Open Access
Original paper

Budownictwo i Architektura / Civil and Architectural Engineering 25(2) (2026) 26024
https://doi.org/10.35784/bud-arch.8636

Understanding indoor thermal perception and comfort through multi-parameter environmental analysis

Okan Şimşek[1,*]

[1] *Department of Architecture; Faculty of Architecture and Design; Adana Alparslan Türkeş Science and Technology University; Balcalı Mah. Güney Kampüs 10 Sokak No:1U Sarıçam, Adana, Türkiye;* osimsek@atu.edu.tr

[*] *Corresponding Author*

Received: 27.10.2025; Revised: 26.02.2026; Accepted: 13.03.2026; Available online: 26.06.2026

Abstract:

In the literature, thermal comfort in indoor environments has traditionally been addressed through single parameters such as temperature, relative humidity, radiant temperature, and air velocity. However, recent studies have shown that auditory and visual conditions also influence users' thermal perception and comfort experience. This study adopts a holistic approach to examine how multiple physical environmental parameters affect thermal perception and comfort in educational spaces. The research was conducted in October 2025 in two studios and one classroom within the Department of Architecture at Adana Alparslan Türkeş Science and Technology University. Simultaneous surveys and environmental measurements were carried out with 74 participants. Measured parameters included temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, and horizontal and vertical illuminance. Participants' thermal perception and comfort evaluations were collected using a seven-point Likert scale. Correlation analyses performed with SPSS 25 revealed that thermal perception was significantly associated with temperature, air velocity, and horizontal illuminance, while thermal comfort was correlated with temperature, relative humidity, and horizontal illuminance. These findings indicate that visual environmental factors, alongside classical thermal parameters, significantly influence indoor comfort. The study emphasises the need to consider multiple environmental parameters when designing educational spaces to develop user-oriented comfort strategies.

Keywords:

thermal perception, thermal comfort, multiple environmental parameters, educational spaces

1. Introduction

People spend most of their time indoors, and their perception of comfort in such environments can influence a wide range of outcomes, including building energy consumption [1,2]. Ensuring a high level of comfort in indoor environments is therefore critical for both user satisfaction and energy efficiency [3]. Thermal comfort is defined as the state in which an individual feels satisfied with the surrounding thermal environment [4]. Classical thermal comfort models are based on a set of physical parameters. Air temperature and mean radiant temperature are the primary factors, while relative humidity and air velocity are also considered, together with personal factors such as clothing insulation and metabolic rate [5,6]. The appropriate combination of these parameters defines conditions that achieve thermal equilibrium or comfort for most users. Air movement is particularly important in warm environments, as even slight air circulation can enhance comfort by facilitating evaporative cooling, whereas in cold environments it may cause discomfort due to draught sensations [7,8]. Similarly, relative humidity becomes critical in extreme conditions: high humidity in hot settings hampers heat dissipation through perspiration, leading to a sense of stuffiness, whereas very low humidity can cause dryness of the skin and mucous membranes, resulting in discomfort [9]. In summary, the literature generally defines indoor thermal comfort as an integrated function of physical environmental parameters such as temperature, humidity, mean radiant temperature, and air velocity.

Educational buildings constitute a particularly important context for indoor comfort research because students and instructors spend extended periods in classrooms and studios, and perceived indoor environmental quality can affect occupants' satisfaction and task performance-related outcomes. Prior work in educational settings has shown that thermal conditions, background noise, and lighting quality are associated with users' comfort evaluations and can influence attention, perceived productivity, and overall satisfaction with the learning environment [10]. Accordingly, studying comfort in real educational spaces is not incidental; it directly supports evidence-based design and operational decisions aimed at maintaining acceptable learning conditions while avoiding unnecessary energy use.

In recent years, indoor comfort has increasingly been examined beyond the thermal dimension, incorporating the effects of acoustic and visual comfort on user satisfaction [11]. Overall indoor comfort encompasses not only thermal aspects but also lighting conditions and noise levels. Although relatively few studies have addressed these comfort dimensions jointly, those that do suggest that different sensory domains interact and collectively shape perceived comfort [12-16]. Torresin et al. (2018) emphasized that thermal, acoustic, and visual comfort are interrelated and should be investigated within the same conceptual framework [17]. This perspective moves beyond traditional single-factor approaches, highlighting the necessity of multi-parameter comfort analyses.

The main physical variables determining indoor thermal comfort – air temperature, relative humidity, mean radiant temperature, and air velocity – are the key components of conventional thermal comfort models [18]. Their combination directly influences the human body's heat balance and perceived comfort. According to Fanger's comfort equation, these four environmental parameters are evaluated together with activity level and clothing insulation to calculate the Predicted Mean Vote (PMV), where values between -0.5 and +0.5 indicate comfort conditions [19]. The literature suggests that balancing these parameters is essential to widen the comfort zone and improve acceptability. Among them, temperature is the most influential parameter affecting thermal sensation [20]. A hot and humid environment is more uncomfortable than a hot and dry one, since high humidity restricts evaporative cooling [21]. Air velocity, on the other hand, can enhance comfort under warm conditions by promoting a refreshing sensation, though at lower temperatures it can cause discomfort due to draughts [22]. Mean radiant temperature, reflecting the heat emitted by surrounding surfaces such as walls, floors, and windows, is also significant. A person may feel cold in a room with cool walls even if the air temperature is neutral, or conversely, may perceive warmth near a sunlit window despite a moderate air temperature [23]. Hence, comfort standards recommend considering both air and mean radiant temperatures together rather than individually.

Recent research has also revealed that noise can influence people's thermal comfort perceptions. Nagano and Horikoshi (2005) examined the interaction between temperature and noise under warm and cool conditions, finding that noise did not alter thermal sensation but affected thermal comfort, while higher temperatures reduced auditory comfort [24]. Similarly, Pellerin and Candas (2004) found that although noise did not directly modify temperature perception, high sound levels negatively impacted thermal comfort [25]. Early studies investigating multi-parameter effects reported inconsistent findings regarding the interaction between noise and thermal comfort. Some indicated that high noise levels reduce thermal comfort in warm environments, while others found no significant effect. More recent controlled experiments, however, have clarified these inconsistencies and demonstrated that thermal and acoustic factors interact in shaping comfort responses [26-28].

For instance, Guan et al. observed that raising the sound pressure level from 55 dB to 85 dB in a warm environment (30 °C) reduced participants' thermal comfort ratings by approximately 1.85 points, accompanied by higher heart rates indicating stress [29]. Under neutral (25 °C) and cool (20 °C) conditions, noise had no significant influence on thermal sensation, suggesting that its effect becomes more pronounced at higher temperatures. These findings highlight that noise control is particularly crucial for maintaining comfort in warm indoor environments.

Conversely, the influence of thermal conditions on acoustic comfort has also been explored. While early studies suggested that moderate temperature variations might not affect noise perception [30], recent work has shown that temperature can indeed modify acoustic evaluations. Guan et al. (2020) and Wu et al. (2020) demonstrated that people tend to tolerate noise better under thermally neutral conditions but become more sensitive when the environment is either too warm or too cold [31,32]. In a climate chamber study, Yang and Moon (2019) found that acoustic comfort was highest under thermally neutral conditions and decreased when temperatures deviated from the comfort zone [12]. Participants also rated noise as the dominant factor influencing overall comfort, exceeding both thermal and visual influences. Collectively, these findings suggest that thermal and acoustic environments interact in complex ways, and their combined effects on human comfort cannot be explained by the simple sum of their independent contributions [33].

Lighting conditions and visual comfort represent another environmental dimension that can shape thermal comfort perception through cross-modal effects [34]. Chinazzo et al. (2019), for instance, investigated whether daylight levels influence thermal perception in an office-like setting. They tested three illuminance levels (low ~130 lx, medium ~600 lx, and high ~1400 lx) combined with three air temperatures (19 °C, 23 °C, and 27 °C). Results showed that a dimly lit, cool environment was rated as less comfortable, whereas in warm conditions, the same dim lighting improved comfort. High daylight levels made cool environments feel warmer and more pleasant, while in already warm settings, excessive brightness was perceived as burdensome. No significant physiological differences were observed, implying that the effects were primarily perceptual. The authors concluded that daylight can make warm environments more tolerable, while artificial lighting tends to intensify thermal discomfort under the same thermal conditions [35]. Such cross-modal influences are particularly relevant for educational buildings, where daylight availability, task lighting requirements, and visual demands vary substantially across classrooms and studios and may therefore modulate thermal perception during learning activities [10].

Despite the growing literature on indoor environmental parameters in educational buildings, two gaps remain important for practice-oriented comfort research. First, many studies examine comfort dimensions in isolation or rely on controlled laboratory conditions, which may not fully reflect real classroom or studio use. Second, field evidence that simultaneously measures a broad set of thermal, acoustic, and visual parameters and links them specifically to both thermal perception and thermal comfort remains limited. Therefore, the contribution of the present work is intentionally positioned as an exploratory, in-situ correlation study that advances current knowledge by providing context-specific evidence from actively used educational spaces rather than proposing a comprehensive framework.

Accordingly, the aim of this study is to examine the associations between measured indoor environmental parameters – air temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, horizontal illuminance, and vertical illuminance – and students' evaluations of (i) thermal perception and (ii) thermal comfort in educational spaces. By clarifying these relationships under real-use conditions, the study offers empirical guidance for integrated comfort strategies in educational buildings.

2. Materials and methods

2.1. Research area and data collection process

This study was conducted during the first week of October 2025 in the indoor educational spaces of the Department of Architecture, Faculty of Architecture and Design, Adana Alparslan Türkeş Science and Technology University. The fieldwork was carried out in three different indoor educational settings within the department: two studios (Studio 1 and Studio 2) and one classroom (Architecture Classroom) (Fig. 1). Studio 1 had façades oriented toward the northeast, southeast, and southwest; Studio 2 toward the northwest and southwest; and the Architecture Classroom toward the northwest. The primary aim of the study was to examine how multiple physical environmental parameters influence users' evaluations of thermal perception and thermal comfort.

A simultaneous data collection approach was adopted. While participants completed the survey, individual measurements of the physical environmental parameters were taken next to them at the same time. Data were collected from a total of 74 participants – 36 in Studio 1, 18 in Studio 2, and 20 in the Architecture Classroom. Participants remained in their assigned classrooms during the measurement sessions, and no rotation between different spaces occurred throughout the day. All participants were undergraduate students from the Faculty of Architecture and voluntarily took part in the research. The participants were not selected randomly; instead, they consisted of students who were present in the study spaces during regular use. Their ages ranged between 18 and 26 years. The gender distribution of the participants was 51% female and 49% male. Participants wore clothing appropriate to the seasonal indoor conditions. However, individual clothing insulation levels and body mass index (BMI) were not recorded. Ethical approval for this study was obtained from the Scientific Research and Publication Ethics Committee of Adana Alparslan Türkeş Science and Technology University. All participants were informed about the purpose and scope of the research prior to participation, and each provided written informed consent through the Voluntary Participation Form in accordance with institutional and ethical research standards.

Data collection sessions were conducted at different times of the day – morning, midday, and afternoon – during the first week of October to reflect the natural variations in indoor conditions (Fig. 2). During the measurements, air-conditioning systems were in active operation. All measuring devices were calibrated before the data collection process to ensure accuracy. The same air-conditioning temperature setpoint was maintained in all spaces during the measurement period. The minimum, mean, and maximum indoor temperature values recorded in the study are presented in Table 1. Each data collection session lasted approximately one hour and was conducted under normal classroom use conditions while students were attending their regular courses. No additional natural ventilation was applied during the measurement periods.

The measured physical environmental parameters included air temperature (°C), relative humidity (%), air velocity (m/s), mean radiant temperature (°C), sound pressure level (dB(A)), horizontal illuminance (lux), and vertical illuminance (lux).

The survey consisted of two main parts: demographic information and thermal evaluation. Participants provided demographic information and rated their thermal sensation and overall thermal comfort using standardized seven-point Likert scales (−3 = very cold/uncomfortable, −2 = cold/uncomfortable, −1 = slightly cold/uncomfortable, 0 = neutral, +1 = slightly warm/comfortable, +2 = warm/comfortable, and +3 = very warm/comfortable). This study focuses specifically on the relationships between these subjective thermal evaluations and the measured physical environmental parameters. In this study, the term thermal perception refers to participants' thermal sensation votes, representing their subjective cold–warm evaluation of the indoor environment.

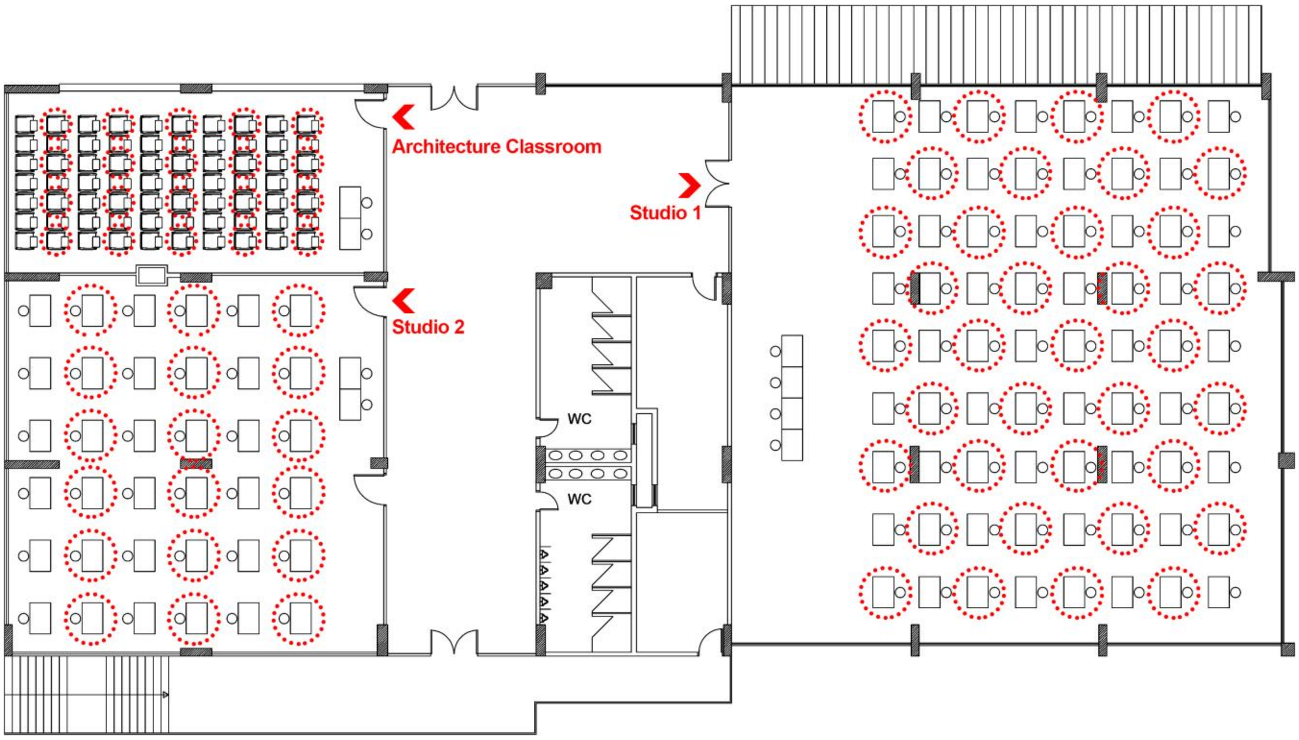

Fig. 1. Measurement and survey points

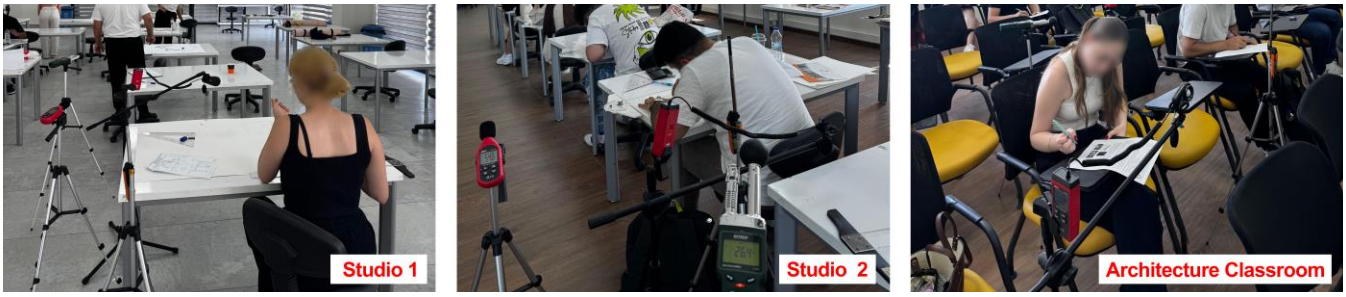

Fig. 2. Measurement and survey study

2.2. Data analysis method

The data analyses were performed using the SPSS 25 software. First, the basic distribution characteristics of all parameters were identified, and descriptive statistics (mean, standard deviation, minimum, and maximum) were calculated to understand the overall structure of the dataset.

To examine the relationships between environmental physical parameters and thermal perception and comfort, a Pearson correlation analysis was conducted. The normality of continuous variables was assessed using the Kolmogorov–Smirnov test, and the distributions were found to conform to normality. Therefore, the Pearson correlation coefficient, a parametric test, was selected to determine the direction and strength of linear relationships between the variables. The level of statistical significance was set at $p < 0.05$. The overall research design, fieldwork procedure, and data analysis workflow are summarized in Fig. 3.

3. Results and discussions

3.1. Descriptive statistics

The data obtained from the measurements conducted in indoor educational spaces and from participants' subjective evaluations were summarized through descriptive statistical analysis prior to inferential testing. The mean, standard deviation, minimum, and maximum values for the physical environmental parameters and subjective comfort assessments are presented in detail in Table 1.

During the study period, the mean indoor air temperature was 25.54 °C, ranging between 23.9 °C and 27.0 °C. These results indicate that the thermal conditions were generally within the neutral temperature range to which users are accustomed. Similarly, the average relative humidity was measured as 38.68%, with values ranging between 27.8% and 46.8%, showing a relatively narrow distribution. Air velocity, consistent with the enclosed nature of the spaces, remained low, with a mean value of 0.17 m/s and a range of 0.01 m/s to 0.69 m/s.

The mean radiant temperature (Tmrt) values varied between 25.32 °C and 28.57 °C, with an overall mean of 26.84 °C. These findings suggest that there was no substantial difference between air temperature and radiant temperature in the studied spaces, indicating a generally balanced indoor radiant environment. The sound pressure level ranged from 49.10 dB(A) to 58.80 dB(A), with a mean value of 53.13 dB(A).

A wider distribution was observed in the visual environmental parameters. Horizontal illuminance levels ranged between 400 lux and 2080 lux, with a mean of 845 lux, whereas vertical illuminance levels varied between 220 lux and 920 lux, averaging 427 lux.

These descriptive statistics provide a general framework for understanding the distribution of physical environmental parameters and subjective comfort perceptions within the study. They also serve as a reference for interpreting the relational findings in the subsequent statistical analyses.

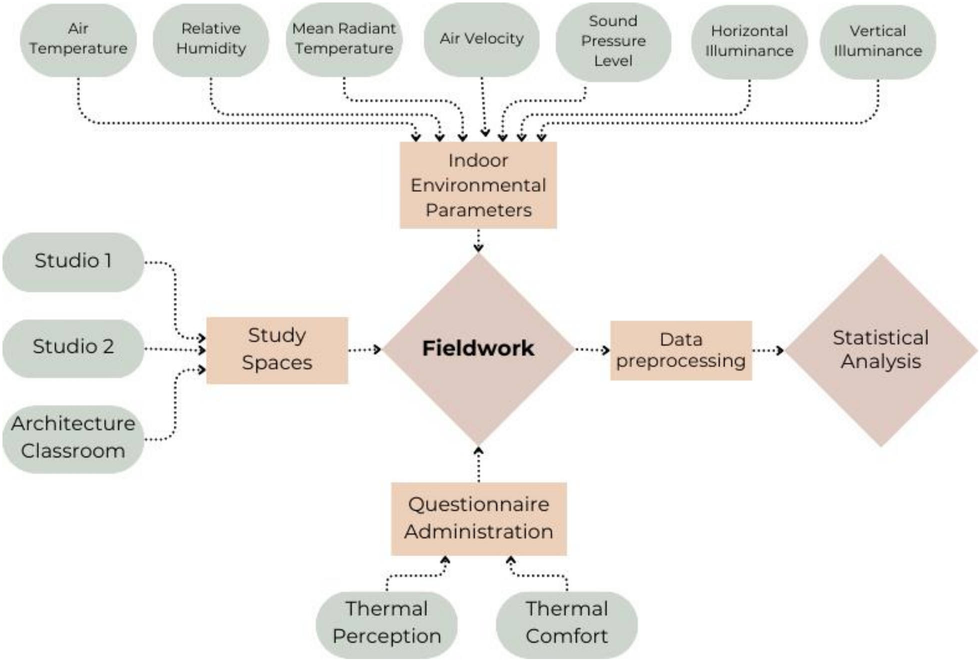

Fig. 3. Methodological flowchart

Table 1. Results of descriptive statistical analysis. Source: own study

Parameter	Mean	Standard Deviation	Minimum	Maximum
Temperature (°C)	25.54	0.77	23.90	27.00
Relative Humidity (%)	38.68	5.91	27.80	46.80
Air Velocity (m/s)	0.17	0.16	0.01	0.69
Mean Radiant Temperature (°C)	26.84	0.70	25.32	28.57
Sound Pressure Level (dB(A))	53.13	2.03	49.10	58.80
Horizontal Illuminance (lux)	845.00	347.27	400.00	2080.00
Vertical Illuminance (lux)	427.73	158.49	220.00	920.00
Thermal Perception (−3 / +3)	−0.02	0.66	−2.00	2.00
Thermal Comfort (−3 / +3)	0.77	1.22	−3.00	3.00

3.2. Relationships between thermal perception and environmental parameters

A Pearson correlation analysis was conducted to determine the linear relationships between users' thermal perception and the physical environmental parameters. The resulting correlation coefficients and corresponding p-values are presented in Table 2. The findings provide significant insights into the influence of indoor environmental conditions on users' thermal perception in educational spaces.

According to the results, a positive and statistically significant relationship was found between air temperature and thermal perception ($r = 0.243$, $p = 0.043$). This finding supports previous studies emphasizing that an increase in temperature directly affects users' perception of warmth [36,37]. As temperature rises, individuals tend to perceive the environment as warmer, and this tendency is reflected in their subjective assessments.

Similarly, air velocity showed a negative but significant relationship with thermal perception ($r = -0.267$, $p = 0.025$). Increased air movement caused participants to perceive the environment as cooler. This result aligns with previous findings indicating that even minor air movements in enclosed spaces can influence thermal sensation [38-40]. The cooling influence of air movement on thermal perception represents a well-established psychophysiological response, particularly in warm environments.

Another noteworthy finding was the positive and significant relationship between horizontal illuminance and thermal perception ($r = 0.277$, $p = 0.020$). This result indicates that as the level of illumination increased, participants tended to perceive the environment as warmer. Prior research has shown that visual environmental conditions can indirectly affect thermal perception and that variations in lighting can alter how thermal environments are experienced [41]. The cross-modal influence of lighting, extending beyond vision to shape multisensory comfort perception, highlights the complex and multidimensional nature of indoor environmental experience.

In contrast, no statistically significant relationships were found between thermal perception and the other environmental parameters, including relative humidity, mean radiant temperature (Tmrt), sound pressure level, and vertical illuminance ($p > 0.05$). This lack of significance may be attributed to the narrow range of variation in these parameters within the studied spaces or to participants' lower perceptual sensitivity to these factors.

Overall, the results indicate that indoor thermal perception is primarily influenced by temperature, air movement, and illuminance, whereas parameters such as humidity, radiant temperature, and acoustic conditions appear to have no substantial perceptual impact. These findings are broadly consistent with previous studies suggesting that thermal perception is shaped by multiple environmental stimuli [42,43].

3.3. Relationships between thermal comfort and environmental parameters

The relationships between users' thermal comfort evaluations and the physical environmental parameters were examined using Pearson correlation analysis, and the results are presented in Table 3. The findings reveal that subjective thermal comfort in indoor educational spaces is particularly associated with specific environmental factors such as temperature, humidity, and illuminance.

The results indicate a moderate, negative, and statistically significant relationship between thermal comfort and both air temperature and relative humidity. This finding clearly demonstrates that higher temperature and humidity levels adversely affect users' comfort perception. In enclosed environments, elevated temperature and humidity can increase both physical discomfort and the psychologically perceived sense of unease. Previous studies have consistently emphasized that temperature and humidity are key determinants of thermal comfort, highlighting that high humidity impairs evaporative cooling through perspiration and thus reduces comfort perception [44-46].

Table 2. Relationships between thermal perception and environmental parameters. Source: own study

Parameter	Pearson r	p-value	Relationship
Temperature (°C)	0.243	0.043	Positive and Significant
Relative Humidity (%)	−0.080	0.510	Not Significant
Air Velocity (m/s)	−0.267	0.025	Negative and Significant
Mean Radiant Temperature (°C)	0.023	0.848	Not Significant
Sound Pressure Level (dB(A))	−0.101	0.407	Not Significant
Horizontal Illuminance (lux)	0.277	0.020	Positive and Significant

Table 3. Relationships between thermal comfort and environmental parameters. Source: own study

Parameter	Pearson r	p-value	Relationship
Temperature (°C)	−0.279	0.009	Negative and Significant
Relative Humidity (%)	−0.323	0.006	Negative and Significant
Air Velocity (m/s)	0.016	0.895	Not Significant
Mean Radiant Temperature (°C)	0.012	0.922	Not Significant
Sound Pressure Level (dB(A))	0.031	0.801	Not Significant
Horizontal Illuminance (lux)	−0.259	0.030	Negative and Significant

Another noteworthy finding is the negative and significant correlation between horizontal illuminance and thermal comfort ($r = -0.259$, $p = 0.030$). This result suggests that higher levels of horizontal illumination may lead to lower subjective comfort ratings. It indicates that visual environmental conditions can influence not only visual perception but also other sensory dimensions, such as thermal comfort. Recent studies have increasingly demonstrated that visual environmental parameters can exert cross-modal effects on thermal comfort perception. Specifically, high levels of brightness may cause the environment to be perceived as warmer or more stifling, which in turn negatively affects comfort [47].

No statistically significant relationships were found between thermal comfort and the other environmental parameters (air velocity, mean radiant temperature, sound pressure level, vertical illuminance) ($p > 0.05$). The absence of significant correlations for classical thermal comfort parameters such as air temperature and radiant temperature may be explained by the relatively narrow temperature range (approximately 23.9–27.0 °C) and the high level of thermal adaptation among participants. Similarly, the low air velocity levels observed during the measurements likely limited its effect on comfort perception.

Overall, these findings demonstrate that thermal comfort in indoor educational spaces is significantly influenced by temperature, relative humidity, and visual environmental conditions. Increasing humidity directly reduces comfort, while higher illuminance levels may indirectly decrease comfort through cross-modal perception effects. These results once again underline that indoor comfort is shaped by the combined influence of multiple environmental factors and cannot be fully explained by classical thermal parameters alone. The literature similarly suggests that comfort perception in offices and educational spaces cannot be limited to temperature and humidity, as acoustic and visual conditions also play important roles in shaping the overall comfort experience [48-49]. Although several relationships were found to be statistically significant, the correlation coefficients indicate weak effect sizes, suggesting that these environmental parameters have a limited but measurable influence on users' thermal perception and comfort.

The results of this study indicate that thermal perception and comfort in indoor educational spaces are shaped not only by basic thermal factors such as temperature but also through interactions with other environmental parameters such as relative humidity, air movement, and lighting conditions (Fig. 4). The observed effects of illuminance on thermal perception and comfort support the multisensory interaction framework increasingly emphasized in recent research [50,51]. These findings suggest that users' responses to environmental conditions are influenced not only by physical factors but also by perceptual and psychological mechanisms. Particularly in educational settings – where occupants spend extended periods of time – comfort experience is a multidimensional and dynamic phenomenon. Hence, the study highlights the need to integrate thermal, visual, and other environmental parameters holistically in the design of indoor environments to achieve enhanced user comfort. The analysis was conducted at the bivariate level to identify the individual associations of each environmental parameter with thermal perception and comfort, rather than to develop a predictive multivariate model. Therefore, the results should be interpreted as indicative relationships highlighting the relative contribution of single parameters under real-use conditions.

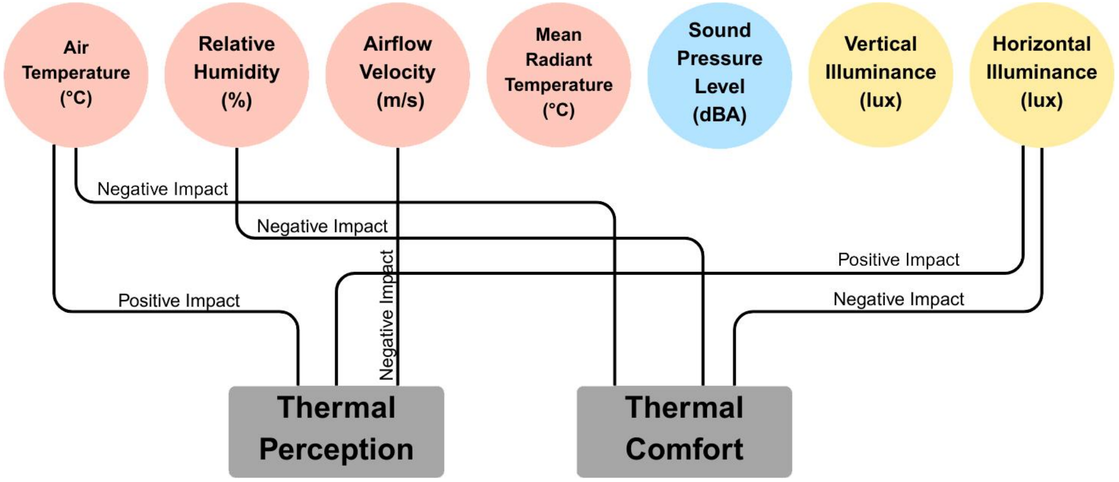

Fig. 4. Relationships between thermal perception, thermal comfort, and environmental parameters

4. Conclusions

This research provides a holistic approach to understanding how multiple physical environmental parameters influence users' thermal perception and comfort in indoor educational spaces. The findings demonstrate that not only classical parameters such as temperature but also other environmental factors – including relative humidity, air movement, and illuminance – play an important role in shaping indoor comfort experiences. In particular, the role of visual environmental conditions in thermal perception and comfort underscores the importance of considering multisensory interactions in comfort evaluation.

Based on these findings, it is recommended that indoor design and management processes address thermal comfort not solely through temperature and humidity control but by considering the combined effects of multiple environmental parameters. To enhance perceptual comfort in educational spaces, it is essential to optimize the various physical environmental conditions in an integrated manner.

While this study contributes new data to the literature on indoor comfort, it also highlights the need for architecture and interior design disciplines to account for the influence of multiple environmental parameters on user perception. Future studies that include a wider range of user profiles and diverse indoor settings will further contribute to a comprehensive understanding of comfort criteria.

This study has several limitations. The field measurements were conducted in a single university building and within a relatively narrow range of indoor environmental conditions. In addition, personal factors such as clothing insulation levels and body mass index (BMI) were not recorded, which may influence individual thermal perception and comfort responses. In addition, the analysis was limited to bivariate correlations; future studies may employ multivariate models to evaluate the combined effects of environmental variables and control for shared variance. Future research, including different building types, broader environmental conditions, and personal variables, would contribute to a more comprehensive evaluation of indoor comfort.

References

[1] Hong T. et al., "Advances in research and applications of energy-related occupant behavior in buildings", *Energy and Buildings* 116 (2016) 694–702. https://doi.org/10.1016/J.ENBUILD.2015.11.052

[2] Schweizer C. et al., "Indoor time-microenvironment-activity patterns in seven regions of Europe", *Journal of Exposure Science and Environmental Epidemiology* 17(2) (2007) 170–181. https://doi.org/10.1038/SJ.JES.7500490;KWRD=MEDICINE

[3] Frontczak M., Wargocki P., "Literature survey on how different factors influence human comfort in indoor environments", *Building and Environment* 46(4) (2011) 922–937. https://doi.org/10.1016/J.BUILDENV.2010.10.021

[4] Jain H., "Critical insights into thermal comfort optimization and heat resilience in indoor spaces", *City and Built Environment* 2(1) (2024) 1–26. https://doi.org/10.1007/S44213-024-00038-Z

[5] de Dear R.J., Brager G.S., "Developing an adaptive model of thermal comfort and preference", *UC Berkeley: Center for the Built Environment*, 1998.

[6] Humphreys M., "Outdoor temperatures and comfort indoors", *Batiment International, Building Research and Practice* 6(2) (1978) 92. https://doi.org/10.1080/09613217808550656

[7] Aqilah N. et al., "Indoor thermal environment and effect of air movement on comfort temperature in Malaysian naturally ventilated dwellings", *Journal of Building Engineering* 104 (2025) 112151. https://doi.org/10.1016/J.JOBE.2025.112151

[8] Sadagopan H. et al., "Humidity or air-speed? A climate chamber investigation into adaptive thermal comfort potential", *Building Services Engineering Research and Technology* 46(3) (2025) 339–359. https://doi.org/10.1177/01436244241296756

[9] Byber K. et al., "Humidification of indoor air for preventing or reducing dryness symptoms or upper respiratory infections in educational settings and at the workplace", *The Cochrane Database of Systematic Reviews* 2021(12) (2021) CD012219. https://doi.org/10.1002/14651858.CD012219.PUB2

[10] Ricciardi P., Buratti C., "Environmental quality of university classrooms: Subjective and objective evaluation of the thermal, acoustic, and lighting comfort conditions", *Building and Environment* 127 (2018) 23–36. https://doi.org/10.1016/j.buildenv.2017.10.030

[11] Wen X. et al., "Effect of thermal-acoustic composite environments on comfort perceptions considering different office activities", *Energy and Buildings* 305 (2024) 113887. https://doi.org/10.1016/J.ENBUILD.2024.113887

[12] Yang W. and Moon H. J., "Combined effects of acoustic, thermal, and illumination conditions on the comfort of discrete senses and overall indoor environment", *Building and Environment* 148 (2019) 623–633. https://doi.org/10.1016/j.buildenv.2018.11.040

[13] Jamrozik A. et al., "A novel methodology to realistically monitor office occupant reactions and environmental conditions using a living lab", *Building and Environment* 130 (2018) 190–199. https://doi.org/10.1016/J.BUILDENV.2017.12.024

[14] Yang W. et al., "Effects of indoor temperature and background noise on floor impact noise perception", *Indoor and Built Environment* 28(4) (2019) 454–469. https://doi.org/10.1177/1420326X17753708

[15] Geng Y. et al., "The impact of thermal environment on occupant IEQ perception and productivity", *Building and Environment* 121 (2017) 158–167. https://doi.org/10.1016/j.buildenv.2017.05.022

[16] Kousis I., Pisello A. L., "For the mitigation of urban heat island and urban noise island: two simultaneous sides of urban discomfort", *Environmental Research Letters* 15(10) (2020) 103004. https://doi.org/10.1088/1748-9326/ABAA0D

[17] Torresin S. et al., "Combined effects of environmental factors on human perception and objective performance: A review of experimental laboratory works", *Indoor Air* 28(4) (2018) 525–538. https://doi.org/10.1111/ina.12457

[18] Brager G.S., De Dear R.J., "Thermal adaptation in the built environment: a literature review", *Energy and Buildings* 27(1) (1998) 83–96. https://doi.org/10.1016/S0378-7788(97)00053-4

[19] Ole Fanger P., Toftum J., "Extension of the PMV model to non-air-conditioned buildings in warm climates", *Energy and Buildings* 34(6) (2002) 533–536. https://doi.org/10.1016/S0378-7788(02)00003-8

[20] Kim Y. et al., "Influencing factors on thermal comfort and biosignals of occupant-a review", *Journal of Mechanical Science and Technology* 35(9) (2021) 4201–4224. https://doi.org/10.1007/S12206-021-0832-5

[21] Amaripadath D. et al., "A systematic review on role of humidity as an indoor thermal comfort parameter in humid climates", *Journal of Building Engineering* 68 (2023) 106039. https://doi.org/10.1016/J.JOBE.2023.106039

[22] Kusi E. et al., "Effect of Airflow on Thermal Comfort in a Naturally Ventilated University Classroom", *MSI Journal of Multidisciplinary Research (MSIJMR)* 2(5) (2025) 6–30.

[23] d'Ambrosio Alfano F.R. et al., "On the effects of the mean radiant temperature evaluation in the assessment of thermal comfort by dynamic energy simulation tools", *Building and Environment* 236 (2023) 110254. https://doi.org/10.1016/j.buildenv.2023.110254

[24] Nagano K., Horikoshi T., "New comfort index during combined conditions of moderate low ambient temperature and traffic noise", *Energy and Buildings* 37(3) (2005) 287–294. https://doi.org/10.1016/j.enbuild.2004.08.001

[25] Pellerin N., Candas V., "Effects of steady-state noise and temperature conditions on environmental perception and acceptability", *Indoor Air* 14(2) (2004) 129–136. https://doi.org/10.1046/j.1600-0668.2003.00221.x

[26] Balazova I. et al., "The influence of exposure to multiple indoor environmental parameters on human perception, performance and motivation", *Clima 2007 WellBeing Indoors*, 2007.

[27] Nagano K. et al., "New index of combined effect of temperature and noise on human comfort: summer experiments on hot ambient temperature and traffic noise", *Archives of Complex Environmental Studies* 13, (2001) 3–4.

[28] Huang L. et al., "A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices", *Building and Environment* 49(1) (2012) 304–309. https://doi.org/10.1016/j.buildenv.2011.07.022

[29] Guan H. et al., "The combined effects of temperature and noise on the comfort perceptions of young people with a normal Body Mass Index", *Sustainable Cities and Society* 54 (2020) 101993. https://doi.org/10.1016/J.SCS.2019.101993

[30] Tiller D. et al., "AB-10-017: Combined effects of noise and temperature on human comfort and performance (1128-RP)", *Architectural Engineering Faculty Publications* 40 (2010) 522–23.

[31] Guan H. et al., "People's subjective and physiological responses to the combined thermal-acoustic environments", *Building and Environment* 172 (2020) 106709. https://doi.org/10.1016/j.buildenv.2020.106709

[32] Wu H. et al., "Investigation of the relationships between thermal, acoustic, illuminous environments and human perceptions", *Journal of Building Engineering* 32 (2020) 101839. https://doi.org/10.1016/J.JOBE.2020.101839

[33] Buratti C. et al., “A new index combining thermal, acoustic, and visual comfort of moderate environments in temperate climates”, *Building and Environment* 139 (2018) 27–37. https://doi.org/10.1016/j.buildenv.2018.04.038

[34] Bellia L. et al., “On the interaction between lighting and thermal comfort: An integrated approach to IEQ”, *Energy and Buildings* 231 (2021) 110570. https://doi.org/10.1016/j.enbuild.2020.110570

[35] Chinazzo G. et al., “Daylight affects human thermal perception”, *Scientific Reports* 9(1) (2019) 1–15. https://doi.org/10.1038/s41598-019-48963-y

[36] Borghero L. et al., “Calculating Comfort Indexes and Applying Comfort Models to Predict Thermal Sensation Vote in Sports Centres”, *Indoor Air* 2024(1) (2024) 9142303. https://doi.org/10.1155/2024/9142303

[37] Li K. et al., “Correlation analysis and modeling of human thermal sensation with multiple physiological markers: An experimental study”, *Energy and Buildings* 278 (2023) 112643. https://doi.org/10.1016/J.ENBUILD.2022.112643

[38] Guo R. et al., “Experimental investigation of convective heat transfer for night ventilation in case of mixing ventilation”, *Building and Environment* 193 (2021) 107670. https://doi.org/10.1016/J.BUILDENV.2021.107670

[39] Hou Y., “Effect of wind speed on human thermal sensation and thermal comfort”, *AIP Conference Proceedings* 1971(1) (2018) 40. https://doi.org/10.1063/1.5041131/887279

[40] Hu J. et al., “Research on Summer Indoor Air Conditioning Design Parameters in Haikou City: A Field Study of Indoor Thermal Perception and Comfort”, *Sustainability* 16(9) (2024) 3864. https://doi.org/10.3390/su16093864

[41] Kompier M. et al., “Effects of light and ambient temperature on visual and thermal appraisals”, *11th Windsor Conference: Resilient Comfort,* WINDSOR 2020, (2020) 968–979.

[42] Dahlan N. D. et al., “Evidence base prioritisation of indoor comfort perceptions in Malaysian typical multi-storey hostels”, *Building and Environment* 44(10) (2009) 2158–2165. https://doi.org/10.1016/J.BUILDENV.2009.03.010

[43] Haldi F., Robinson D., “On the unification of thermal perception and adaptive actions”, *Building and Environment* 45(11) (2010) 2440–2457. https://doi.org/10.1016/j.buildenv.2010.05.010

[44] Kong D. et al., “Effects of indoor humidity on building occupants’ thermal comfort and evidence in terms of climate adaptation”, *Building and Environment* 155 (2019) 298–307. https://doi.org/10.1016/J.BUILDENV.2019.02.039

[45] Jing S. et al., “Impact of Relative Humidity on Thermal Comfort in a Warm Environment”, *Indoor and Built Environment* 22(4) (2013) 598–607. https://doi.org/10.1177/1420326X12447614

[46] Watanabe H. et al., “Mechanism underlying the influence of humidity on thermal comfort and stress under mimicked working conditions”, *Physiology & Behavior* 285 (2024) 114653. https://doi.org/10.1016/J.PHYSBEH.2024.114653

[47] Azmoon H. et al., “The Relationship between Thermal Comfort and Light Intensity with Sleep Quality and Eye Tiredness in Shift Work Nurses”, *Journal of Environmental and Public Health* 2013 (2013) 639184. https://doi.org/10.1155/2013/639184

[48] Cao B. et al., “Development of a multivariate regression model for overall satisfaction in public buildings based on field studies in Beijing and Shanghai”, *Building and Environment* 47(1) (2012) 394–399. https://doi.org/10.1016/j.buildenv.2011.06.022

[49] Ncube M., Riffat S., “Developing an indoor environment quality tool for assessment of mechanically ventilated office buildings in the UK - A preliminary study”, *Building and Environment* 53 (2012) 26–33. https://doi.org/10.1016/j.buildenv.2012.01.003

[50] te Kulve M. et al., “Interactions between the perception of light and temperature”, *Indoor Air* 28(6) (2018) 881–891. https://doi.org/10.1111/ina.12500

[51] Luo W. et al., “Effects of correlated color temperature of light on thermal comfort, thermophysiology and cognitive performance”, *Building and Environment* 231 (2023) 109944. https://doi.org/10.1016/J.BUILDENV.2022.109944