PIONEER
ACADEMIC PUBLISHING LIMITED

Studies in Art and Architecture
ISSN 2958-1540
www.pioneerpublisher.com/SAA
Volume 1 Number 1 December 2022

Do Students with Different Genders Have a Different Perception of Temperature, Thermal Comfort, Learning and Clothing?

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doi:10.56397/SAA.2022.12.06

Abstract

Workers of different genders have different demand for thermal comfort. If the thermal environment of the classroom is unsatisfactory, it may harm learning performance. Therefore, it is worth further exploring whether there is a perception difference between students of different genders in thermal comfort. Although differences in thermal comfort between different genders, ages and clothes have been found by many types of research recently, there are few experiments to research the influence of gender differences on thermal comfort among students in educational architecture.

This paper aims to research whether there are differences in the perception of thermal comfort, clothing and temperature among students of different genders of UCL in the lecture theatre. The research objective is to obtain relevant data based on the combination of objective and subjective investigation, analyze the data with T-test and Correlation, and compare the data to research the differences and the reasons behind them.

There is no gender difference in thermal comfort among students in the individual lecture theatre study, but there is a significant gender difference in the all lecture theatre study. In LT05b, no correlation was found between the clothing of different genders and thermal comfort, but a strong linear negative correlation was found between thermal preference and thermal comfort variables of the male group. There is no correlation between the clothing and thermal comfort of students in all the lecture theatre, while there is a strong negative correlation between thermal preference and thermal comfort.

Finally, the conclusion of this study provides some data support for UCL to improve lecture theatre conditions (thermal environment). When the thermal environment of the lecture theatre satisfies the thermal comfort and effective learning needs of students, female students should be fully considered.

Keywords: gender, thermal comfort, clothing, difference, correlation

1. Introduction

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) defines thermal comfort as "the mental condition to express satisfaction in a thermal environment" (Snow, 1982). Thermal comfort is a cognitive process that is influenced by physical (air temperature, radiation temperature, air velocity, relative humidity), physiological (activity level and clothing insulation), psychological and other factors (Lin & Deng, 2008) (Handbook-Fundamentals, 2009). Even in the same indoor environment, the occupant's perception of heat is different (Kuchen & Fisch, 2009). Previous studies on thermal comfort did not take into account the gender differences in thermal comfort perception. Differences in thermal comfort between genders, ages and clothing have recently been discovered. In the field survey of office workers, it is found that different genders have different needs for thermal comfort(Fishman & Pimbert, 1979). The influence of indoor thermal comfort on students is more important in educational architecture (Sarbu & Pacurar, 2015). Wang et al. (2018) research found that students' academic performance would increase with the increase of the heat satisfaction vote. Therefore, it is worth further exploring whether there is a perception difference in thermal comfort between different genders of students.

Through the field study of UCL, questionnaire data of a total of 50 lecture theatre were obtained. Questionnaire data from LT05b from two different time periods (9:00-11:00, 11:00-12:30). This paper aims to investigate whether research scholars of different genders have different perceptions of thermal comfort, clothing and temperature in the lecture theatre, create indoor environment conditions to reduce students' discomfort with heat, so as to eliminate the negative impact on learning. The objective is to obtain the relevant data based on the combination of objective and subjective survey and analyze the data with T-test and correlation.

UCL needs to consider the thermal comfort of the teaching staff and students in the lecture theatre. If the thermal environment of the classroom is unsatisfactory, it may distract students and harm learning status and academic performance. It is necessary to pursue appropriate indoor conditions.

2. Literature Review

The thermal sensation is a subjective factor, it cannot be directly measured. ASHRAE and ISO have developed evaluation standards to evaluate the degree of human comfort (AC08024865, 2005). Laboratory and field studies have shown that when buildings are relatively mild, the slower adaptation process is not significantly correlated with thermal adaptation, but the effect of behavioral adjustment and expectations is greater (De Dear & Brager, 1998).

Many studies have shown that people perceive heat differently under the same indoor conditions (Karjalainen, 2012). Regardless of the physical condition of the measurement, the sensors show the same data, but differ from the human body. Due to the combination of different indoor thermal environment factors that affect the perception of occupants, people who have experienced the same thermal environment have expressed different views on thermal comfort. Therefore, the investigation of subjects is an important part of the evaluation of the research subject (Kuchen & Fisch, 2009).

In recent years, field studies combining questionnaire survey and indoor environmental parameter measurement have found that there are significant differences in thermal sensation among different genders, ages and clothing levels (Cena & de Dear, 1999, Hwang et al., 2006). Other studies have found that there is only a small difference in thermal comfort between different genders (Humphreys & MA, 1976), but when it's cooler inside, the female generally feel cooler than men (Parsons, 2002).

Beshir and Ramsey (1981) found that there was a significant gender difference in heat dissatisfaction, and women were more likely to show heat dissatisfaction in extreme cases. Karjalainen (2007) found that women felt more uncomfortable than men under extreme heat and liked the indoor temperature higher than men. Karjalainen (2012) found that women were more likely to express dissatisfaction in the same indoor environment. In a room with a natural ventilation strategy, the occupant feels comfortable within a wider range of micro-climatic values than in a mechanically ventilated room (De Dear & Brager, 1998). Beshir and Ramsey (1981) analyzed the results and found that the preferred temperature of females (25 °C) was significantly higher than that of males (22 °C), and females were more likely to feel uncomfortable than males. The neutral temperature range of men and women is similar, while the skin temperature of women is always lower than that of men. Women are more sensitive to temperature (Lan et al., 2008).

Busch (1992) analysis of Office buildings in Thailand found few significant gender differences. Cheong et al. (2003) study of lecture halls in Singapore concluded that more women than men felt "cool". The study also showed gender differences in perceptions of air flow rates, with women reporting air as "draughty" and men reporting air as "still". However, there was little gender difference in overall thermal comfort in lecture halls. Malliani et al. (1991) analyzed changes in skin temperature for men and women with thermal comfort, and concluded that there was no difference in optimal skin temperature for the seated.

Wargocki and Wyon (2006) shows that the important factors in the learning process are indoor temperature and air quality. Participants learn best when they perceive "slightly warm" in the Lecture Theatre. Cold and hot uncomfortable environments have more adverse effects on academic performance than hot and uncomfortable environments. With the increase of students' vote of satisfaction, their academic performance also increases (Wang et al., 2018). High-quality school buildings are required to facilitate quality education. These buildings should provide good thermal comfort and suitable quantities of fresh air (Corgnati et al., 2007). In Figure 1 the literature review is summarised in a casual map.

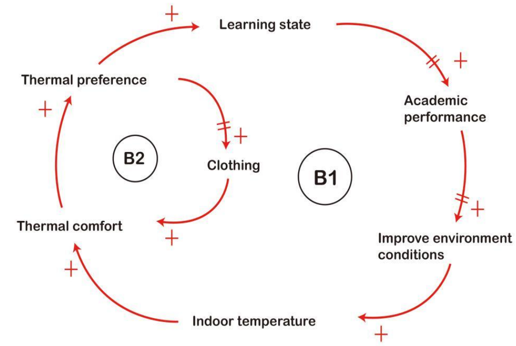

Figure 1. Casual map for literature review

3. Methods

3.1 Overall Idea of the Study

The overall idea of this study is to investigate the perceptions of students of different genders in the Lecture Theatre on various factors in the indoor environment and analyze the requirements for thermal comfort. The data used in the study were obtained from the previous MSc EDE and MSc HWSB cool Season survey in 2019. Objective indoor environment measurement and subjective questionnaire survey were carried out in 50 lecture theatre. In this study, data were analyzed using T-test and Correlation, which were described in detail in 3.5. Finally, the average values of heat sensation, heat preference and clothing of students of different genders in the individual sample and the population sample were calculated, and the differences of their perception of the three variables were compared and analyzed, and the reasons leading to different results were explored.

3.2 Subject

LT05b is measured to be 12m long, 6.4m wide and 3m high. The total capacity of the lecture theatre was 80 people, and the total number of people in the ladder classroom during the survey was 57 and 45, respectively. The number of subjects was 30 and 31, and the response rate was 0.53 and 0.69, respectively. It has been used for two years since the last renovation, and the ventilation type is mechanical ventilation system.

3.3 Student Subjective Assessment (Questionnaire)

The subjects were asked to rate their heat perception, their heat preferences. According to

ASHRAE's research on the thermal comfort of students in a sedentary state, the subjects used the traditional ASHRAE 7-point scale ranging from cold (−3) to hot (+3) to record their perception degree (Han et al., 2007). Students were also asked to indicate their perception of the air flow, acoustics, air quality, lighting, seat comfort, and learning satisfaction in the classroom. The questionnaire was conducted in the classroom, including breaks.

3.4 Objective Investigation (Indoor Thermal Environment Monitoring)

Indoor thermal environment monitoring uses HOBO equipment to collect indoor climate variables, such as temperature, relative humidity and light intensity in the classroom.

3.5 Statistical Analysis

Data from 61 participants were analyzed using T-test and Correlation. T-test is used to determine whether there are significant differences in the data. Correlation tests are used to evaluate the Correlation coefficients between variables. The significance of the data analysis was set at 95% ($P \leq 0.05$), which means the data were statistically significant.

- T-TEST:

To analyze whether there is a big difference between gender and thermal comfort, first test students from 9-11 (LT05b(1)), and then test students from 11-12.30 (LT05b(2)). Finally, the mean value of thermal comfort of 50 lecture theatre is used to test the differences in the overall data. Three sets of data are used to compare and analyze the hypotheses.

H0 (Null hypothesis): There is no difference in thermal comfort satisfaction levels between different genders.

H1 (Alternative hypothesis): There is a difference in thermal comfort satisfaction levels between different genders.

- Correlation:

Correlation was used to detect correlations between thermal comfort and clothing, and between thermal sensation and thermal preference. First, the LT05B boys were tested for two groups of different variables, and then the girls were tested accordingly. In the end, the mean values of 4 variables of all males and females in 50 classrooms were tested twice for correlation coefficient, and finally 8 groups of data were obtained for analysis.

4. Results

4.1 T-TEST Questionnaire Results

The unpaired T-test is shown in Table 1. In LT05b(1) and LT05b(2), subjects' thermal sensation voting is not correlated with gender variable, and P value is not statistically significant ($P>0.05$), P-values were 0.06 and 0.77, respectively. The difference in coefficient between the two surveys could be attributed to different combinations of clothing and different insulation performance, resulting in masking the real difference in perception.

However, the results of all classrooms showed that the influence of gender variables on thermal sensation voting was moderately significant ($0.05 > P > 0.01$), indicating that there was a statistically significant gender difference in students' perception of heat ($P<0.05$).

Comparing the results of LT05b with all lecture theatre samples, it was found that the P-value was not statistically significant in the individual study samples, but it was statistically significant in all the samples. The reason for the different results in the survey may be that the results obtained may not be accurate due to the small sample size.

Table 1. Differences of thermal comfort perception among students of different genders T-Test

Group	Tailed	Type	P-value	Reject H0 at the 0.05significance level?
Students in LT05B(1)	two-tailed distribution	unpaired	P=0.06 (P>0.05)	NO
Students in LT05B(2)	two-tailed distribution	unpaired	P=0.77 (P>0.05)	NO
Total students in lecture theatre	two-tailed distribution	unpaired	P=0.04 (P>0.05)	YES

4.2 Correlation Coefficient Questionnaire Results

The statistical values of correlation between thermal comfort and different indoor environmental parameters are shown in Table 2. The table lists correlations between thermal sensation, thermal preferences, and clothing for male and female.

Table 2. Statistical table of correlations between thermal comfort and gender, clothing, and thermal preference

Group	Coefficient of correlation for clothing vs. thermal comfort	Correlation	Coefficient of correlation for thermal comfort vs. thermal preference	Correlation
LT05b-Male	-0.176	Weak linear negative correlation	-0.742	Strong linear negative correlation
LT05b-Female	-0.226	Weak linear negative correlation	-0.467	Incomplete linear negative correlation
Total Male	-0.337	Incomplete linear negative correlation	-0.809	Strong linear negative correlation
Total Female	-0.463	Incomplete linear negative correlation	-0.88	Strong linear negative correlation

The correlation between different genders and thermal sensation and clothing shows that both men and women in the LT05b show a weak linear negative correlation between clothing and thermal comfort (Table 2), while the data related to gender, clothing and thermal comfort in all samples show a slightly stronger correlation than that in the LT05b, the values are -0.337 and -0.463, respectively. However, according to the scatter diagram (Figure 2, Figure 3), there is no correlation between clothing and thermal comfort for all women and men.

The correlation between different genders, heat preference and heat sensation shown in Table 2 indicates that these factors have a strong linear negative correlation based on the analysis of the male group of the individual sample, while the female group shows an opposite situation. Male perception of thermal comfort in this classroom influenced their thermal preference, but female thermal comfort and thermal preference did not show a correlation. The correlation coefficients in Table 2 were analyzed men and women in all the ladder classrooms showed a strong linear negative correlation between thermal preference and thermal comfort, the correlation coefficients are -0.809 and -0.88, respectively.

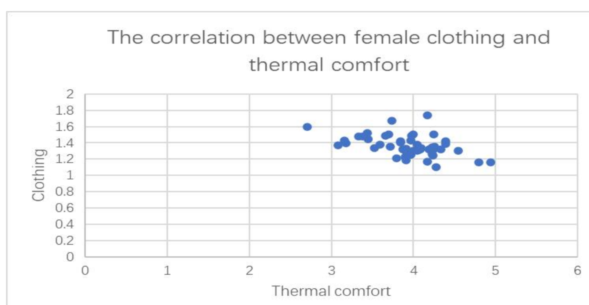

Figure 2. The correlation between female clothing and thermal comfort

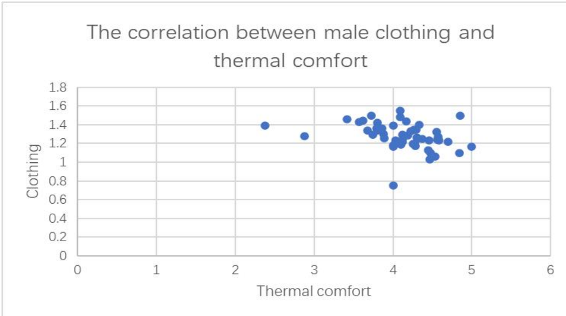

Figure 3. The correlation between male clothing and thermal comfort

There is an incomplete linear negative correlation between clothing and thermal comfort for all women and men. The results showed that for students of different genders, clothing in the cool season (October) had little correlation with thermal comfort.

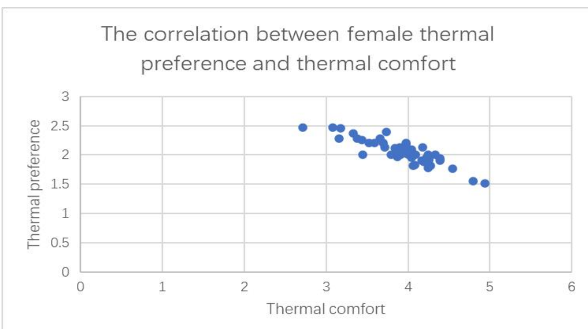

Figure 4. The correlation between female thermal preference and thermal comfort

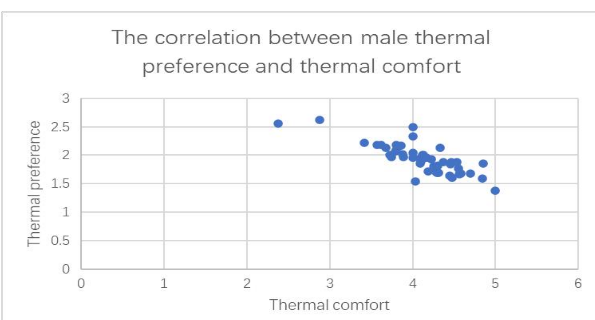

Figure 5. The correlation between male thermal preference and thermal comfort

The scatter diagram in Figure 4 and Figure 5 shows that there is a strong linear negative correlation between thermal preference and thermal comfort for all students of different genders. However, the linear negative correlation between thermal preference and thermal comfort in female groups was more significant than that in male groups.

4.3 Questionnaire Results

Table 3. Table of mean values of three variables (thermal comfort, thermal preference, clothing level) for individual study and total study lecture theatre

Group	Average thermal comfort	Average thermal preference	Average clothing
LT05b	3.8	2.1	1.4
Male	3.57	2.17	1.42
Female	3.9	2	1.29
All lecture theatre	4.01	1.99	1.32
Total male	4.12	1.27	1.92
Total female	3.93	1.36	2.04

The mean analysis of the data obtained from the questionnaire shows that the average thermal comfort values of the student samples in LT05b and the overall student samples are 3.8 and 4.01 (Table 3), which means that they all believe that the indoor temperature is neutral and the perception of indoor thermal environment is comfortable. However, the results were different when calculating the average thermal comfort value of different genders. The average thermal comfort value of men in LT05b was 3.57, while that of total men was 4.12 (Table 3), which meant that the men in the individual sample thought the indoor temperature was slightly cooler. This result may be due to the use of a mechanical ventilation strategy in the LT05b. The women in the different samples all rated the temperature as neutral and comfortable.

The average thermal preferences of the LT05b sample of middle school students and the total sample of students were 2.1 and 1.99 respectively (Table 3), which meant that they believed that the indoor thermal environment did not need to change and the temperature was comfortable.

Only the male group in the individual sample had a thermal preference of 2.17 for warmer rooms (Table 3). The overall sample was 1.27 for men and 1.26 for women, who thought the lecture theatre should be cooler (Table 3).

The average clothing level of different genders in the individual sample and the overall sample was 1.4 and 1.32, respectively (Table 3), which means that their clothing combination is similar, that is, short-sleeved shirt or T-shirt sitting in the lecture theatre and learning. The average clothing level for all women was 2.04 (Table 3), meaning they wore long-sleeved shirts, wore more than men and had better insulation. Although female skin is more sensitive to temperature, they wear more clothes when male feel cool in certain situations, while female consider temperature to be neutral.

The positive or negative effects of thermal comfort are not simply related trends. Female students are more likely to be uncomfortable when they are below neutral, which means they prefer neutral or slightly warmer states for their learning environment. Men showed the opposite trend, preferring neutral or cooler conditions.

5. Discussion

The above results indicate that there is no gender difference in thermal comfort among the students in the LT05b, but there is a significant gender difference among all the ladder classrooms. In the LT05b study, no correlation was found between clothes of different genders and thermal comfort, but a strong linear negative correlation was found between the thermal preference of male students and thermal comfort variables.

For all the male and female students, there is no correlation between clothing and thermal comfort, while there is a strong negative correlation between thermal preference and thermal comfort. The reasons for these different results after comparison are as follows:

- Effects of clothing levels

Differences in thermal comfort can be explained by differences in clothing, but may not be the most effective explanation (De Giuli et al., 2012). Many studies on clothing have found that gender does not significantly affect the choice of clothing. The different clothing combinations in my study (women wear less than men) may mask the real differences. All women wear more than men and have better insulation. So, when men feel cool indoors, women think the temperature is neutral.

- Influence of different ventilation types

Three different ventilation strategies were used in the 50 staircases: natural ventilation, mixed ventilation and mechanical ventilation. Ventilation strategy will affect indoor airflow speed, air temperature, air quality and other variables, which will affect perception of thermal comfort (Mavrogianni et al., 2014).

- The impact of sample size

The LT05b study found no statistically significant gender difference, and the statistical significance may be attributed to a small number of subjects, which reduced the statistical power of the test. When the sample size is large, it has a greater impact on the accuracy of data. However, the sample size of individual cases is only 30 and 31 people, so the results obtained from the analysis of small samples may not be accurate enough.

- The influence of extremum

The extreme problem should also be taken into account, as the probability of an extreme value is greater when the sample size is large. If the standard deviation gets bigger, the normal distribution will get better.

- Influence of gender

The P-value indicates that there is a difference in thermal sensation between the sexes, and the reason may be as follows Modera (1993) findings suggest that women are more sensitive to fluctuations in body temperature, with statistically significant differences found between the biological responses of the sexes.

6. Conclusion

This study, based on objective and subjective surveys, provides evidence to support gender-based differences in thermal comfort among UCL students. The following conclusions can be drawn: T-test results showed that there was no gender difference in thermal comfort among the students in the individual study case, but there was a significant gender difference in the total sample. Even in the same indoor environment, students of different genders have different perceptions of heat. Temperature, air movement and humidity are also environmental variables affecting perceived thermal comfort. No correlation was found between clothes and thermal comfort in personal research cases, but a strong linear negative correlation was found between thermal preference and thermal comfort in male. Female prefer a neutral or slightly warmer learning environment.

It should be noted that this study conducted in cool weather is not far from the neutral environment, and there is a lack of investigation on the very hot and very cold indoor environment, so further investigation is needed. The students' score of thermal comfort (TC) was not obtained in the questionnaire survey. The next step is to add a nine-point thermal comfort score (TC), which can enrich the research data and make the results more accurate.

When improving the thermal environment of lecture halls, UCL should be advised to take full account of female requirements for indoor thermal environment, so as to meet students' thermal comfort and effective learning requirements. Gender differences surveys show that women have a greater need for adaptive action than men. When it comes to the thermal comfort requirements in the examination room, the female should be the main target, and when the female is satisfied, the male is likely to be satisfied as well.

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