol [44,51], Nicol et al. [52] and ASHRAE standard [40], thermal sensation votes between -1 and 1 shows subject’s thermal satisfaction. Accordingly, in this study, approximately 78% and 80 % of the students in Edinburgh and Coventry, respectively, are thermally satisfied. This shows that the classrooms in Coventry, where the surveys were conducted, were already in the thermal acceptable zone [44,51,53]. In contrast, the classrooms in Edinburgh were slightly below this acceptability reference value. As expected, there was an opposite trend between students’ TSVs and TPs in both locations. Around 40 % of students in Edinburgh and Coventry voted for ‘0 no change’. 41 % of students in Edinburgh preferred to be cooler, while only 19% wanted a warmer environment. In Coventry, 27 % and 32 % of the participants preferred to be cooler and warmer, respectively.

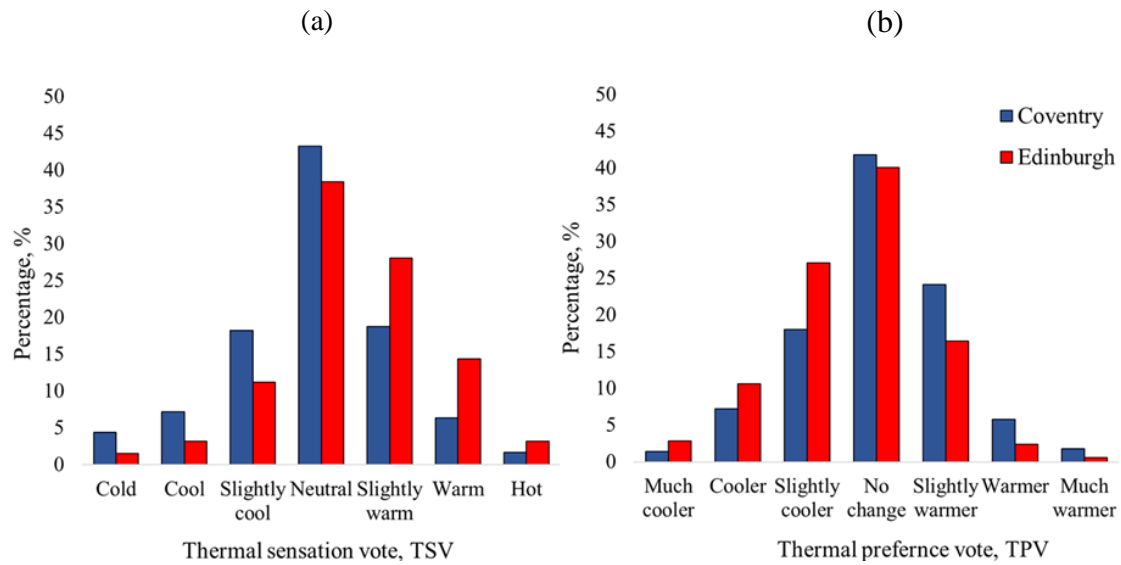


Figure 4. Distribution of thermal sensation (a) and preference votes (b) in Edinburgh and Coventry

According to Figure 5, the majority of the respondents with a TSV of ‘cold’ preferred to be ‘warmer’, but not ‘much warmer’. The highest proportion of students with a ‘cool’ TSV preferred to be ‘slightly warmer’, one scale unit lower than ‘warmer’. Also, the majority of the occupants with ‘hot’ and ‘warm’ TSVs wanted to be ‘cooler’ and ‘slightly cooler’, respectively. This shows that students mainly do not prefer extreme changes when dissatisfied to the warm or cold thermal environments. Occupants who felt warm or cold, with a TSV of 3, 2 or -3 , -2 , preferred to be 2, 1 or -2 , -1 , respectively, showing a one unit move toward ‘0 no change’ from the corresponding TSV value (Figure 4). However, the respondents with a TSV of ‘1 slightly warm’ or ‘ -1 slightly cool’ preferred to be ‘1 slightly cooler’ and ‘ -1 slightly warmer’, respectively. The existing inconsistency between TSVs of ± 3 and ± 2 and the same TPs can be a result of subjects’ various thermal preferences which does not necessarily match their neutrality. It is indicated in previous studies that people with non-neutral thermal sensations may prefer to be warmer or cooler not toward their neutrality [54,55]. For instance, people with warm thermal sensation votes, may still want to be warmer.

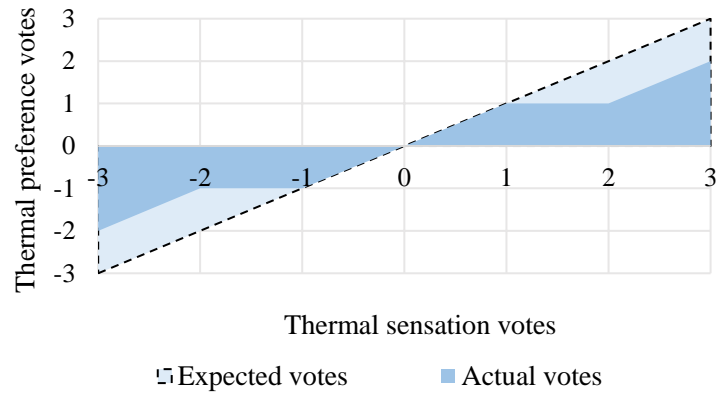


Figure 5. Prevalent thermal preferences in each thermal sensation vote

3.3. Comfort zone

Equations from Probit regression analysis (statistically significant, $p < 0.001$) are presented in

Table 6.

Table 6.
Results of the Probit analysis

Location	Classroom type	Equation *	Median	SD
Coventry	FR	$P(\leq -3) = 0.35 T_{op} - 6.14$	17.5	2.85
		$P(\leq -2) = 0.35 T_{op} - 6.69$	19.1	
		$P(\leq -1) = 0.35 T_{op} - 7.37$	21.0	
		$P(\leq 0) = 0.35 T_{op} - 8.66$	24.8	
		$P(\leq 1) = 0.35 T_{op} - 9.58$	27.4	
		$P(\leq 2) = 0.35 T_{op} - 10.29$	29.4	
	CL	$P(\leq -3) = 0.23 T_{op} - 3.57$	15.5	4.34
		$P(\leq -2) = 0.23 T_{op} - 4.08$	17.7	
		$P(\leq -1) = 0.23 T_{op} - 4.86$	21.1	
		$P(\leq 0) = 0.23 T_{op} - 6.07$	26.4	
		$P(\leq 1) = 0.23 T_{op} - 6.88$	29.9	
		$P(\leq 2) = 0.23 T_{op} - 7.68$	33.4	
HT	$P(\leq -3) = 0.35 T_{op} - 5.69$	16.3	2.85	
	$P(\leq -2) = 0.35 T_{op} - 6.49$	18.6		
	$P(\leq -1) = 0.35 T_{op} - 7.29$	20.1		
	$P(\leq 0) = 0.35 T_{op} - 8.55$	24.4		
	$P(\leq 1) = 0.35 T_{op} - 9.27$	26.5		
	$P(\leq 2) = 0.35 T_{op} - 10.28$	29.4		
Edinburgh	FR	$P(\leq -3) = 0.25 T_{op} - 3.86$	15.4	4.00
		$P(\leq -2) = 0.25 T_{op} - 4.29$	17.2	
		$P(\leq -1) = 0.25 T_{op} - 4.91$	19.6	
		$P(\leq 0) = 0.25 T_{op} - 6.13$	24.5	
		$P(\leq 1) = 0.25 T_{op} - 6.85$	27.4	
		$P(\leq 2) = 0.25 T_{op} - 7.90$	31.6	
	HT	$P(\leq -3) = 0.31 T_{op} - 4.87$	15.7	3.22
		$P(\leq -2) = 0.31 T_{op} - 5.47$	17.6	
		$P(\leq -1) = 0.31 T_{op} - 6.23$	20.1	
		$P(\leq 0) = 0.31 T_{op} - 7.42$	23.9	
		$P(\leq 1) = 0.31 T_{op} - 8.34$	26.9	
		$P(\leq 2) = 0.31 T_{op} - 9.28$	29.9	

* All the equations are statistically significant ($p < 0.001$)

In Figure 6 (a) and (b), each layer indicates the proportion of comfort votes equal to a particular vote (the lowest layer shows the actual proportion of vote -3) [30]. The mean neutral temperature, which can be identified with a probability of 0.5 in TSV between -1 and 1 is around 23°C in FR and HT modes and 24°C in CL mode in Coventry. In Edinburgh, it was around 22°C under both FR and HT modes. Figure 6 (c) indicate the optimal temperature at which the highest proportion of the occupants are thermally satisfied. In Coventry, this value is equal to 24°C under both FR and CL modes and 22°C under HT mode and in Edinburgh, 22°C under FR and HT modes. Considering the standard of minimum 80% acceptability as recommended in regulatory documents such as ASHRAE 55 [40], the comfort zone in Coventry is equal to 22-25°C under FR and CL and 21-24°C under HT mode and in Edinburgh, 21-24°C under HT mode (Figure 6, c).

3.4. Comfort temperature

Results regarding the comfort temperature (calculated by Griffiths' method) using three different constant values are presented in Table 7. A negligible difference is indicated between the obtained comfort temperatures. As the assumption behind Griffiths' method is no presence of occupants' thermal adaptation [30], the value of 0.5 for the Griffiths' constant (α) is considered in order to compensate the influence of thermal adaptation. This shows that each 2°C change in the operative temperature leads to 1 scale unit increase or decrease of the thermal sensation votes.

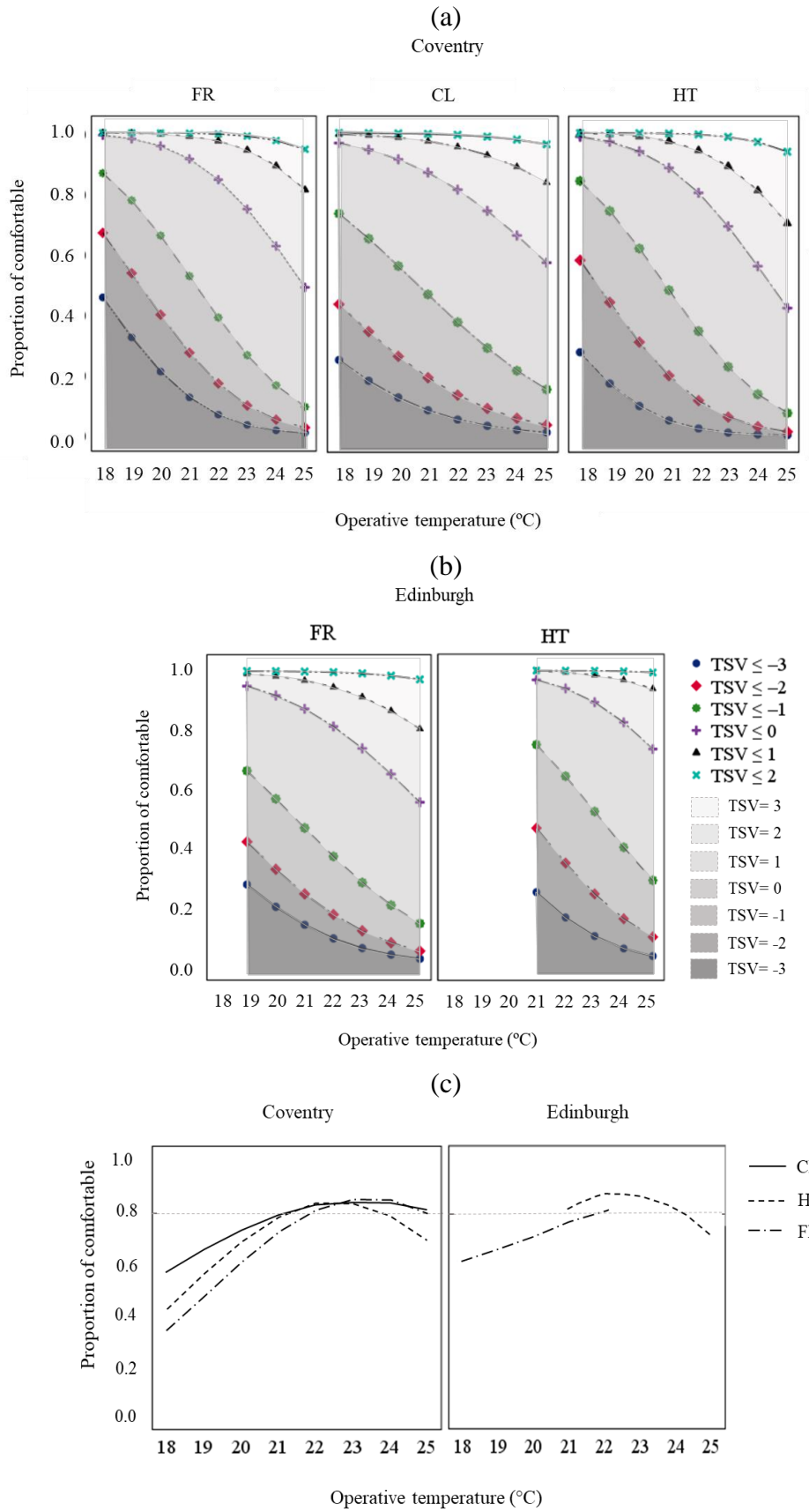


Figure 6. Proportion of thermal sensation votes vs operative temperature (a,b) and proportion of comfortable vs operative temperature (c)

Table 7.
Comfort temperature estimated by Griffiths' method

Location	Classroom	Mode	N	Comfort temperature (°C)					
				$\alpha = 0.25$	S.D.	$\alpha = 0.33$	S.D.	$\alpha = 0.50$	S.D.
Coventry	Lecture room	FR	513	23.4	4.4	23.2	3.3	23.0	2.1
		CL	580	23.3	4.5	23.1	3.5	22.9	2.5
		HT	154	22.9	4.4	22.4	3.3	21.8	2.1
	Studio	FR	261	23.2	4.5	23.4	3.4	23.8	2.3
		HT	147	22.2	4.4	22.4	3.3	22.7	2.1
	PC lab	FR	192	22.6	4.3	22.8	3.2	23.0	2.2
Edinburg	Lecture room	FR	353	22.1	4.7	22.6	3.5	23.1	2.4
		HT	1013	21.6	4.2	22.2	3.2	22.7	2.1

α : Griffiths' constant, SD: standard deviation

According to the Griffiths' method assumption, the comfort temperature was calculated for each data record. The mean of the comfort temperature in the lecture rooms was similar; 23°C in both Coventry and Edinburgh under FR mode, but Edinburgh has a 1°C higher comfort temperature than Coventry under HT mode (Figure 7).

Regarding the influence of diurnal cycle on thermal comfort perception, results show insignificant difference in the thermal sensation, preferences and comfort temperature zone of the students in the morning and afternoon classes.

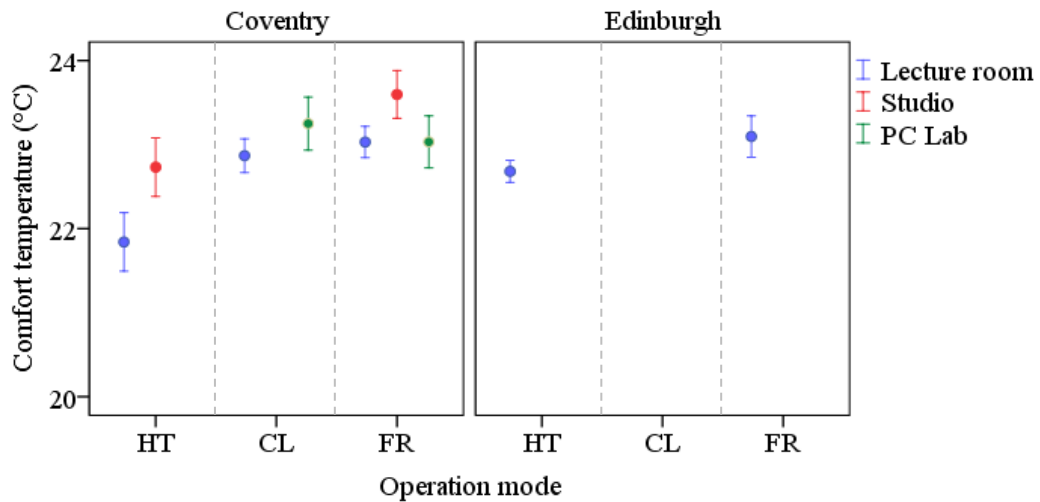


Figure 7. Comfort temperature in the classrooms in each mode

A one-way ANOVA test confirmed that there was no statistically significant difference between comfort temperatures in the lecture rooms and PC labs in Coventry. However, a

statistically significant difference is illustrated between the comfort temperature in the studios and the other classroom types ($p < 0.05$). Comfort temperature was approximately 1°C higher in the studios compared to the lecture rooms and PC labs under FR and HT modes. Considering the warmer thermal sensation and cooler preference of the students in studios compared to the lecture rooms and PC labs (Table 5), this higher comfort temperature can be due to the higher operative temperature in studios than the other classroom types, followed by the students' physiological and psychological adaptation to the exposed thermal environment. Figure 8 indicates a direct association between mean comfort and operative temperature, in all classroom types showing an increase of the comfort temperature as a result of growth of the operative temperature. According to Table 4 and Table 7, proximity of the comfort temperature and prevailing operative temperatures is greater in studios compared to the other classroom types. Similar comfort and operative temperatures in studios can be explained by considering the occupants' physiological and psychological thermal adaptation to the studios as a result of two influential factors; thermal adaptation and students' control over the space:

1. *Thermal adaptation:* People physically adapt to a thermal environment to maintain a constant internal body temperature against environmental fluctuations. Long occupancy periods in the studios gives enough time for occupants' physiological and psychological thermal adaptation to the environment. From psychological point of view, occupants' thermal assessments during the initial occupancy in a space results from their thermal history, not the currently exposed thermal environment [25,54–56]. However, after extended period of occupancy, they change the set mental benchmark according to the experiencing indoor climatic condition [58]. Therefore, higher operative temperature along with the longer occupancy period in studios than the other classroom types leads to the occupants' warmer thermal adaptation and higher comfort temperature in studios than lecture rooms and PC labs.

2. *Control over the space:* due to the students' great freedom and consequently higher levels of control over the space in the studios, they can take proper environmental or personal adaptive behaviour to improve their physiological thermal adaptation and to maintain their thermal comfort. Psychologically, perception of control over an environment reduces the occupants' thermal sensitivity and improves their thermal comfort perceptions [34]. According to Brager et al. [59], the availability of control opportunities in an environment leads to proximity of the occupants' neutral temperature and the prevalent mean operative temperature. This obviously explained the similar comfort temperature to the operative temperature in the studios.

Results in this section are supported by previous studies showing that optimal comfort and neutral temperature for occupants with a high level of environmental control is very close to the actual experiencing temperature [48,49]. It is also proved in the existing literature that control over a space leads to an improvement in the occupants' thermal comfort [27,52], neutral temperature [61] and thermal acceptability [48-52].

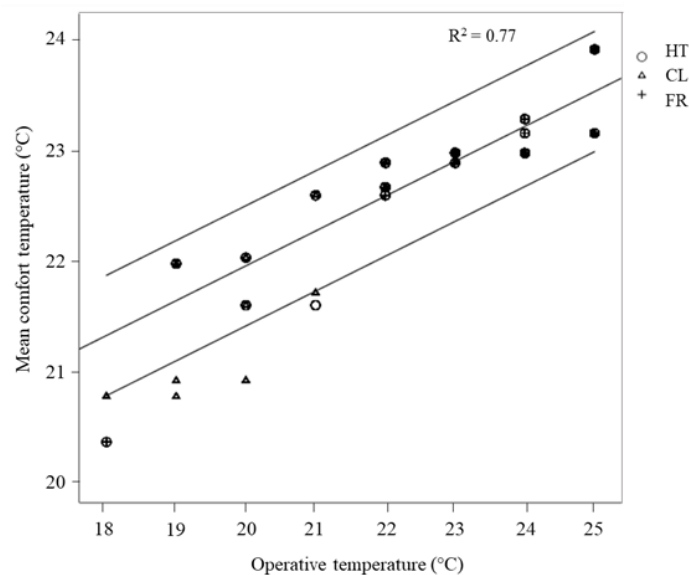


Figure 8. Relation between indoor operative and comfort temperature under each operation mode

3.4.1. Comparison of comfort temperature with other studies

Table 8 summarises the findings from other studies regarding the comfort temperatures in higher educational buildings. As there is no study of the studio type of classrooms in university buildings, comparison between the current and previous studies is mainly focused on the results from lecture rooms.

Table 8.
Comparison of comfort temperature with previous studies in higher educational buildings

Ref.	Year	Location	Season	Analysis method	Sample size	T_{out} (°C)	T_{op} (°C)			T_c (°C)		
							FR	CL	HT	FR	CL	HT
[62]	2011	China	Summer & winter	Linear regression	206	Summer:24.5-30 Winter: 2.5-12.5	CL: 25.1 HT: 21.6			26.8	20.7	
[22]	2013-2014	India	Autumn & spring	Griffiths' method	357	14.5-32.5	29.8	29.5				
[63]	2014	China	Summer	Linear regression	488	20.4-25	22.5 - 22.8			22.6, 21.7		
[17]	2015	Italy	Spring	Linear and Probit regression Adaptive model Rational model	126	13.5-14.6	22.6	21.8				
[18]	2016	Netherland	Spring	Linear regression	384	3.5-8	21.3 - 23.5				20- 24	
[20]	2016	Japan	Summer	Griffiths' method	660	28-32	26.6					
[19]	2017	Malaysia	Summer	Linear and Probit regression Griffiths' method	561	25.3-33.4	25.6					
[19]	2017	Japan	Summer	Linear and Probit regression Griffiths' method	449	25.5	CL: 25.5 FR: 25.3	25.1	26.2			
[64]	2019	Singapore		Linear regression & Griffiths' method	1043	20-30	25					
Current study	2017-2018	UK	Autumn, winter, summer	Probit regression Griffiths' method	3511	Coventry: 1-15 Edinburgh : 2-13	23.4	23	22.9	22.3		

The most outstanding feature in Table 8 is the proximity of the operative and comfort temperatures in all the mentioned studies, reinforcing the results from the current work. Students tend to feel comfortable in a thermal environment they have been exposed to for a period of time. This finding is also confirmed by other researchers [45,49,59,60], declaring that people's comfort temperatures are close to the mean temperatures they have experienced over a period of time. This confirms the influence of thermal adaptation on thermal comfort in classrooms. The comfort temperature obtained in this work is very close to studies conducted in European countries such as Italy [17] and the Netherlands [18]. The comfort temperature introduced in Italy [17], is equal to 21.8°C under FR mode, showing an almost

1°C lower comfort temperature than the UK. Also, the comfort temperature of 22°C and the comfort zone of 21–25°C in lecture rooms under HT mode in the UK is close to the comfort temperature range in the Netherlands, 22–24°C [18], with wider range in the UK than the Netherlands showing approximately similar thermal comfort for students in both locations under HT mode. However, a higher comfort temperature compared to the UK is illustrated in other studies conducted in warm and tropical climates such as Malaysia, Singapore, Japan and India [19,20,23,46]. Higher operative temperatures and occupants' warmer thermal adaptation and expectations can be the main reasons for the distinctions between these countries and the UK.

3.5. Preferred adaptive behaviour for thermal comfort

3.5.1. Priorities of personal and environmental behaviours

Students' priorities for either personal or environmental adaptive behaviours in uncomfortably warm or cold environments (TSV beyond -1 to 1) is evaluated in all types of classrooms using the students' answers to the question "what would you prefer to do in uncomfortably warm and cold thermal conditions when you are in the classroom?" The available adaptive opportunities in the classrooms were listed in the questionnaire, including adjusting clothing, operating windows and doors, having a hot or cold drink, changing position and operating the HVAC system. The students were asked to choose three of them based on their priorities in uncomfortably warm and cold thermal environments. Approximately 9 % of the students did not provide reliable answers; therefore, their votes were removed from the data.

Results in Figure 9 show that adjusting clothing and operating windows were the most common actions among students in both uncomfortably warm and cold conditions. In uncomfortably warm thermal condition, nearly half of the students in both lecture rooms (48 %) and PC labs (47 %) preferred to adopt personal behaviours (adjust clothing) to restore

their thermal comfort, whereas half of the students in the studios (48 %) preferred to adopt an environmental behaviour (operating windows) before any personal action. This indicates students' priorities for personal behaviours before environmental actions in lecture rooms and PC labs. However, they preferred environmental behaviours in the studios.

The main reason for such priorities is the different levels of freedom in each classroom type. Occupants in the lecture rooms do not have enough freedom to take environmental actions such as operating windows or doors and changing the HVAC set points. They may not feel comfortable about walking in the classroom to access the windows, doors or the HVAC control point while a lecture is running. This happens due to the nature of teaching in such spaces. However, there are less strict rules in the studios than the lecture rooms. Students in studios tend to have greater freedom to move around and adjust the environment based on their comfort levels.

Operating HVAC systems was shown as the third priority for the students either because working with HVAC systems was not very clear for them or that the thermal environment was centrally operated by the university building management system.

It should be noted that even if the HVAC control point is accessible, the majority of students in all the classrooms in uncomfortably cold thermal conditions were expected to prefer adjusting clothing first, operating windows second and changing the HVAC set point third. Operating windows was not the first priority as windows are rarely open in cold thermal conditions. Even if there are open windows, operating them cannot improve thermal comfort in cold conditions as it does in uncomfortably warm environments. Heating systems, either through supplier ducts or radiators, were also not a main priority, as mentioned above. As a result, the easiest option may be adjusting clothing to gain comfort in thermally cold conditions. Common personal adaptive behaviours in lecture rooms can be another reason for the wider comfort zone in such spaces compared to the studios. According to the existing

literature [59], personal behaviour provides a high level of thermal comfort for occupants in an environment. Occupants tend to change the thermal conditions in different patterns which can differ from person to person. It may be difficult to provide a comfortable and satisfactory thermal environment for all the occupants. Therefore, individual control, in comparison to centrally controlled systems, leads to far greater thermal comfort [58,66]. Environmental behaviours such as opening/closing windows and doors or operating HVAC in lecture rooms may thermally satisfy one group of occupants but may cause thermal discomfort for the others. Personal behaviours such as adjusting clothing, changing position, etc. provides comfort conditions for each student based on their own preferences.

3.5.2. Comparison of adaptive behaviour with other studies

The results in this section are supported by previous studies showing the influence of occupants' freedom levels on preferred adaptive behaviours. Results from the study conducted in the university buildings showed that students usually prefer personal adaptive behaviours before environmental actions in classrooms [4,18,59,61,63]. Adjusting clothing is the first preferred behaviour by occupants in university buildings in China [59,63], with a mean indoor air temperature of 22°C and 30°C.

Drinking a beverage has priority in Japanese universities with a mean indoor air temperature of 25°C and 27°C [4,18,61]. Likewise, employees in mixed mode office buildings in the UK prefer personal adaptive behaviours before any environmental actions in thermally uncomfortable conditions, with a mean indoor air temperature of 22°C [34]. Among the environmental behaviours, HVAC operation was preferred by occupants in higher educational spaces in the hot climates of Malaysia [19] and Indonesia [67] with mean indoor air temperatures of 27°C and 30°C, respectively. Operating windows is also the most common action in a school building in Taiwan with a mean indoor air temperature of 35°C [68].

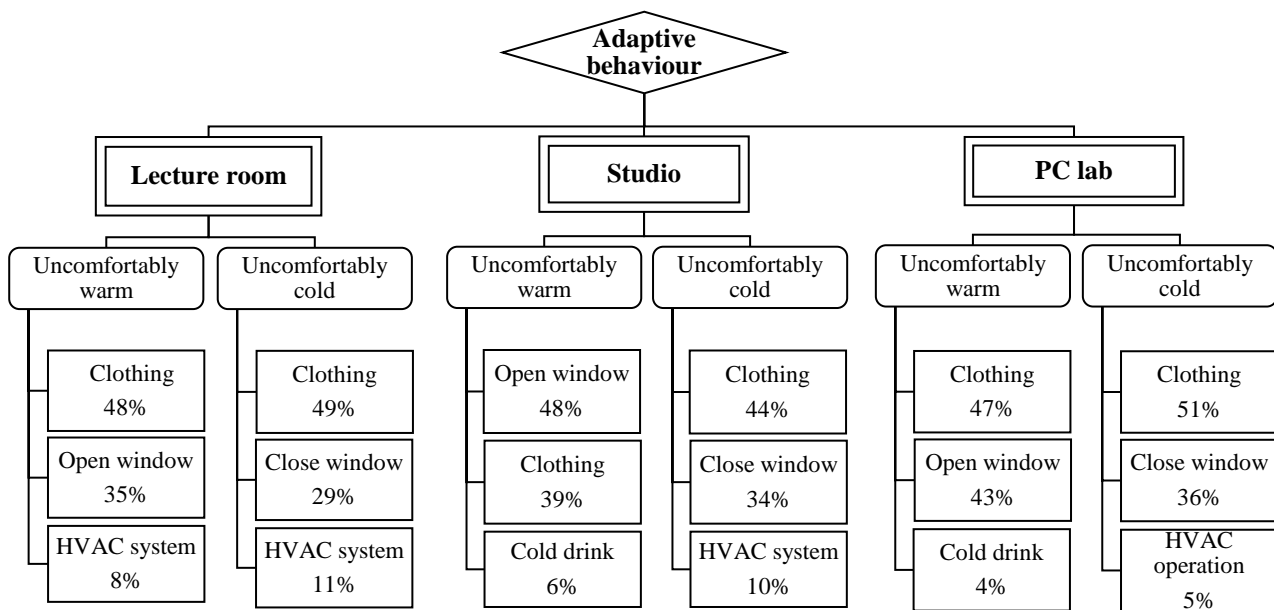


Figure 9. Priority of students for adaptive behaviour in uncomfortably warm or cold environment

In contrast, studies conducted in residential buildings in the hot climate of Indonesia [66,69] and the warm and tropical climate of Singapore [33], with a mean indoor air temperature of 27°C and 29°C, respectively, evidence that people usually prefer to gain comfort through environmental actions before any personal adjustments. Creating higher air movement through applying air conditioning systems, fans and opening windows are the most preferred actions during the day in residential buildings in both locations [66,69].

Occupants in classrooms and offices tend towards personal behaviours before any environmental adjustments. Similar to the current study, adding or removing clothes, taking hot/cold drinks or changing position are common behaviours in such spaces. However, in residential buildings where the occupants have enough freedom, environmental adjustments such as HVAC and operating windows have priority over personal ones, despite their financial costs.

A main reason for this can be that in public spaces like classrooms and offices, occupants may not feel fully allowed to change the thermal environment as these changes could cause thermal discomfort for the others. Limited access to environmental opportunities like windows or HVAC systems for some of the occupants and low levels of freedom to adjust the thermal environment are other reasons why personal behaviour is more preferred in such spaces. Nevertheless, the influence of climatic condition and indoor air temperature on the selection of adaptive behaviours should not be overlooked. As mentioned above, in educational buildings with indoor air temperatures between 22°C and 30°C, personal behaviours are preferred over environmental ones [19,20,67,70,71], while in extreme conditions with indoor air temperatures from 27°C to 35°C, environmental actions are more common [4,61,72]. In other words, in extreme thermal conditions, environmental behaviours are more preferred because the personal adjustments may not properly provide comfort for the occupants [73]. Such information on the prediction of occupants' adaptive behaviours helps to provide the proper adaptive opportunities in teaching and learning spaces, which not only provides the subjects with thermal comfort, but also helps to save energy and minimise the buildings' running costs.

4. Conclusions

This study evaluates thermal comfort in higher learning environments in two climates within the UK (Coventry and Edinburgh) through environmental measurements, questionnaire surveys and observations. In total, 3,511 undergraduate and postgraduate students in art and science- based subjects participated in this study whilst in lecture rooms, studios and PC labs. The output of this work shows that the same thermal environment is not required in all operation modes or in all classroom types as the occupants' activities and exposure duration to each classroom differs one from the other. Comfort temperature is shown to be

approximately 2°C lower under HT mode compared to the FR and CL modes, which suggests 2°C decrease of the indoor air temperature set point under HT mode.

In terms of classroom type, comfort temperature is shown to be around 23°C in studios and 22°C in lecture rooms under HT mode, therefore, 1°C lower indoor air temperature can be set in the lecture rooms than studios.

According to Humphreys et al. [30], in the UK, reduction of the indoor air temperature for only 1°C can save 10% of energy used for heating purposes. Considering the number of campuses and learning environments in higher educational buildings, 10% reduction of energy consumption in each building can lead to a considerable energy saving in this sector.

Thus, it should be considered that providing the same thermal environment in all classroom types, not only causes overheating/overcooling and students' discomfort, but also leads to waste of energy and related emissions in higher educational buildings.

We have also summarized the key findings as follows:

- In terms of thermal sensation votes (TSV) and thermal preferences (TP), respondents do not prefer extreme changes in uncomfortably warm or cold thermal environments. Occupants with a TSV of 3, 2 or -3, -2, preferred to be 2, 1 or -2, -1, respectively, showing a one unit move toward '0 no change' from the corresponding TSV value. However, students with a TSV of '1 slightly warm' or '-1 slightly cool' prefer to be '-1 slightly cooler' and '1 slightly warmer', respectively.
- Considering the standard of a minimum 80% acceptability as recommended in regulatory documents, the thermal comfort zone evaluated by Probit regression analysis is wider in lecture rooms than in studios and PC labs. The apparent reason for this is due to students' wider exposure to temperature ranges in lecture rooms than in studios and PC labs and students' preferences for personal behaviours in lecture rooms.

- Comfort temperature calculated by Griffiths' method tends to be 1°C higher in studios than lecture rooms and PC labs in Coventry. Comfort temperature in lecture rooms is similar (23°C) in Coventry and Edinburgh under free-running (FR) mode, but there is a 1°C higher comfort temperature in Edinburgh than Coventry under heating (HT) mode.
- There is a very close and linear relationship between comfort and operative temperatures in studios and PC labs. This shows the occupants' thermal adaptation to their thermal environments as a result of long occupancy periods and high levels of freedom/control over the space.

In terms of adaptive behaviour, students' priorities differ in lecture rooms, studios and PC labs as a result of different freedom levels in such spaces. The majority of occupants in lecture rooms prefer personal adaptive behaviours before environmental ones. However, in studios and PC labs, they prefer environmental behaviours before the personal ones. It should also be noted that the findings in this study are limited to the mean outdoor air temperatures 5°C to 16°C in the UK under which access to the heating systems (along with the air conditioning) were available for the occupants. It was targeted to collect data in both academic semesters (September-December and January-March) in higher learning environments to cover the thermal comfort of the occupants in such spaces in both semesters.

Acknowledgements

The authors gratefully acknowledge the lecturers at Coventry and Heriot-Watt Universities for their assistance in conducting the field survey within their teaching sessions. We appreciate the guidance of IEA Annex 69 towards completing this work. This work was supported by Coventry University, UK and we would like to thank this institution for the funding provided to complete this research.

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Survey questionnaire

Please answer the following questions and tick the box that best corresponds to your answer, where applicable.

1) **Are you...**

- Female Male Other Do not wish to specify

2) **How old are you?** (Please tick one of the options)

- <21 21-25 26-30 31-35 36-40 >40 Do not wish to specify

3) **Please write down the country and the city in which you are mainly living at the moment.**

Country City

4) **How long have you been living in the UK?**

- < 1 year 1 – 3 years > 3 years

5) **Please write down the country and city in which you were mainly living before moving to Portsmouth.**

Country City

6) **Please write down the country and city in which you mainly grew up.**

Country City

7) **How do you describe the climate condition of your hometown compared to Portsmouth's weather?**

- Much colder Colder Similar Warmer Much warmer Warmer in summer and colder in winter

8) **At your home before moving to Portsmouth** (if you are from Portsmouth, please answer this question based on your family home there condition),

- Heating system was used more than cooling system in a year
 Cooling system was used more than heating system in a year
 Heating and cooling system was used for the same months of a year
 There is not mechanical heating/ cooling systems at home

9) **How do you describe thermal condition of your current accommodation compared to this classroom?**

My accommodation is:

- Much colder than this classroom Colder than this classroom Similar to this classroom Warmer than this classroom Much warmer than this classroom

10) **Do you have control on heating/cooling system at your current accommodation?** Yes No

11) **What do you prefer to do in uncomfortably warm or cold thermal conditions when you are in the classroom?** You can select the most preferred action from options A to F based on your priority. Please write it down in the boxes provided below.

- A. Opening/ Close the windows
- B. Reducing/ Increasing my clothing
- C. Opening/ Closing the door
- D. Having cold/ hot drink
- E. Changing my position in the classroom
- F. Adjust the heater/ air conditioner thermostat

In **warm** condition

First	<input type="text"/>
Second	<input type="text"/>
Third	<input type="text"/>

In **cold** condition

First	<input type="text"/>
Second	<input type="text"/>
Third	<input type="text"/>

12) How do you feel right now?

- Cold
 Cool
 Slightly cool
 Neutral
 Slightly warm
 Warm
 Hot

13) Do you find this...?

- Comfortable
 Slightly uncomfortable
 Uncomfortable
 Very uncomfortable

14) At this moment, would you prefer to be...?

- Much cooler
 Cooler
 Slightly cooler
 Without change
 Slightly warmer
 Warmer
 Much warmer

15) At this moment, do you find this climatic environment ...?

- Clearly acceptable
 Just acceptable
 Just unacceptable
 Clearly unacceptable

16) Please tick the circle for each item of clothing that you are wearing right now.



Example

<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Socks	Shoes- thin soled	Shoes- thick soled	Boots
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Short	Light weight trousers	Normal trousers	Thick trousers
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
No underwear	Underwear top	Underwear short sleeves	Underwear long sleeves
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
T shirt	Normal shirt	Thick shirt long sleeves	Thin sweater long sleeves
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Light skirt	Heavy skirt	Light dress	Heavy dress
<input type="radio"/>	<input type="radio"/>	Any other clothing? Please write it down	
Jacket/ thick sweater long sleeves	Thick coat		

Any additional comments?

.....

Thank you for taking part in this study