A study of the effects of indoor thermal-light-acoustic environments on undergraduates' comforts under the pressure

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ABSTRACT

Human comfort is a complex feeling that is hard to be evaluated accurately. This could be affected by a variety of environmental factors and/or subjective events. This study investigated a special group of people's specific comforts under certain circumstance. College students' comforts under the conditions of various factors (thermal stress, poor natural lighting, noises, and psychological pressures) were investigated by field monitoring combining questionnaire. There were some important findings acquired. Initially, students' neutral temperature (the temperature points that people are thermal free, indicated by operative temperature, T_{op}) were 23.0 °C (males) and 24.1 °C (females); their neutral acoustic pressures (indicated by A-weighted continuous sound pressure, LAeq) were 45 dBA (males) and 49 (females) dBA, and the neutral lighting level illuminations (LUX) were 32.22 lx (male) and 54.53 lx (female). In addition, under psychological circumstances, students were less heat and light tolerable. This could be presented by lower neutral T_{op} (less than 22 °C) and lower NLUX (less than 30 lx for males & less than 45 lx for females) at emotional stressed conditions. Nevertheless, their acoustic sensations were poorly affected by that. Students' comforts were affected by environment qualities in physics and the test schedule. They were less comfortable as T_{op} increase or getting closer to the test. Volunteers of the two genders were influenced differently, especially the acoustic environments. This study has developed a better understanding toward room occupants' comforts in campuses.

KEYWORD: Specific comfort vote; Indoor thermal environment; Indoor acoustic environment; Distance from the test; Undergraduate

1. Introduction

Current college students are in the presences of issues in various aspects currently (Li et al., 2024a). They were influential on study efficiencies (Li et al., 2023) and health (Liu et al., 2024a). In recent decades, College students are usually mentally unhealthy, which results in the occurrences of some extreme events (Yuan, 2023). Poor physical environments and psychological issues are commonly negatively affecting undergraduates' living qualities. This problem is more serious as approaching to the semester end that students are busy studying academic exams and/or assignments (Cui, 2021). These issues are more serious during the early summertime as poor thermal comforts resulting in mental stress (Wang, 2024). The

semester end and summer arrive at the same time in most universities in the north hemisphere. The combination of multiple issues causes more complex stressful perceptions.

Researchers are exploring ways to combat them. They have to investigate students' responses toward either of the influential factor. Subjects are sensitive with environment qualities in physics. Their perceptions could be assessed by models, such as thermal sensation vote (TSV (Wang et al., 2024)) and acoustic sensation vote (ASV (Ren, 2023)) physically. In indoor spaces, TSV varied for air temperature (T_a) and/or operative temperature (T_{op}) (Ma et al., 2024). Prof Kristie L Ebi et al. (2023) showed that the higher the T_{op}, the more uncomfortable people felt; that was presented by the higher TSV. In contrast, the sound environment could be indicated by A-Weighted equivalent continuous sound pressure level (LAeq (Mohamed et al., 2021). Zhen et al. (2023a) revealed that the ASV and LAeq positively linearly correlated. According to Li and Managi (2023), increased light at night is negatively correlated with living comfort. Indoor lighting has a deep impact on human emotional alertness and visual comfort (Du, 2024). Recent studies have shown that thermal and visual comfort are related (Yin et al., 2022).

Their total comforts against various factors are usually assessed by overall comfort vote (OCV (Zhao et al., 2024)). It should be influenced by certain factors more significantly under special circumstance (Yin et al., 2022) although any single one is effective (Liu et al., 2023). The psychology is another essential comfort affecting factor (Lam et al., 2024). Dwellers would have poor mental conditions in face of some important affairs, i.e., tests. Examination participants would be increasingly psychologically stressful as approaching to that (Ren, 2019). Yet the most complexly, various factors are interactively impactive. Occupants, for instance, would have different thermal perceptions under various acoustic contexts (Wen et al., 2024). Mental conditions and thermal comforts were also interactive influential (Liu et al., 2024b).

Previous studies have crucially explored diverse factors influencing subjective comforts. They would be directive for future works in occupants' comfort improvements. However, certain limitations of them should not be ignored. Multiple studies involving several factors usually combined that relating to physics interactively (Xiao et al., 2024). Psychology was rarely combined with them to investigate. In addition, the semester-end test is an important event influencing mental conditions, especial college students (Tengxun, 2023). They were crucial yet rarely evidently investigated previously. This study aimed to find college students' comforts toward certain factors under specific conditions. Finding of that might be directive to resolve some problems faced by college students. The whole work was processed as follows:

✓ Collecting data about indoor environmental qualities and interviewing (undergraduate) volunteers about their perceptions toward impactive factors;
✓ Statistically associating subjective responses to their affecting elements by linear models;
✓ Summarising data analysis results conclusively;
✓ Proposing practical design strategies.

2. Methodology

2.1. The study area

Mianyang (Fig. 1) is a city with hot-summer and cold-winter climate. Its average monthly temperature

often exceeds the comfortable range for residents (32 ℃ (Anhui Meteorological Service, 2019)). Summers of Mianyang suffer from very unsuitable weathers, including both high temperature and heavy rainfall. Apart from extreme meteorology, citizens of this city are in the presence of various social issues relating to economic development, such as transport noise (Yu et al., 2023), overlighting (Cao et al., 2023), and environmental pollution (MMBEE, 2022). The combination of these problems resulted in further phenomena e.g., poor psychology (Ahmadi Dehrashid et al., 2023), anxiety (Jigeer et al., 2022), and depression (Leung et al., 2023). Therefore, it is urgent to find ways to address them.
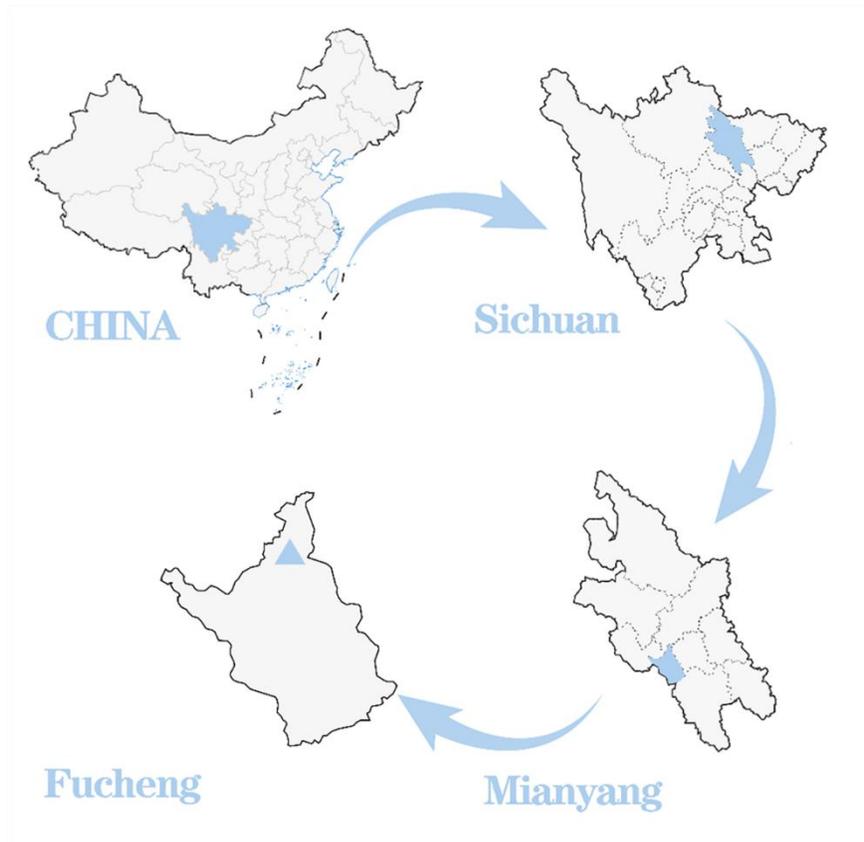

Fig. 1. Locations of study city and the sample campus (Image source Guihuayun (2024))**.**

2.2. Site selection

Southwest University of Science and Technology (SWUST) is a comprehensive institute representing the top level of education in Mianyang (Bai, 2024c). The main campus of SWUST is located in the Fucheng District (Fig. 2). The university was suffering from negative effects resulting from campus activities and the nature, which should not be ignored. They affected campus lives in diverse aspects, such as thermal discomforts in extreme seasons and traffic noises from nearby roads (Deng et al., 2021). This study selected student dwellings as experiment sites. Male and female students were investigated in separation as differences in gender and accommodation environments.
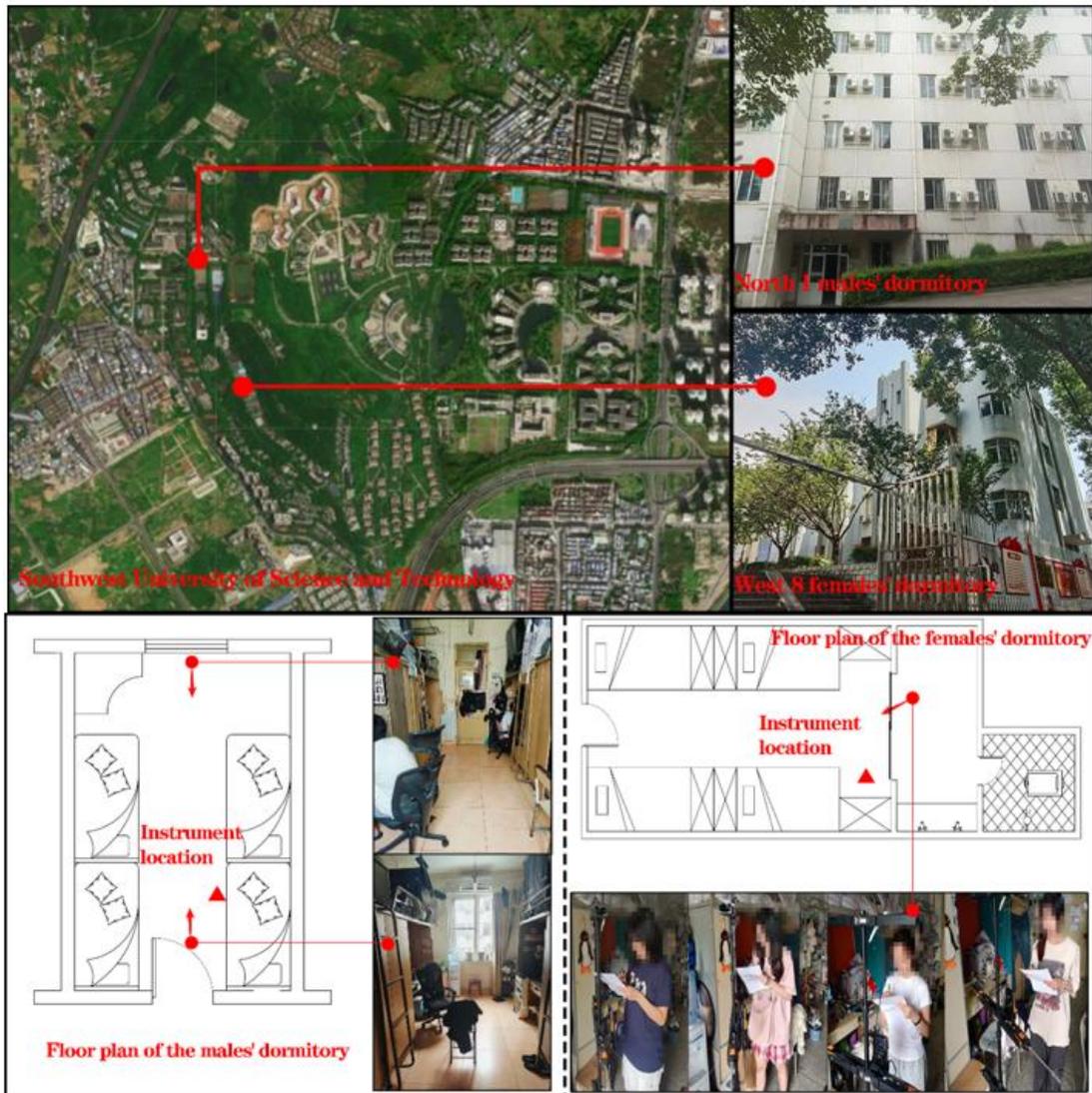
Fig. 2. Locations of the survey sites and their environments (Image source Gaode (2023) and graphed by authors).

2.3. Environmental quality parameters

The environment quality plays a significant role in people's comforts. Indoor environmental qualities are affected by thermal, visual, acoustic environments, and the air quality (An et al., 2024). This study selected that relating to physics for further investigation since sample sites are more significantly affected by them.

Indoor thermal comfort (ITC) (Buonomano et al., 2024) is a complex feeling including various meteorological parameters and some personal elements. Some complex indices including various parameters have been proposed for comprehensive evaluating.

The mean radiation temperature (MRT) refers to the average temperature of the radiation effect of the surrounding surfaces on the human body (Bai, 2024a). It is usually supportive for the calculation some

complex indices, such as physiologically equivalent temperature (Zhang et al., 2022), universal thermal climate index (Mahdavinejad et al., 2024), and T_{op} (Hao et al., 2020). MRT could be calculated by Equation (1)

$$\text{MRT} = [(T_g + 273)^4 + \frac{1.10 \times 10^8 V_{0.6}}{\varepsilon D^{0.4}} (T_g - T_a)]^{\frac{1}{4}} - 273 \quad (1)$$

D and ε are the sphere diameter (0.15 m) and emissivity (0.95); T_g. T_a, and V_a represent the globe temperature (℃), air temperature (℃), and wind speed (m/s), respectively. Values of the parameters could be collected by Testo 400 (Table 1).

The T_{op} was frequently utilised to indicate indoor thermal environments. It refers to the operative temperature of electrical or mechanical equipment. The equipment would be operative effectively within a specific temperature range, which varies according to the equipment function and application environment (Bai, 2024b). This index could be calculated by Equation (2):

$$T_{op} = \frac{\text{MRT} + T_a}{2} \quad (2)$$

People are often sensitive to T_{op} (Zhang et al., 2023). Some studies revealed that people were thermal free (TSV = 0) when T_{op} was 20 ℃ (Wang et al., 2023).

The indoor acoustic environment is another perceptive factor. The LAeq (Equation 3) was exported directly by Testo 816 (Table 1), it not only related to the performances of buildings, but also occupants' health (Lun et al., 2024). Abnormal or excessive noise may have negative effects on people's health (Jo and Baek, 2024). Levels of the sound are usually evaluated by LAeq that could calculated by Equation (3):

$$\text{LAeq} = 10 \ \lg(\frac{1}{T} \int_0^T 10^{\frac{\text{LpA}^T}{10}} \, dt) \quad (3)$$

Among them, LAeq refers to the A-weighted continuous sound pressure level ((dBA)) at a certain moment; and T represents the specified measurement time (s) (Xu et al., 2024). People felt neutral, quiet, and noisy at 45, 30 (below), and 70 dBA (above (Sun et al., 2021)), respectively.

Illuminance is a physical term referring to the luminous fLx received per unit area of visible light. It is also known as illuminance for short, with the unit Lx (Lx or lx). It is used to indicate the intensity of light and the degree to which the surface area of an object is illuminated (Du, 2024).

Table 1

Properties of all sensors (Testo, 2024a; Testo, 2024b).

Instrument	Parameters	Range	Precision
Testo 400	Air temperature	-40 ~ +150 ℃	±0.2 ∘C
	Relative humidity	0%–100%	±1.8 %RH + 3 %
	Globe temperature	0–120 ∘ C	±(0.3 + 0.1%)
	Air velocity	0–20 m/s	±(0.03 + 0.5%)
	Illuminance	0–100000 Lx	0.1 Lx (< 10000)
			1 Lx (> 10000)
Testo 816	A-weighted sound	30 dB – 130 dB	/

pressure level

Students' comforts were also affected by the test schedule. They might be decreasingly comfortable as getting closer to that (Ren, 2019). It was applied as another comfort-affecting factor. The schedule was defined as distance from the test (Dis, numbering between 1 and 27).

2.4. Field measurements

2.4.1 Measurement locations and data

Undergraduates majoring in Architecture (SWUST) accommodate in North (males) and West (females) Residential Districts. Students' residences numbering in West 8 (female) and North 1 (male) were selected. They are representative as the average dwelling qualities of the districts and volunteers are dwelling in them. The measurement was performed from May 20 to late June, which is usually a highly stressful and emotionally tensive period due to academic tasks. The daily measurements were from 9:00 to 22:00. Instruments were installed regarding ISO (2024) in the sample rooms (approx. 1.5 m above the ground). The measurements collected various environmental quality parameters. The rooms were all with air conditioners on during the monitoring (setting as 20 – 23 ℃).

2.4.2. The content of the questionnaire

A total of 45 volunteers (Architectural undergraduate students in Class of 2021 from SWUST) participated in this experiment. Surveys were implemented in their rooms. Instruments were installed at the corners of their rooms during the full day measurements, students could complete that at any time when they were in. Indoor environment qualities were collected by sensors. Questionnaires collected their responses about perceptions on various aspects (Table 2). Individuals in this and neighboring rooms filled in the questionnaire repeatedly at different periods and time to obtain their personal data. In total, 1267 questionnaire sheets from male and female students were collected.

Subjective perceptions are evaluated by models. They generally divide people's perception levels into 7 scales (ISO, 2024). This included thermal sensation vote (TSV (Yuan et al., 2023)), acoustic sensation vote (ASV (Sun et al., 2021)), light sensation vote (LSV (Lam et al., 2020)), overall comfort vote (OCV (Sunagawa et al., 2023) for the total environment quality), and emotional state vote (ESV). Most of them were applied. Yet OCV was replaced by specific comfort vote (SCV) since the air quality was ignored and the emotion was included. Interviewees were told to vote about comforts in environments in physics as well as psychological conditions on SCV.
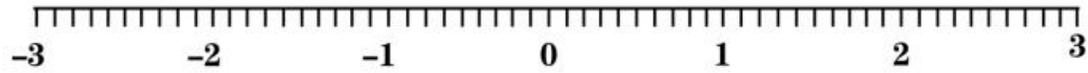
Table 2

Questionnaires in the questionnaire sheets.

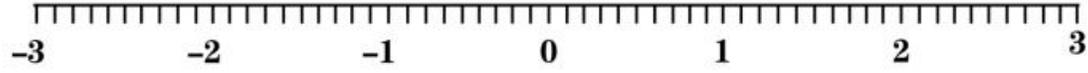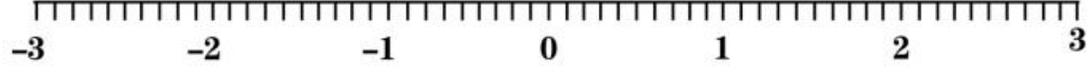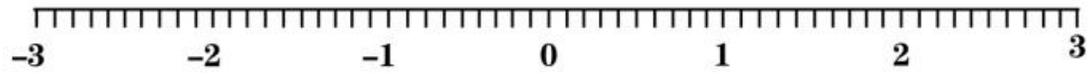| |
|---|
| 1. What is your current location (fill in the dormitory number)? |
| 2. Current time (by instrument reading) |
| yyyy_____mm_____dd_____hh_____ mm_____ |
| 3. What is your gender? |
| A. Male   B. Female |
| 4. What is your current thermal sensation vote (accurate to 0.1)? |
| Cold   Cool   Slightly cool   Neutral   Slightly warmer |
| Warm   Hot |
| −3   −2   −1   0   1   2   3 |
| 5.   What is your current acoustic sensation vote (accurate to 0.1)? |
| Very quiet   Quiet   Slightly quiet   Neutral   Slightly noisy |
| Noisy   Very noisy |
| −3   −2   −1   0   1   2   3 |
| 6.   What is your current light sensation vote (accurate to 0.1)? |
| Very dark   dark   Slightly dark   Neutral   Slightly light |
| light   Very light |
| −3   −2   −1   0   1   2   3 |
| 7. At present, the time of the nearest test you are to is ___ Dis (fill in the number directly). |
| 8. What is your current emotion state vote (to the nearest 0.1)? |
| Very terrible   Terrible   Slightly terrible   Neutral   Slightly happy |
| Happy   Very happy |
| −3   −2   −1   0   1   2   3 |
| 9. What is your current specific comfort level (combined with the combined perception of environmental comfort and current psychological condition, accurate to 0.1)? |
| Very uncomfortable Uncomfortable Slightly uncomfortable Neutral Slightly comfortable comfortable |
| Very uncomfortable |
| −3   −2   −1   0   1   2   3 |
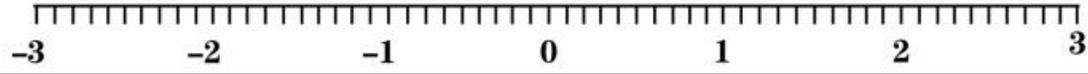
2.5. Data analyses

Multiple linear regression (MLR) can be used to find the linear relationship between a dependent variable and one or more independent variables (Uyanık and Güle, 2013). In this study, the physical environments (Li et al., 2024b) and the test schedule were independent variables; subjective perceptions and comforts (Mao et al., 2024) were dependent variables. Due to differences in pedestrian responses to changes in environmental parameters, a large quantity of data were collected, the bin method was adopted to simplify. Thermal comfort researches often use linear regressions to explore the neutral temperature of the human (Jo and Baek, 2024) (NT, the temperature point without thermal stress). The whole analysis was separated into two parts. One is the subjective response of one aspect against corresponded affecting factor, which is processed by Bayesian models; another is the comprehensive effects of diverse elements on specific comforts, which is processed by multiple models.

3. Results

3.1. Neutral points towards various environments

3.1.1. Subjective responses towards thermal environments

TSV of all students positively changed with the increase of T_{op} significantly (Fig. 3, R^2 = 0.91 & 0.89). As to males, the increase of T_{op} from 21 to 25 °C resulted in TSV ascent by nearly 6 scales (-3 – 3). This outputs the neutral operative temperature (NT_{op}) of 23.0 °C. In contrast, females were thermal sensitive slightly less significantly (lower R^2 value). Although both positively correlated, it exported the NT_{op} of 24.1 °C. The NT_{op} of females was slightly higher than that of males by approximately 1.1 °C.
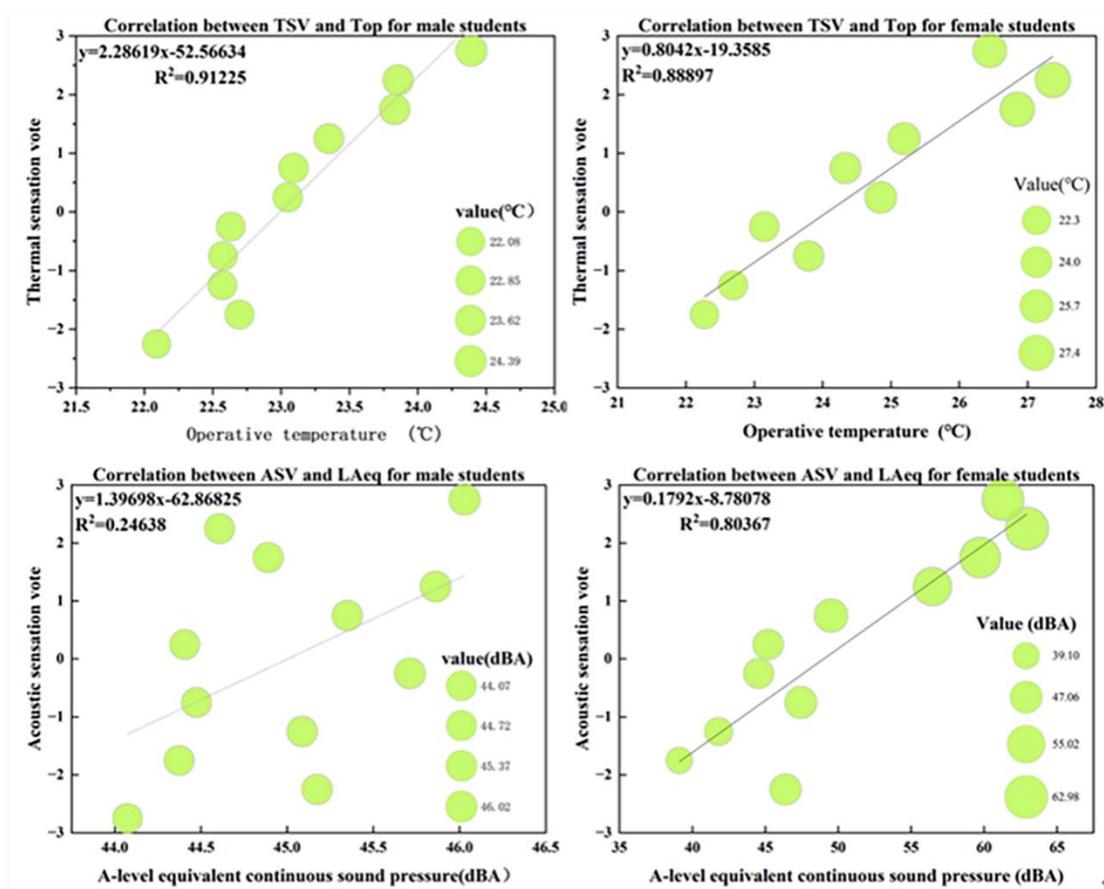
Fig. 3. Correlation between TSV and T$_{op}$ & ASV and LAeq for male and female students

3.1.2. Responses towards acoustic environments

The analysis results of acoustics expressed similar trends with thermal perceptions (Fig. 3). Males were less sensitive than females, which could be presented by lower R^2 values of males (approx. 0.25). As to males, the growth of LAeq from 33 to 55 dBA caused ASV rising by about 6 scales ($-3 - 3$). The neutral LAeq (NLAeq) of 45 dBA was calculated. In contrast, females were sound-sensitive more observably. It exported the NLAeq of 49 dBA. However, the sound perception of females has a strong link with the acoustic environment ($R^2 = 0.8037$), indicating that females are more sensitive to sound perception.

3.1.3. Responses towards light environments

The illuminance that LSV is positively correlated with illuminance, that is, the larger the illuminance, the larger the LSV. The correlation between LSV and illuminance is stronger in female students (R=0.69 & 0.91), which reflects the difference in perception of light environment between male and female students. This output neutral values of 32.22 lx (male) and 54.53 lx (female). However, the difference in illuminance of men's dormitory environment is significantly greater than that of women. Females were more visually sensitive and had the higher neutral value (Fig. 4).
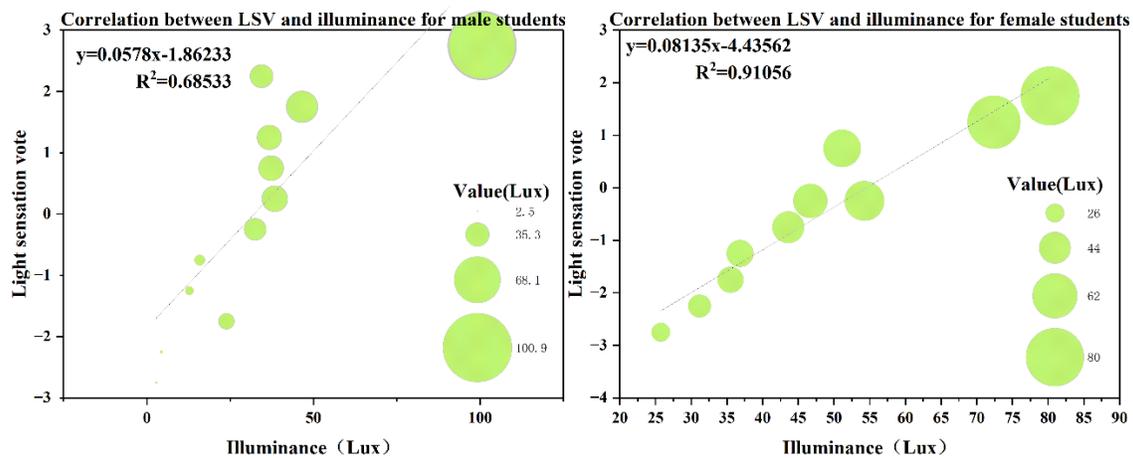
Fig. 4. Correlation between LSV and illuminance for male and female students.

3.2. Subjective responses towards EnQ parameters under various emotional conditions

Perceptions against various factors used to be found interactively effective. This study assumed that thermal/acoustic/light sensations would vary for emotion. They were proved by the variations of neutral points under different emotion conditions.

People's thermal sensations might vary for emotions. All data were divided into six ranges regarding ESV. The data of various emotion vote ranges were regressed separately (Table 3). NT_{op} of either male or female students were different within various voting ranges. This also took place in NLAeq and NLUX. In addition, ESV and NT_{op} showed significant increase trends ($R^2 = 0.62$ & 0.89). It shows that NT_{op} of students would decrease when they became depressed. As to males, their NT_{op} at good emotions were higher by around 1 °C than that under emotional stress, female students presented more remarkable difference (above 2 °C). Similar trends were also witnessed in light sensations ($R^2 = 0.51$ & 0.32). Hence, students were less tolerable as becoming depressed. There were certain changing regulars witnessed (Fig. 5), which is positive correlating significantly. However, the effect of emotion on NLAeq of either men or women was insignificant ($R^2 = 0.17$ & 0.23) and even opposite. The reason for this is that the two experimental sites are in a comfortable acoustic environment.

Table 3

Correlating significances and intensities for thermal, acoustic, and light sensations under different emotion conditions.

Gender	ESV range	Linear correlation between TSV and T_{op} (R^2)	NT_{op} (°C)	Linear correlation between ASV and LAeq (R^2)	NLAeq (dBA)	Linear correlation Between LSV and LUX (R^2)	NLUX (lx)

|							
Male	[3, 2)	y = 0.7192x - 15.261 (0.84)	22.29	y= 0.0541x - 1.5422 (0.0204)	45.5	y = 17.43x + 16.255 (0.26)	48.6
	[2, 1)	y = 0.6686x - 14.652 (0.27)	22.04	y = 0.0006x + 1.0556 (0.0207)	46.2	y = 15.035x + 24.943 (0.532)	36.4
	[1, 0)	y = 0.8266x - 18.356 (0.44)	22.06	y = -0.0106x + 1.2157 (0.0037)	45.6	y = 13.581x + 26.087(0.5127)	32.3
	[0, -1)	y = 0.777x - 17.143 (0.41)	22.20	y = 0.0022x - 0.069 (0.0001)	45.9	y = 12.465x + 34.819(0.517)	37.8
	[-1, -2)	y = 0.7354x - 16.212 (0.35)	21.90	y = 0.0031x + 0.2716 (0.0002)	46.0	y = 8.6575x + 19.416(0.4281)	26.6
	[-2, -3]	y = 0.115x - 0.2636 (0.21)	21.21	y = -0.0119x + 2.5359 (0.0091)	44.8	y = -3.5326x + 29.985(0.3411)	33.4
Female	[3, 2)	y = 0.6417x - 14.843 (0.55)	23.13	y = 0.0888x - 4.5949 (0.97)	54.4	-	-
	[2, 1)	y = 0.4128x - 9.2811 (0.37)	22.48	y = 0.0367x - 1.066 (0.87)	55.5	y = 10.447x + 40.959(0.2896)	45.3
	[1, 0)	y = 0.1905x - 4.2771 (0.21)	22.45	y = 0.044x - 1.4485 (0.84)	45.3	y = 11.93x + 48.034(0.3321)	49.6
	[0, -1)	y = 0.2265x - 5.077 (0.21)	22.42	y = 0.0613x - 2.3047 (0.74)	41.9	y = 12.225x + 52.916(0.3687)	53.1
	[-1, -2)	y = 0.2863x - 6.1672 (0.22)	21.54	y = 0.0552x - 2.1695 (0.79)	52.7	y = 8.3081x + 50.378(0.2142)	50.7
	[-2, -3]	y = 0.3784x - 7.9246 (0.72)	20.94	y = 0.0422x - 1.3061 (0.94)	82.6	y = 20.369x + 59.962(0.4247)	38.5
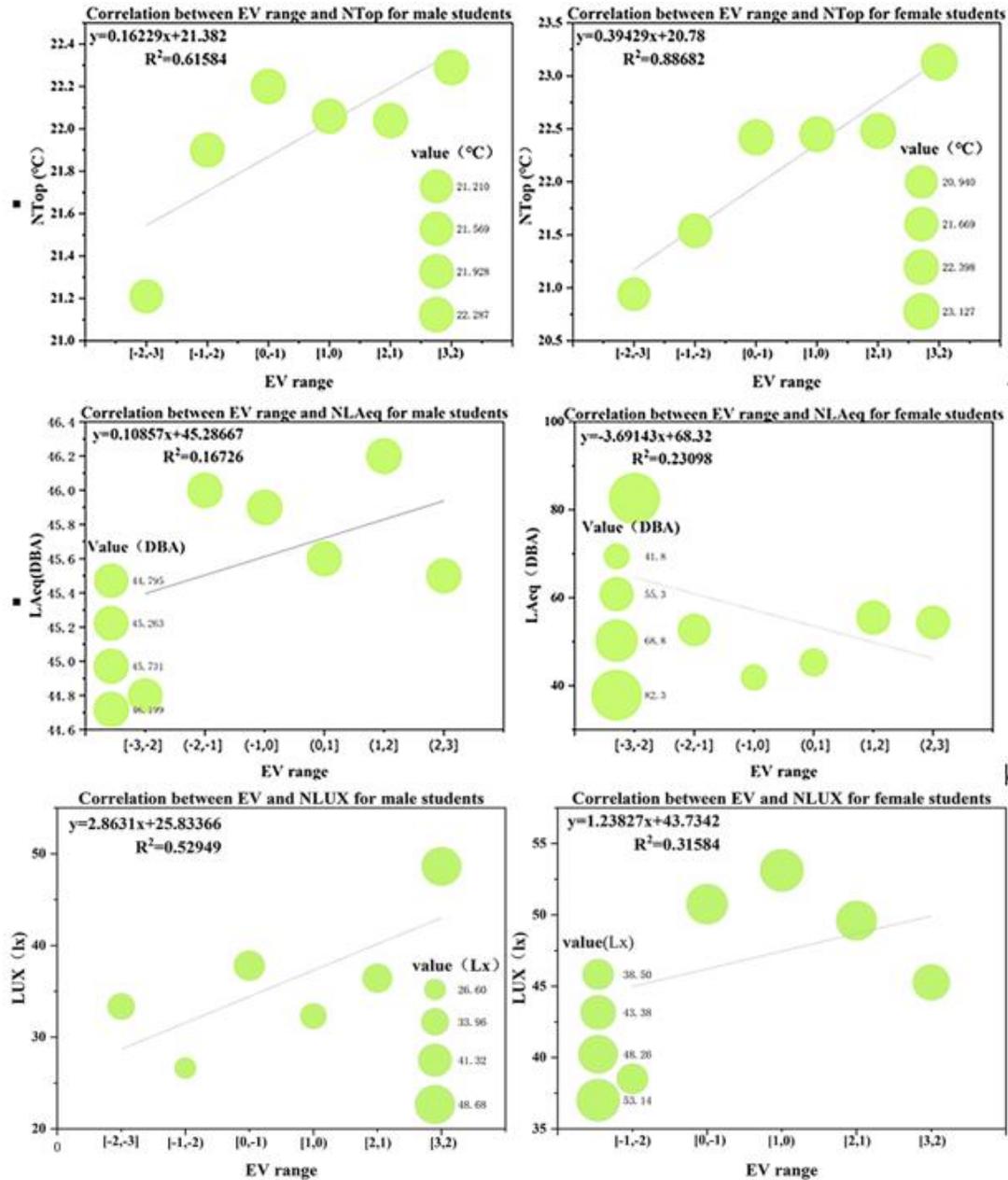
Fig. 5. The changes of NT_{op} and NLAeq and NLUX towards ESV ranges for male and female students.

3.3. The effects of objective environments on specific comfort

This study assumed that specific comforts were affected by three factors commonly. This included environmental qualities and the distance from the test (Dis, evaluated by number of days). Their parameters were associated with SCV in multiple linear models. This outputs Models 1 (male) and 2 (female):

Model 1: male: SCV = -0.594T_{op}***+0.023LAeq **+0.006Lux***+0.025Dis***+12.099,

(R^2 = 0.32, Sig < 0.001)

Model 2: female: SCV = $-0.006T_{op}*-0.0251LAeq***+0.002Lux -0.028Dis*+5.773$, ($R^2 = 0.21$, Sig < 0.001)

Various factors were impactive differently. This could be expressed by both affecting significances as well as changing trends. The heat levels (T_{op}) showed negative effects in males and females. Occupants' comforts decreased as getting warm. The increase of T_{op} by 1 °C caused SCV reduction of 0.594 (male, p < 0.001) and 0.006 (female, p = 0.922) respectively. More considerable and intensive change was witnessed in males thermally (p < 0.001). Nevertheless, the acoustic circumstances were impactive with confusion. Different trends between males (positive) and females (negative) were revealed. Similar with the sounds, lighting environments were also partially effective emotionally. Finally, they were sensitive with the tests. Higher SCV emerged if being farther from the tests. Approaching to the test by 10 days resulted in SCV declines of 0.25 (male, p < 0.001) or 0.28 (female, p = 0.056). This was relatively significant for male students. Conclusively, volunteers were more sensitive with thermal environments, since higher coefficients were witnessed. However, males' comforts were more sensitive with T_{op}. This was presented in both varying intensities and significances. Also, as approaching to the test (fewer Dis), SCV would reduce. (Table 4).

Table 4

The effects of multiple factors on OCV for males and females for the whole period.

Model 1	Unstandardised Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	12.099	0.985		12.285	<0.001
T_{op}	-0.594	0.038	-0.483	-15.739	<0.001
LAeq	0.023	0.009	0.078	2.588	0.010
Lux	0.006	0.002	0.112	3.490	<0.001
Dis	0.025	0.005	0.167	5.278	<0.001
Model 2	**Unstandardised Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	β	Std. Error	Beta		
(Constant)	1.971	1.433		1.375	0.170
T_{op}	-0.006	0.064	-0.013	-0.098	0.922
LAeq	-0.025	0.003	-0.427	-9.416	<0.001
Lux	-0.002	0.002	-0.047	-1.050	0.294
Dis	0.028	0.015	-0.254	-1.913	0.056

4. Discussion

This study has explored the effects of environmental quality parameters on subjective perceptions based on various psychological contexts. There were certain important findings acquired. They could be explained by some principles in physics and psychology.

Local people's neutral points were 23.0 and 24.1 °C (thermal) and 45 and 49 dBA (acoustics). They were compared with results found by earlier relevant studies in Table 5. Thermally, NT_{op} of Mianyang were

23.0 and 24.1 °C. They were close to Kuwait, higher than Harbin, lower than Jalandhar as well as Ouagadougou. This might result from human thermal adaptation. Zhang et al. (2023) have revealed that residents' NT_{op} negatively correlating with latitude. The calculated NT_{op} values in Mianyang generally met this regular. Moreover, sample students were partially sensitive with acoustic environments. This study roughly exported neutral LAeq of 45 and 49 dBA. They were lower than that found in 53 dBA (Xiao et al., 2024) and 49~57 dBA (Zhen et al., 2023a). Similar result was witnessed male students' rooms. That is to say, there were good indoor sound environments in the sample sites, especially males. Their neutral illuminations were also lower than that found by Xiao et al. (2024) as the difference between indoor and outdoor circumstances.

Table 5

Comparative study of neutral T_{op} and LAeq of Mianyang and other cities.

City (latitude)	Research season	Study area	Operative temperature (℃)	LAeq （dBA）	Illumination (Lx)	Reference
Kuwait (29.37 °N)	Summer	Indoor	23.3	-		Al-ajmi and Loveday (2010)
Ouagadougou (12.37 °N)	Summer	Indoor	31.0	-		Djongyang et al. (2012)
Jalandhar (27.43 °N)	Summer	Indoor	28.0	-		(Kumar et al., 2019)
Ambala (30.21 °N)	Winter	University Campus	19.6	-		(Jindal, 2018)
Changsha (28.23 °N)	Winter	Residential area	11.5	-		(Han et al., 2009)
Harbin (44.04 °N)	Winter	Indoor	16.8	-		(Shao and Jin, 2020)
Mianyang (31.46 °N)	Summer	University campus		53	1800	Xiao et al. (2024)
Xian (34.15 °N)	Summer	University Campus		50		Zhen et al. (2023b)
Mianyang (31.46 °N)	Summer	University campus	23.0/ 24.1	45.5		This study
Korea (37.63 °N)	Summer	University campus			650/1050	Yang and Jeon (2023)
Yongin (37.57°N)	Summer	University campus			150/500/1000	Yang and Moon (2018)

Subjective thermal responses varied for emotions (Haiying Wang and Liu, 2020). Lower NT_{op} as well as neutral LUX were calculated for both two genders under bad emotional contexts. Higher temperatures resulted in more heat stress during the summer (Bai et al., 2014). Human hope becoming cooler for keeping comfortable (Jay et al., 2021). They needed to reduce the heat stress as the rise of psychological stress to balance their physiological conditions (Kawakami et al., 2024). Humans perceive light differently in different emotional states, and the emotions of the perceiver can affect the perception of brightness in a metaphorically consistent way (Zhang et al., 2016). Dim daylight intensity can lead to higher depression and anxiety-like behaviors, as well as impaired spatial learning and memory. The mechanisms by which light regulates emotion and cognition must vary between time types (Yan et al., 2018).

Students' comforts were commonly affected by various factors. As to the whole period, T_{op} showed negative correlations with SCV in all students significantly. It meant, occupants preferred lower temperatures in the warm season. Nevertheless, the LAeq was impactive with confusion; different trends males and females were witnessed. This could be explained by the difference the residential acoustic environments. Female students were more acoustically sensitive for the sound intensities around their living spaces. This resulted in remarkable fluctuations of ASV. Light is an essential component of the indoor environment, and illuminance and associated color temperature (CCT) are reported to be closely related to human mood, alertness and comfort (Cai et al., 2024). In educational buildings, efficient daylight design has a significant impact on students' visual comfort, well-being and productivity (Ziaee and Vakilinezhad, 2022).

Acoustic sensations also varied for emotions. However, data of males and females showed opposite trends and were poorly correlating (R^2 = around 0.15 & 0.25). Hence, it is hard to say if volunteers' sound sensations were affected by emotions in certain regulars. This might result from the good acoustic conditions of their (male students) rooms.

This study has proposed SCV assessing people's comforts against indoor thermal and acoustic environments as well as emotions. It was affected by T_{op}, LAeq, and the test schedule commonly. Their impacts varied for genders. This might result from both gender and contextual factors. As to the whole period, T_{op} showed negative correlations with SCV in all students significantly. It meant, occupants preferred lower temperatures in the warm season. Also, the distance to the test showed positive trends. It can be seen, being closer to the test caused worse comforts. This meant that the specific comfort is a combined perception towards environment quality (e.g. thermal stress (Lehnert et al., 2021)) and personal issues (Lehnert et al., 2021)). Nevertheless, the LAeq was impactive with confusion; different trends between males and females were witnessed. This could be explained by the difference the residential acoustic environments. Female students were more acoustically sensitive for the sound intensities around their living spaces. This resulted in remarkable fluctuations of ASV.

Findings this study would be practically impactive for indoor perception improvement for undergraduate students. The indoor equipment setting, e.g., air-conditioners, should follow the semester schedules with considering students' mental fluctuations. Also, university administrators/staff should pay more attentions to students' psychologies, especially the testing periods.

Limitations of this study should be admitted although some essential findings obtained. The sample sites might have good acoustic environments. Therefore, some volunteers (males) expressed poor sound

sensations, and the acoustic environments expressed confused comforting effects. This limited the significances of this research. Meanwhile, as a significant factor on indoor environments and affecting study efficiencies, the illumination was unconsidered by this study. Finally, semesters of the full year span four seasons. Psychological stresses also take place in neutral and cold seasons, which is presently ignored. They should be significantly involved in the future. Future studies in this field could be improved by a variety of aspects: 1) seasonal thermal discomforts in emerged in both winter and summer, the winter is necessary to be considered; 2) the whole semester-end tests usually take a few weeks since several courses, there would be more complex psychological conditions, exploring the whole period of test is essential; 3) the environmental quality contains many aspects, such as light environment and air quality, they might cause more complex psychological conditions.

5. Conclusion

This study has investigated the effects of various physical environments on college students' comforts under various psychological conditions. There were some important and interesting findings acquired. Details of them are listed as follows.

- ✓ Neutral points were 23.0 and 24.1 °C (thermal, T_{op}), 32.22 and 54.53 lx (light, illumination), and 45 as well as 49 dBA (acoustic, LAeq) for males and females.
- ✓ Students of both two genders were significantly thermally sensitive (R^2=0.91 & 0.89), but only females were acoustically sensitive (R^2=0.25 & 0.80).
- ✓ Volunteers were decreasingly thermal and lighting tolerable as becoming psychologically stressed, which could be explained by the fact that lower NT_{op} emerged in poorer ESV ranges.
- ✓ Light perception was positively correlated with emotion, and illumination has a strong influence on the specific comfort.
- ✓ Indoor occupants' comforts were affected by thermal and environments as well as the test schedule.

This research has carried out a comprehensive and in-depth exploration on the influence of various factors on the overall comfort of undergraduate students. The findings are significantly practically impactive for environmental design. There are still problems in this field to address in the future.

Conflict of interest
There is no conflict of interest in this study.

Data availability statement
Data applied in this paper were temporarily to the public as other uses.

Ethical approval statement
This study is ethically approved by the author institute with the case number of 23zx7107.

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