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Relationship Between Auditory Perception and Comfort and Multiple Physical Environmental Parameters: An Evaluation in Educational Buildings

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RELATIONSHIP BETWEEN AUDITORY PERCEPTION AND COMFORT AND MULTIPLE PHYSICAL ENVIRONMENTAL PARAMETERS: AN EVALUATION IN EDUCATIONAL BUILDINGS

KEYWORDS

AUDITORY COMFORT
AUDITORY PERCEPTION
EDUCATIONAL SPACES

ABSTRACT

Acoustic comfort in educational buildings plays a key role in user satisfaction and learning efficiency. This study investigates the effects of multiple physical environmental parameters-air temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, and horizontal and vertical illuminance-on auditory perception and comfort in educational spaces. The research was conducted in two design studios and one classroom at Adana Alparslan Türkeş Science and Technology University, using simultaneous subjective surveys with 88 participants and objective environmental measurements taken at the same locations. After reliability and normality checks, Pearson correlation and multiple linear regression analyses were applied. Results show that sound pressure level is the only significant determinant of auditory perception, while auditory comfort is significantly influenced by sound pressure level, relative humidity, and horizontal illuminance. The findings emphasize the importance of a holistic approach to evaluating indoor auditory comfort.

INTRODUCTION

Indoor environmental quality is generally defined by four main comfort components: thermal comfort, auditory comfort, visual comfort, and indoor air quality (Lee, Lee and Lee, 2023). Each of these components is represented by measurable physical parameters such as air temperature, relative humidity, air velocity, mean radiant temperature, illuminance, and sound pressure level (Riffelli, 2021). In recent years, particularly in indoor environments where users spend extended periods – such as educational spaces – the effects of these environmental conditions on occupants have been extensively investigated. User comfort and health are directly influenced by indoor environmental conditions, and inadequate environments may result in dissatisfaction, reduced attention, and decreased performance (Vischer, 2008). For this reason, adopting a holistic approach to comfort criteria, with particular emphasis on auditory comfort, is of critical importance in terms of both user well-being and productivity.

Indoor comfort is a multidimensional phenomenon, and improving acoustic parameters alone cannot be assumed to fully enhance user experience. Adequate thermal comfort conditions (air temperature, mean radiant temperature, humidity, and air velocity) and visual comfort conditions (illuminance levels) must also be ensured. The literature emphasizes that different comfort domains interact with one another and, when evaluated collectively, significantly influence overall comfort perception (Wu et al., 2020). One study reported that thermal and acoustic environments exhibit a veto effect on user satisfaction, meaning that severe dissatisfaction with either of these conditions may independently determine overall satisfaction (Huang et al., 2012). Similarly, a review study has revealed that thermal comfort and acoustic comfort are the most influential factors affecting overall comfort, followed by visual comfort (Du et al., 2023). Nevertheless, user perception of indoor comfort may vary depending on context. While some office and classroom studies identify thermal conditions and air quality as the most critical factors (Riffelli, 2022), others indicate that the influence of acoustic comfort on overall satisfaction can be at least as strong as, or even more dominant than, thermal comfort (Sakellaris et al., 2016).

LITERATURE REVIEW

Auditory comfort in educational environments is widely recognized as a critical factor influencing learning processes and users' overall environmental satisfaction. Beyond purely acoustic characteristics, however, recent research increasingly emphasizes that auditory comfort is shaped through interactions with other physical environmental dimensions, particularly thermal conditions. Studies have shown that identical noise levels tend to be perceived as more disturbing under thermally uncomfortable conditions, such as elevated air temperatures, whereas tolerance to noise increases under thermally neutral or cooler conditions (Yang, 2017; Jin, Jin and Kang, 2020; Lin et al., 2023; Chen et al., 2024). Multi-parameter experimental studies further demonstrate that thermal conditions can exert cross-modal effects on perceived acoustic comfort, while noise levels may simultaneously influence thermal comfort perception (Wu, Sun and Wu, 2020; Yang and Moon, 2019). In addition to air temperature, other thermal parameters such as relative humidity and air velocity have been reported to indirectly affect auditory comfort by increasing sensations of stuffiness or introducing additional background noise through ventilation systems (Wu et al., 2019; Yang, Moon and Kim, 2018; Bhandari, Tadepalli and Gopalakrishnan, 2025). Moreover, evidence suggests that these thermal-acoustic interactions are context-dependent and may diminish under extreme environmental conditions, where a single dominant discomfort factor overrides other sensory influences (Pellerin and Candas, 2004; Wen et al., 2025).

Visual comfort conditions also constitute an important component of user experience in indoor environments. Although illuminance levels may not appear to be directly related to auditory perception, several studies suggest that lighting conditions and visual stimuli can influence noise tolerance and perceived auditory comfort (Yang and Moon, 2018). Recent research on multisensory comfort has provided valuable insights into visual-auditory interactions.

Within this context, Li et al. (2025) investigated combined temperature-lighting-noise conditions in a learning environment and reported cross-modal effects between lighting and acoustics. Their results suggest that higher illuminance can reduce acoustic acceptability, with identical noise levels perceived as more disturbing under brighter conditions. The study also indicated that higher sound levels may negatively influence visual comfort evaluations, highlighting the integrated nature of multisensory environmental perception.

FIG. 1 LOCATION OF THE STUDY AREA IN ADANA ALPARSLAN TÜRKEŞ SCIENCE AND TECHNOLOGY UNIVERSITY

However, the literature does not present a full consensus regarding visual-acoustic interactions. Some studies report no significant influence of visual environmental conditions on auditory comfort. An experimental study conducted in an office laboratory in Vienna exposed participants to varying illuminance and noise levels and found that visual conditions did not statistically affect auditory comfort evaluations (Berger and Mahdavi, 2021). In that study, the temperature range was limited, and lighting was manipulated only in terms of glare presence, which may have constrained the detection of cross-modal effects. Consequently, other studies also report statistically insignificant effects of visual and thermal conditions on auditory comfort (Du et al., 2023). These inconsistencies suggest that the emergence of cross-modal interactions may depend on experimental design, the intensity of sensory stimuli, and participants' sensitivity.

Overall, existing studies indicate that auditory perception and comfort in indoor environments are shaped not only by acoustic characteristics but also by thermal and visual conditions, highlighting the growing importance of multisensory interactions in indoor comfort research. Because users perceive indoor environments holistically, discomfort in one domain may limit the effectiveness of improvements in others, particularly in educational buildings where learning efficiency and user satisfaction are strongly linked to environmental quality. However, despite increasing evidence of cross-modal interactions, the literature reveals a lack of studies that simultaneously and comprehensively examine the effects of multiple physical environmental parameters on auditory perception and auditory comfort in indoor educational spaces. Therefore, the present study aims to analyse the combined effects of air temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, and horizontal and vertical illuminance on users' auditory perception and auditory comfort. By integrating objective environmental measurements with subjective user evaluations, the study seeks to contribute new insights into the multidimensional nature of environmental comfort in educational settings.

METHODOLOGY

Both quantitative environmental measurements and subjective user survey data were collected simultaneously, and the resulting dataset was evaluated through statistical analyses to identify the effects of multiple physical variables on auditory comfort. The study was conducted in accordance with institutional ethical guidelines. Ethical approval was obtained from the relevant ethics committee prior to data collection. All participants were informed about the purpose and scope of the study, and written informed consent was obtained through a Voluntary Participation Form.

STUDY AREA AND PARTICIPANTS

The study was conducted in three different indoor educational spaces – Studio 1, Studio 2, and the Architecture Classroom – within the Faculty of Architecture and Design at Adana Alparslan Türkeş Science and Technology University (Fig. 1). The studios are group-work environments characterized by high ceilings, open-plan layouts, and access to natural light-

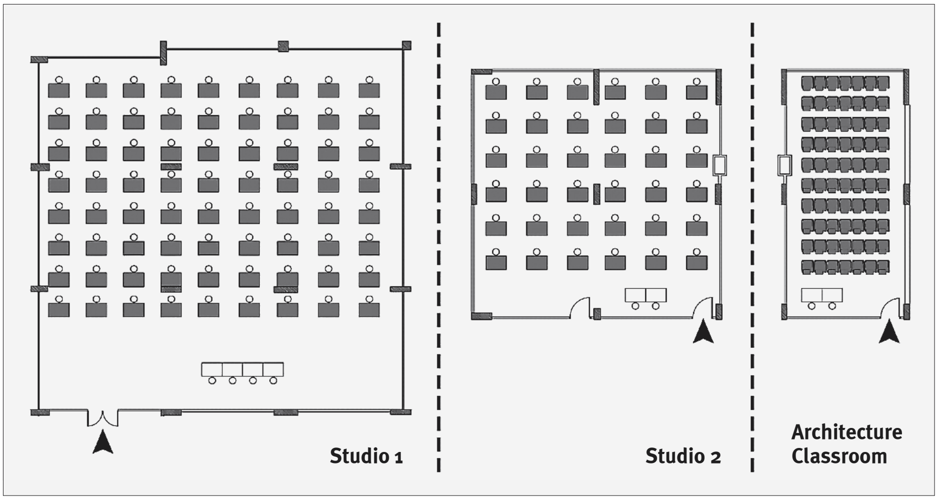

FIG. 2 INDOOR SPACES WHERE THE FIELD SURVEYS AND MEASUREMENTS WERE CONDUCTED

ing, whereas the Architecture Classroom has a conventional classroom layout designed for individual focus and note-taking activities (Fig. 2). The study was carried out in December, under winter conditions, and active split-type air-conditioning systems were observed in all spaces. This context provides an important environmental setting for interpreting users' comfort evaluations.

Data were collected through survey applications conducted with undergraduate students from the Department of Architecture who were present in the study areas. This participant group, consisting entirely of individuals who actively used the studied environments, provides an appropriate sample in terms of the reliability of user experience. The study was conducted on a voluntary basis, and data were obtained from a total of 88 participants. Participants' ages ranged from 19 to 27, and a balanced gender distribution was maintained. In addition, participants' familiarity with the study environments contributed to the sound implementation of the evaluation process. The distribution of participants across the study spaces was as follows: 36 participants in Studio 1, 28 in Studio 2, and 24 in the Architecture Classroom. Due to the nature of the study design, participants were not restricted to a single space. Data were collected from students present in each environment at the time of measurement; therefore, some participants took part in the study in more than one space (two or three), depending on their presence in different sessions.

DATA COLLECTION PROCESS AND MEASUREMENT INSTRUMENTS

During the survey administration for each participant, seven different environmental physical parameters were measured simultaneously at the same spatial position: air temperature, relative humidity, air velocity, mean radiant temperature (Tmrt), sound pressure level, horizontal illuminance, and vertical illuminance. All measurements were conducted using pre-calibrated instruments, and each measurement value was directly matched with the corresponding survey response. Each survey and measurement lasted approximately 5 minutes per participant. During the data collection process, the researcher moved between participants and conducted measurements individually at each participant's seating position while they were engaged in routine drawing activities. No controlled or artificial sound sources were introduced during the measurements; participants were exposed only to typical background noise conditions of the indoor environment.

In addition to demographic information such as age, gender, and educational status, the questionnaire included items related to auditory perception and auditory comfort levels. The auditory perception items were structured on a 7-point Likert-type scale ranging from "very noisy" to "very quiet." The auditory comfort items were assessed using the same scale, ranging from "very uncomfortable" to "very comfortable." The questionnaire comprised of a total of six items, including three statements related to auditory perception and three statements related to auditory comfort. The auditory perception dimension included items asking participants how they would describe the sound environment in the space, how noisy or quiet they perceived the environment, and how they evaluated the level of surrounding sounds.

The auditory comfort dimension included items asking participants how comfortable they felt in terms of the acoustic environment, to what extent the sound environment disturbed them, and how satisfied they were with the acoustic conditions of the space. This integrated data collection approach enabled the direct linking of users' subjective evaluations of environmental experience with simultaneously recorded physical measurement data, thereby supporting a more reliable analysis of relationships between environmental conditions and user perceptions. In this study, auditory perception and auditory comfort were treated as conceptually distinct constructs. Auditory perception refers to participants' subjective evaluation of the acoustic environment in terms of how noisy or quiet it is, whereas auditory comfort reflects the degree of satisfaction or discomfort experienced under those acoustic conditions. Accordingly, auditory perception in this study does not refer to the mere ability to hear sounds, but rather to the subjective ap-

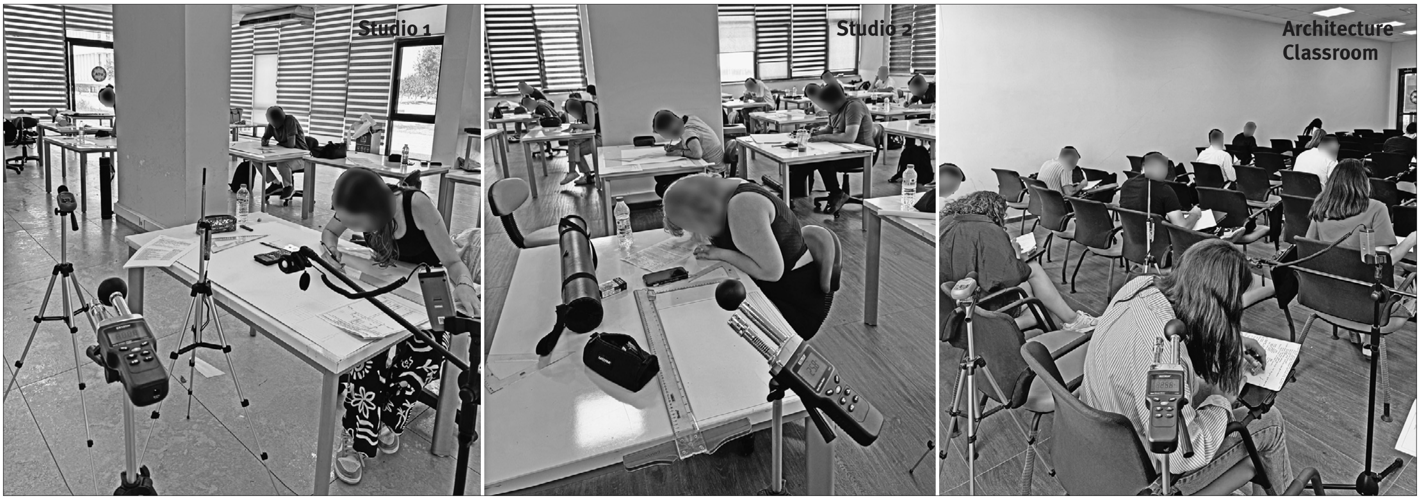

Fig. 3 Field survey and measurement study

praisal of the acoustic environment, which allows meaningful interpretation of its relationship with sound pressure level.

To provide a clearer understanding of the environmental context in which the data were collected, descriptive statistics of the measured environmental parameters are presented below. Across all measurement points, air temperature ranged between 21.70 and 25.90 °C (mean: 23.58 °C), relative humidity varied between 25.37% and 43.22% (mean: 35.41%), and air velocity remained generally low, ranging from 0.03 to 0.84 m/s (mean: 0.26 m/s). Mean radiant temperature (Tmrt) ranged between 23.88 and 25.35 °C (mean: 24.91 °C).

Sound pressure levels (SPL) ranged from 46.40 to 54.20 dB(A), with a mean value of 50.07 dB(A), representing typical background noise conditions in educational spaces. Horizontal illuminance levels varied between 387 and 1972 lx (mean: 789.00 lx), while vertical illuminance ranged from 195 to 875 lx (mean: 407.65 lx).

Data Analysis Methods

The collected data were analysed using IBM SPSS Statistics 25. In the first stage, Pearson correlation analysis was applied to determine relationships between environmental physical variables and auditory perception and auditory comfort evaluations. This method is suitable for identifying the strength and direction of linear relationships between variables.

In the second stage, only variables that showed statistically significant relationships with auditory comfort were included in multiple linear regression analysis. This analysis aimed to determine the extent to which auditory comfort, as the dependent variable, was influenced by environmental variables. A significance level of $p < 0.05$ was adopted as the criterion for statistical significance in the model. All environmental variables included in the analysis were expressed in their original measurement units: air temperature (°C), relative humidity (%), air velocity (m/s), mean radiant temperature (°C), sound pressure level (dB(A)), horizontal illuminance (lx), and vertical illuminance (lx). Prior to the statistical analyses, outlier diagnostics were performed to ensure the robustness of the results. Boxplot inspections and standardized z-scores were examined for all variables. No extreme outliers were detected, and therefore no data points were removed from the dataset.

Results

Internal consistency of the scales was assessed using Cronbach's alpha (α). Cronbach's α was calculated as 0.812 for the auditory perception items and 0.868 for the auditory comfort items. These values indicate a high level of reliability for both subscales ($\alpha > 0.70$).

To assess the suitability of the dataset for parametric analyses, the normality assumption was tested. Based on the results of the Kolmogorov-Smirnov and Shapiro-Wilk tests, auditory perception and auditory comfort scores were found to be normally distributed. Accordingly, the normality assumption required for Pearson correlation analysis was considered satisfied.

Relationships Between Auditory Perception and Environmental Physical Parameters

Based on the collected data, relationships between auditory perception and air temper-

Table I Pearson correlation results between auditory perception and environmental physical variables

Variable	Pearson (r)	p-value	Significance
Temperature	0.199	0.099	Not significant
Relative humidity	-0.157	0.195	Not significant
Mean radiant temperature (Tmrt)	0.078	0.521	Not significant
Air velocity	-0.104	0.392	Not significant
Sound pressure level (SPL)	-0.530	< 0.001	Significant
Horizontal illuminance	0.084	0.487	Not significant
Vertical illuminance	0.062	0.611	Not significant

Table II Pearson correlation results between auditory comfort and environmental physical variables

Variable	Pearson (r)	p-value	Significance
Temperature	0.055	0.650	Not significant
Relative humidity	-0.263	0.027	Significant
Mean radiant temperature (Tmrt)	-0.016	0.894	Not significant
Air velocity	-0.018	0.883	Not significant
Sound pressure level (SPL)	-0.963	< 0.001	Significant
Horizontal illuminance	-0.050	0.678	Not significant
Vertical illuminance	0.137	0.256	Not significant

Table III Multiple linear regression results for auditory comfort

Independent variable	Coefficient (b)	p-value	Significance
Temperature	-0.046	0.745	Not significant
Relative humidity	0.021	0.023	Significant
Mean radiant temperature (Tmrt)	0.003	0.986	Not significant
Air velocity	-0.650	0.233	Not significant
Sound pressure level (SPL)	-0.605	< 0.001	Significant
Horizontal illuminance	0.0003	0.017	Significant
Vertical illuminance	-0.0003	0.302	Not significant

ature, relative humidity, air velocity, mean radiant temperature (Tmrt), sound pressure level (SPL), horizontal illuminance, and vertical illuminance were examined using Pearson correlation analysis. The results are presented in Table I.

As shown in Table 1, a statistically significant relationship was identified only between auditory perception and sound pressure level (SPL) ($r = -0.530$, $p < 0.001$). This relationship was negative and indicates a strong correlation. No statistically significant relationships were found between auditory perception and the remaining environmental variables.

A weak positive relationship was observed between temperature and auditory perception ($r = 0.199$); however, this association was not statistically significant ($p = 0.099$). Relative humidity showed a weak negative association with auditory perception ($r = -0.157$), which was also not statistically significant ($p = 0.195$). The relationship between mean radiant temperature (Tmrt) and auditory perception was very weak ($r = 0.078$, $p = 0.521$) and non-significant. Similarly, air velocity exhibited a weak negative relationship with auditory perception ($r = -0.104$, $p = 0.392$), which was not significant. Horizontal and vertical illuminance were associated with very weak positive relationships with auditory perception; however, these relationships were not statistically significant.

Relationships Between Auditory Comfort and Environmental Physical Parameters

Based on the collected data, relationships between auditory comfort and air temperature, relative humidity, air velocity, mean radiant temperature (Tmrt), sound pressure level (SPL), horizontal illuminance, and vertical illuminance were evaluated using Pearson correlation analysis. The results are presented in Table 2.

As shown in Table II, a very strong, negative, and statistically significant relationship was identified between auditory comfort and sound pressure level (SPL) ($r = -0.963$, $p < 0.001$). This finding indicates that auditory comfort decreases as sound pressure level increases.

In addition, a weak negative and statistically significant relationship was found between relative humidity and auditory comfort ($r = -0.263$, $p = 0.027$). No significant relationships were found between auditory comfort and the remaining environmental physical variables. Temperature showed a very weak positive association with auditory comfort ($r = 0.055$), which was not statistically significant ($p = 0.650$). Mean radiant temperature (Tmrt) exhibited a very weak negative and non-significant relationship with auditory comfort ($r = -0.016$, $p = 0.894$). Air velocity also showed a very weak relationship ($r = -0.018$, $p = 0.883$). Neither horizontal nor vertical illuminance was significantly associated with auditory comfort.

Regression Results

To determine the effects of environmental physical parameters on auditory comfort, multiple linear regression analysis was performed. Auditory comfort was considered as the dependent variable, while temperature, relative humidity, air velocity, mean radiant temperature (Tmrt), sound pressure level (SPL), horizontal illuminance, and vertical illuminance were included as independent variables. The results are presented in Table III.

The model was statistically significant overall ($p < 0.001$), and the independent variables collectively explained 95.2% of the variance in auditory comfort (R¸ = 0.952). Sound pressure level (SPL) had a statistically significant negative effect on auditory comfort ($b = -0.605$, $p < 0.001$), indicating that increases in SPL lead to decreases in auditory comfort scores. Relative humidity had a statistically significant positive effect on auditory comfort ($b = 0.021$, $p = 0.023$). Horizontal illuminance also showed a statistically significant positive effect (b ff 0.0003, $p = 0.017$), indicating that higher horizontal illuminance was associated with higher auditory comfort scores. The remaining independent variables – temperature, mean radiant temperature (Tmrt), air velocity, and vertical illuminance – did not have statistically significant effects on auditory comfort ($p > 0.05$).

To facilitate a clearer interpretation of the statistical findings, the relationships between auditory perception, auditory comfort, and the examined environmental physical parameters are synthesized and schematically illustrated in Fig. 4. This relational diagram visually distinguishes the variables that were found to have statistically significant effects from those that did not, based on the correlation and regression analyses. By providing an integrated overview, the figure supports a holistic understanding of how multiple environmental factors collectively influence auditory comfort and perception in educational spaces.

AUDITORY COMFORT PREDICTION MODEL

Based on the significant predictors identified in the regression analysis, a simplified auditory comfort prediction model was developed (Table IV).

An auditory comfort prediction model was established using only the variables found to be statistically significant. The coefficients and constant term are presented in the following equation:

$$\text{Auditory Comfort} = 31.763 + (0.024 \times \text{Relative Humidity}) - (0.599 \times \text{SPL}) + (0.0003 \times \text{Horizontal Illuminance})$$

This regression model may be used as a practical prediction tool for similar indoor studies or applied research contexts. By entering the measured relative humidity (%), sound pressure level (dB(A)), and horizontal illuminance (lux) values for a given indoor environment, the model enables a numerical estimation of users' expected auditory comfort perception in that setting. The auditory comfort value obtained from the model yields an outcome within the range of -3 to +3 in accordance with the 7-point Likert scale used. Values approaching the negative end indicate that the environment is perceived as uncomfortable by users, whereas values approaching the positive end indicate a comfortable auditory environment. In this respect, the model provides an applicable tool for comparing auditory comfort across different spaces or design alternatives and for anticipating the effects of changes in environmental parameters on user perceptions.

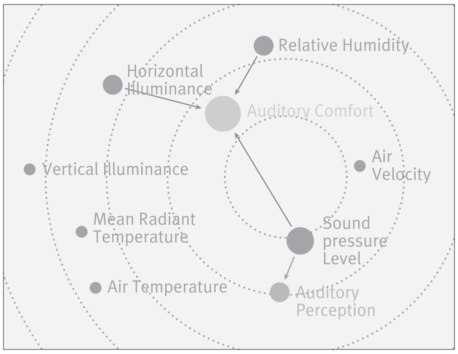

FIG. 4 RELATIONAL DIAGRAM OF ENVIRONMENTAL PHYSICAL VARIABLES AFFECTING AUDITORY PERCEPTION AND AUDITORY COMFORT

TABLE IV SIMPLIFIED REGRESSION MODEL RESULTS FOR AUDITORY COMFORT

Independent variable	**Coefficient (b)**	**p-value**	**Significance**
Relative humidity	0.024	0.023	Significant
Sound pressure level (SPL)	-0.599	< 0.001	Significant
Horizontal illuminance	0.0003	0.017	Significant
Constant (const)	31.763	–	–

DISCUSSION

This study aimed to analyse the effects of multiple physical environmental parameters – including air temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, horizontal illuminance, and vertical illuminance – on users' auditory perception and auditory comfort evaluations in indoor educational spaces. The findings of the study reaffirm the decisive role of sound pressure level in auditory comfort, which has been consistently emphasized in the literature. In particular, the very strong negative correlation identified between sound pressure level and auditory comfort, along with the dominance of this variable as the strongest predictor in the regression analysis, is in line with previous scientific evidence (Dias, dos Santos and Mariano, 2019; Liang et al., 2021; Zhang et al., 2025).

From the perspective of auditory perception, a statistically significant relationship was identified only with sound pressure level, while no significant associations were found with the other environmental parameters. This result aligns with the well-documented finding that noise level constitutes the primary determinant of auditory perception (Yang, Moon and Kim, 2018). However, the lack of confirmed cross-modal interactions between thermal environmental conditions (such as temperature and humidity) and auditory perception – reported in some previous studies (Yang and Moon, 2019; Li et al., 2025) – may be attributed to the characteristics of indoor settings and user profiles examined in this study. In particular, the relatively limited range of thermal conditions during the measurements and the participants' familiarity and adaptation to these environments may have influenced the absence of such effects.

Regarding auditory comfort, statistically significant relationships were identified not only with sound pressure level but also with relative humidity and horizontal illuminance. The limited positive effect of relative humidity is consistent with findings reported in certain previous studies (Wu et al., 2019; Granzotto, Yan and Tronchin, 2023). However, the relationship between relative humidity and auditory comfort should be interpreted with caution, as it may not represent a direct causal effect. Relative humidity can influence users' overall environmental perception by contributing to sensations such as stuffiness or reduced air freshness, which may in turn affect tolerance to background noise. In this context, the observed association may be explained through cross-modal interactions between thermal and auditory domains, where discomfort in one environmental dimension influences perception in another. Furthermore, the role of relative humidity may vary depending on its interaction with other environmental variables. While its individual effect appears limited, it may contribute indirectly to auditory comfort evaluations through its combined influence with dominant factors such as sound pressure level. Similarly, the modest positive effect of horizontal illuminance supports existing evidence on visual-acoustic environmental interactions (Yu et al., 2023). It is well established that visual environmental conditions can influence users' overall environmental perception and, consequently, their evaluations of auditory comfort. Nevertheless, the effect of lighting level observed in this study remained relatively weak.

This study contributes to the literature as one of the relatively few integrated environmental analyses focusing on auditory comfort in educational spaces. Its originality lies in the simultaneous collection of multiple environmental measurements and their direct association with subjective user perception data. However, several limitations should be acknowledged. First, the study is limited to three indoor spaces within a single university campus. Second, the user profile represents a specific demographic group. To enhance the generalizability of the findings, future studies should be conducted across different climatic regions, involving more diverse user groups and larger datasets. In addition, the auditory comfort prediction model developed in this study was derived and tested using the same dataset. Therefore, the model has not been validated using an independent dataset or a separate measurement campaign. This limitation suggests that the predictive performance of the model should be interpreted with caution, and the findings should be considered preliminary. Future studies should aim to validate the proposed model using independent datasets or cross-validation techniques to ensure its robustness and generalizability.

CONCLUSION

This study represents one of the relatively few investigations that examine the effects of multiple physical environmental parameters – including air temperature, relative humidity, air velocity, mean radiant temperature, sound pressure level, and horizontal and vertical illuminance – on users' auditory comfort and auditory perception in indoor educational spaces from a multidimensional perspective. At the same time, the limited but statistically significant effects observed for secondary environmental variables such as relative humidity and horizontal illuminance suggest that acoustic comfort should not be considered solely as an auditory phenomenon, but rather as one that interacts with thermal and visual components.

Regarding auditory perception, only sound pressure level was found to have a statistically significant effect, while no meaningful relationships were identified with other physical variables. This finding suggests that acoustic perception may be more directly sensitive to sound-related stimuli and relatively more resistant to interactions with other environmental factors. However, this outcome may also be associated with the limited variability of environmental conditions in the studied settings and the users' familiarity with these conditions.

One of the primary contributions of this study to the literature lies in its simultaneous modelling of the effects of multiple environmental parameters on auditory comfort and in directly linking subjective user perceptions with objective measurement data. This approach highlights the need for a more holistic evaluation frameworks in user-cantered environmental performance analyses of educational spaces. In particular, the findings indicate that visual and thermal environmental conditions, even when their direct effects are limited, may influence users' acoustic comfort through indirect pathways.

Future research should replicate the findings of this study across different climatic regions, architectural typologies, and user groups to enhance generalizability. In addition, experimental designs capable of more deeply examining cross-modal sensory interactions should be developed. Longitudinal studies that account for extended user experience are especially important for advancing an understanding of how environmental comfort affects learning, attention, and cognitive performance over time.

In conclusion, this study suggests that auditory comfort should be addressed within a holistic framework of environmental perception and comfort in spatial performance evaluations. In educational buildings, multi-comfort strategies that integrate acoustic, visual, and thermal comfort components form the foundation of user-cantered design approaches.

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Author’s Biography

Okan Şimşek, Ph. D. His current research interests include architectural design, environmental comfort and building physics, multisensory perception in architecture, urban and indoor environmental quality, and sustainable design strategies.

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