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Demographic Variations in Acoustic Sensitivity: Implications for Auditorium Design in Nigerian Higher Education

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Abstract

Acoustic comfort is increasingly recognised as a critical factor in the performance and well-being of users within educational environments. However, limited attention has been paid to how demographic variables influence users' perception of acoustic quality in university auditoria, particularly within the Nigerian context. This study investigates how age, gender, and user role shape subjective experiences of acoustic comfort, with the goal of informing more inclusive and responsive architectural design. A structured questionnaire was administered to 365 respondents comprising students, lecturers, and institutional guests in a private Nigerian university. Using a quantitative descriptive design, data were analysed through descriptive statistics and cross-tabulations to identify perceptual patterns across demographic groups. Findings revealed significant variations in acoustic sensitivity. Female respondents and individuals aged 21–30 years reported higher levels of discomfort, particularly with echo, reverberation, and speech clarity. Students, who constitute the most frequent users of auditoria, expressed the greatest dissatisfaction and were most vocal in advocating for improved acoustic environments. These trends underscore the importance of integrating user perceptions into design and evaluation processes. Drawing from psychoacoustic theory and the salutogenic design framework, the study proposes a suite of responsive strategies including psychoacoustic zoning, adaptive ceiling treatments, modular sound systems, and post-occupancy evaluation mechanisms. The study contributes a novel perspective to African-based architectural acoustics literature by emphasizing the psycho-social dimensions of auditory comfort. It argues that the traditional one-size-fits-all approach to auditorium design often neglects perceptual diversity and may inadvertently reinforce discomfort among certain demographic groups. The research offers a replicable methodology for assessing and integrating demographic sensitivity into design decisions and concludes with practical recommendations for architects, planners, and policy-makers in higher education. Ultimately, the study promotes equity-focused, user-centred spatial planning as a necessary step towards sustainable and inclusive learning environments in Nigerian universities.

Keywords: Acoustic Comfort**,** Inclusive Design**,** Psychoacoustics**,** Higher Education Architecture**,** Demographic Sensitivity.

Introduction

Acoustic comfort is a pivotal but often overlooked element in educational environments. It plays a significant role in supporting speech intelligibility, cognitive performance,

emotional well-being, and overall user satisfaction. High background noise levels, echoes, and prolonged reverberation can severely impair concentration and communication, placing increased vocal strain on lecturers and creating distraction and fatigue for students (Acoustic Comfort Special Issue, 2024; Tong et al., 2022). Inadequate acoustic design in lecture halls and auditoria has been linked to reduced comprehension, lower academic engagement, and increased psychological stress, particularly in acoustically untreated or poorly maintained spaces (Yang et al., 2024; Taşdemir & Karcı, 2024).
Contemporary psychoacoustic research highlights that acoustic comfort is not universally experienced, but is shaped by personal and psychological factors including age, gender, and social roles (Grassi et al., 2024). These demographic factors affect how individuals perceive sound intensity, echo, speech clarity, and background noise. Emerging design approaches now advocate for inclusive, user-sensitive strategies that respond not only to physical acoustic standards but also to the perceptual diversity within user groups (Şentürk & Akdağ, 2023).
In Nigeria, the issue of acoustic comfort in university auditoria remains largely under-researched. Most institutional buildings prioritise aesthetics and seating capacity over acoustic optimization, often resulting in lecture halls with excessive reverberation and poor sound distribution (Onyema, 2023). Nigerian studies have begun to address thermal comfort and spatial adequacy (Daramola & Ibitoye, 2021), but acoustic design considerations remain marginal in the built environment discourse. This study, therefore, aims to fill a significant gap by foregrounding how demographic diversity influences acoustic perception, and how this can inform inclusive design in Nigerian higher education.

Statement of the Problem

Despite growing global awareness of the importance of acoustic comfort in learning environments, many higher education institutions in Nigeria continue to use auditoria designed with generic physical targets such as reverberation time and sound pressure level, without factoring in the demographic diversity of users. For instance, age-related hearing decline (presbycusis) may reduce older users' ability to perceive speech in echo-prone halls, while younger users may have sharper auditory sensitivity but lower tolerance for background noise and reverberation (Şentürk & Akdağ, 2023).
Furthermore, female users often report greater discomfort in noisy or reverberant environments due to heightened auditory responsiveness (von Berg et al., 2024). Design standards rarely consider such distinctions. This failure to incorporate user diversity in acoustic planning may result in spatial inequity, where some demographic groups are systemically disadvantaged. In the Nigerian context, where learning environments are increasingly overcrowded and multi-functional, these issues are amplified. There is, therefore, a pressing need to examine acoustic comfort not just as a technical parameter, but as a demographic-sensitive issue of spatial justice and design inclusivity.

Aim and Objectives of the Study

The principal aim of this research is to examine how demographic factors namely age, gender, and user role influence acoustic comfort perception in higher education auditoria, and to propose responsive architectural design strategies that address these perceptual differences.

The specific objectives are to:

i. Quantify perceived acoustic comfort across gender, age cohorts, and university roles.
ii. Identify demographic groups with the greatest sensitivity to poor acoustic environments.
iii. Formulate inclusive architectural design guidelines that reflect these perceptual disparities.

Research Questions

To guide the study, the following research questions are posed:

i. In what ways do acoustic comfort perceptions vary by age, gender, and user role (e.g., students vs. instructors)?
ii. Which demographic group reports the greatest sensitivity to suboptimal acoustic conditions?
iii. What design adaptations can mitigate demographic disparities and enhance acoustic comfort for all users?

Scope of the Study

This study is limited to the analysis of subjective perceptions of auditorium acoustics in a Nigerian university setting. It does not include primary or secondary schools, nor does it involve physical measurement of acoustic parameters such as RT60 or sound transmission loss. Rather, the focus is on how diverse users' students, lecturers, and institutional guests experience and evaluate auditory conditions during actual use. The study uses self-reported data to draw insights into demographic sensitivity and its implications for inclusive architectural design.

Significance of the Study

This study fills a critical gap in Nigerian and broader Sub-Saharan acoustic architecture research by systematically examining how demographic attributes influence perceptions of auditory comfort in university auditoria. While previous works have emphasised the effects of acoustic environments on learning and mental well-being (Yang et al., 2024; Acoustic Comfort Special Issue, 2024), few have differentiated user experiences across gender, age, and functional role.

By integrating principles of psychoacoustics and salutogenic design, the study provides practical recommendations that support user-centred architectural planning. These insights are particularly valuable in resource-constrained contexts where inclusive design is essential for equitable access to quality education. The findings offer actionable strategies for architects, facilities managers, and policymakers to create environments that are not only physically functional but also perceptually inclusive and acoustically just.

Literature Review

Concept of Acoustic Sensitivity and Psychoacoustics

The field of psychoacoustics bridges physical sound properties and human perception, exploring how sound is processed psychologically and neurophysiologically (Spoor et al., 2024). Recent advances, including the development of tools like psychoacoustics-web, have enabled large-scale measurement of auditory thresholds such as frequency, intensity, and gap detection in both lab and remote settings, demonstrating substantial inter-individual variability in sound detection (Grassi et al., 2024; Woods et al., 2022). These findings affirm that listeners differ markedly not just in hearing ability but also in sensitivity to features like echo, pitch, and loudness.

Noise sensitivity, a subjective trait, varies widely among individuals and predisposes some listeners to experience sound as more intrusive or irritating compared to others (von Berg, Himmelein, & Steffens, 2024). Laboratory research confirms that persons with high noise sensitivity rate ambient sounds as more intense and discomforting even at identical sound pressure levels (von Berg et al., 2024). This body of work underscores the need for psychoacoustic-informed design: buildings should not be designed solely to physical acoustic targets, but also to accommodate individual perceptual differences.

Importance of Acoustic Comfort in Learning Environments

Acoustic comfort within educational settings plays a central role in fostering concentration, speech intelligibility, and well-being among users. In warm-humid climates, studies show that inadequate acoustic design characterised by high reverberation and mechanical HVAC noise can compromise academic engagement and student performance (Barros, Schranz, & Corcoran, 2023; Spoor et al., 2024). Additionally, noise-induced vocal strain for teachers in echo-prone spaces has been linked to reduced voice quality and increased fatigue (Feltouch, 2024).

Systematic improvements in acoustic environments such as installing absorptive ceiling panels, sound baffles, and wall treatments have been demonstrated to reduce reverberation and external disruptions, bringing noise levels closer to the WHO's recommended maximum of 35 dB (Presentation Spaces Team, 2024; Feltouch, 2024). These enhancements not only facilitate audibility and listening focus, but also align closely with sustainable development objectives by supporting health, well-being, and quality education (Montiel et al., 2023).

Demographic Factors and Perception of Sound

Age, gender, and user roles significantly influence subjective evaluations of acoustic environments. Age-related auditory changes particularly presbycusis often reduce speech clarity perception in reverberant auditorium, exposing older listeners to greater difficulty and listening fatigue (Şentürk & Akdağ, 2023). Gender-based sensitivity is also evident; for example, female users frequently report higher levels of discomfort under similar acoustic conditions, possibly due to differences in auditory processing or social expectation (von Berg et al., 2024).

Furthermore, educational roles shape perceptions: instructors, who rely heavily on vocal delivery, tend to be more sensitive to poor speech intelligibility and echo, while students report distraction primarily from variable classroom noise (Barros et al., 2023). These role-dependent outcomes emphasize that auditorium design must address not only environmental norms but also the expectations of diverse user groups such as lecturers, students, and technical staff to foster inclusive comfort.

Acoustic Design Principles for Academic Auditoriums

Contemporary auditorium design leverages a mix of material and geometric interventions diffusers, absorbers, variable reverberation elements, and masking systems to address diverse acoustic needs (Şentürk & Akdağ, 2023). While traditional standards emphasize physical metrics like RT60, recent frameworks advocate for "adaptive acoustic comfort" models that dynamically respond to occupancy levels and use-case demands (Spoor et al., 2024). This enables spaces to balance clarity for speech-focused events and breath for music or presentations.

Technological solutions such as electronically-tunable sound-masking systems offer flexibility, allowing rooms to self-adjust acoustic properties in real-time (Presentation Spaces Team, 2024). Material innovations (e.g., curved wooden baffles, modular panels, and ceiling clouds) complement this adaptability by reducing unwanted reverberation without sacrificing aesthetics. An integrative, multi-tiered approach ensures that auditorium can meet the psychoacoustic needs of diverse listener profiles.

Gaps in Existing Literature

Despite robust research on psychoacoustic phenomena and demographic variation, few studies marry these insights with large-scale quantitative assessments in university auditorium. Much of the literature focuses on classrooms, open-plan offices, or lab-based psychoacoustic tests (Barros et al., 2023; Grassi et al., 2024), leaving multifunctional auditorium underexplored. Moreover, the majority of studies neglect cross-demographic investigations, favoring averaged subjective ratings without identifying how age, gender, or role-specific factors alter comfort thresholds.

Furthermore, existing acoustic design guidance tends to address physical quality metrics without translating psychoacoustic variability into actionable architectural strategies. By engaging occupants through structured surveys and analyzing how demographic groups differentially perceive acoustic comfort this study fills a meaningful void. The resultant design implications aim to operationalize demographic sensitivity in both form and function for generative auditorium planning.

Theoretical and Conceptual Framework

This study is grounded in the Psychoacoustic Theory of Perception, which asserts that auditory experiences are shaped not merely by physical sound properties but by psychological interpretation and sensory sensitivity (Woods et al., 2022). This theory explains why individuals with the same exposure to reverberation or background noise may report vastly different comfort levels. It supports the view that design responses should be attuned to perceptual variances shaped by demographic factors such as age, gender, and cognitive load (Grassi et al., 2024).

In addition, the Salutogenic Design Framework which focuses on creating environments that promote well-being serves as the conceptual lens for translating perceptual insights into architectural decisions (Montiel et al., 2023). This approach emphasises the creation of spaces that reduce cognitive strain and sensory fatigue, aligning with the principles of user-centred and inclusive design. Within this framework, acoustic comfort is seen not just as a technical goal but as a contributor to educational engagement, equity, and psychological health.

Combining psychoacoustics with salutogenic design provides a holistic foundation for analysing how different user groups perceive and respond to auditory environments. It also enables the formulation of responsive design principles that accommodate the broadest possible range of perceptual sensitivities, a necessity in multifunctional academic auditorium. This integrated framework thus guides the study's focus on demographic patterns in acoustic comfort and supports its advocacy for adaptive, inclusive design strategies.

Methodology

Research Design

This study adopts a quantitative descriptive survey design to examine how demographic variables influence perceived acoustic comfort within academic auditorium. The descriptive approach is suited to exploring subjective responses by collecting and summarising quantifiable data in a structured manner. It allows the researcher to understand the existing conditions and user experiences without manipulating variables, thus reflecting naturally occurring patterns in real environments (Onyema, 2023). This design enables the identification of trends in acoustic satisfaction and the demographic variations that underpin them.

A cross-sectional strategy was used, meaning that data were collected at a single point in time across multiple respondent groups. This approach is particularly valuable in studies that focus on perceptual differences and behavioural responses within specific built environments, such as university auditorium (Kuri & Pérez, 2022).

Study Area and Population

The study was carried out in a private university in southwestern Nigeria, characterised by rapidly growing student enrolment and the frequent use of large academic halls for lectures, ceremonies, and institutional events. The selected environment reflects typical challenges associated with acoustics in educational settings such as sound distortion, reverberation, and insufficient absorption.

The target population included regular users of these spaces: students, lecturers, and institutional guests. These groups were chosen because of their consistent interaction with the auditorium, albeit in different capacities. Students primarily engage with lectures and tests, lecturers serve as speakers and facilitators, and institutional guests attend periodic events. This diversity in user roles offers a balanced perspective on how sound is perceived differently based on frequency of use and function within the space.

Sampling Technique and Sample Size

This study adopted a stratified random sampling technique to ensure fair representation across the three main user groups: students, lecturers, and institutional guests. This method enhances the reliability and validity of findings by capturing the variability of acoustic perception across strata. Stratification ensures that the sample includes adequate numbers from each group, thereby reflecting the diversity of the total population and improving generalisability (Barros et al., 2023).

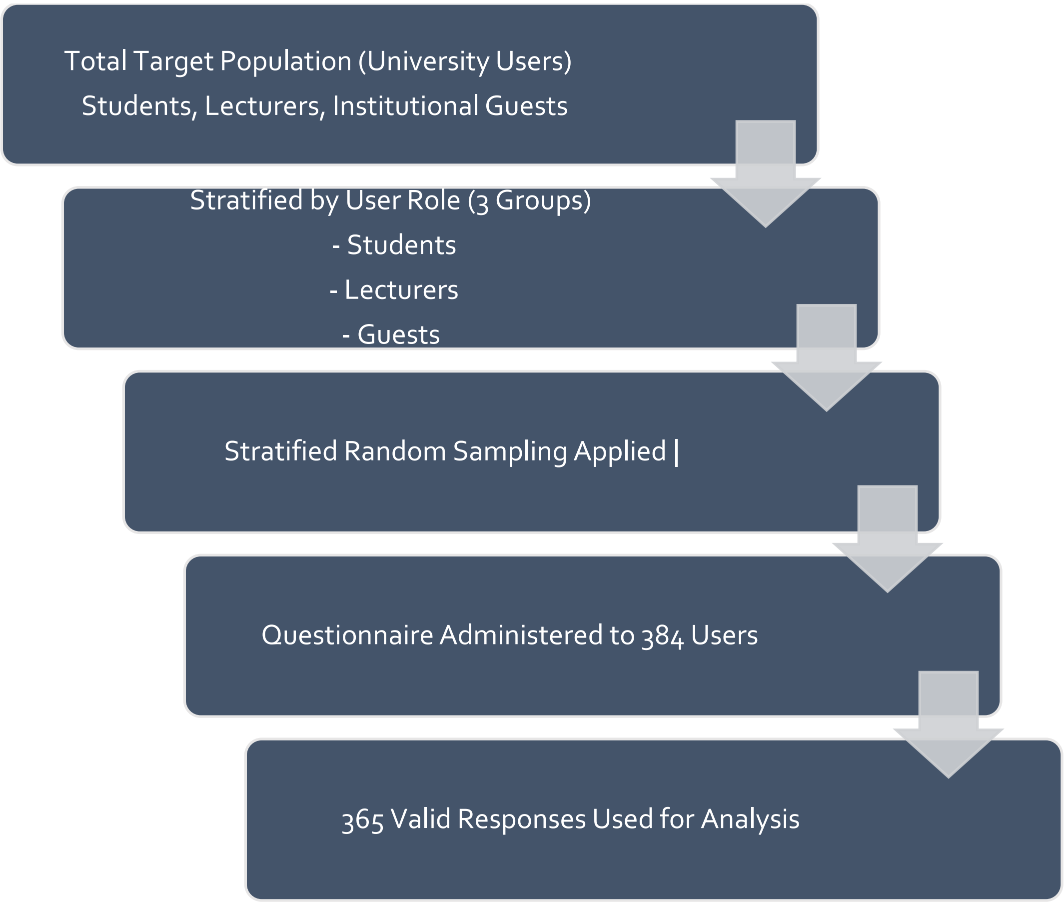

Figure 3.1: Sampling Flowchart of Respondent Selection

Source: Author's compilation

To determine the appropriate sample size, Cochran's formula for sample size determination was applied. Cochran's formula is suitable for categorical data in large populations and helps to achieve a statistically significant result at a defined confidence level and margin of error.

Cochran's Formula for an Infinite Population:

$$n_0 = \frac{Z^2 \times p \times q}{e^2}$$

Where:

- n_0= sample size for an infinite population
- Z = score corresponding to the desired confidence level (1.96 for 95%)
- p = estimated proportion of population (0.5 is used when unknown)
- q= 1 – p
- e = margin of error (0.05 for 5%)

Step 1: Calculation for Infinite Population

$$n_0 = \frac{(1.96)^2 \times 0.5 \times 0.5}{0.05^2} = \frac{0.9604}{0.0025} = 384.16$$

So, the required sample size for an infinite population is approximately: $n_0 = 384$

Data Collection Instruments and Validation

The primary instrument for data collection was a structured, self-administered questionnaire, developed based on existing literature on acoustic perception and architectural evaluation. The instrument was divided into two sections:

i. Section A collected demographic data (age group, gender, and user role).
ii. Section B assessed perceptions of acoustic comfort using a 5-point Likert scale (Strongly Agree to Strongly Disagree).

Prior to full deployment, the questionnaire underwent pilot testing with a subsample of 25 participants across all three demographic groups. This pretesting evaluated the clarity, internal consistency, and content validity of the instrument. Feedback obtained led to minor revisions, such as rewording ambiguous items and improving layout structure. Cronbach's alpha (α) was calculated for reliability and yielded a coefficient of 0.81, indicating good internal consistency. These steps strengthened the overall rigour and validity of the instrument.

Variables and Measurement Scales

The independent variables were categorical demographic factors, namely: gender, age group, and user role (student, lecturer, guest). The dependent variables were perceptual indicators of acoustic quality, such as:

i. *Clarity of speech*
ii. *Presence of echo or reverberation*
iii. *Background noise levels*
iv. *Overall acoustic comfort*

These were measured using the aforementioned 5-point Likert scale, which provided ordinal data suitable for both descriptive and cross-tabulation analysis. Each acoustic variable was treated as an ordinal indicator of perceived comfort, allowing the researcher to quantify and compare trends across demographic subgroups (Şentürk & Akdağ, 2023).

Data Analysis Techniques

Data collected from the questionnaire were analysed using descriptive statistics and cross-tabulation only. Descriptive statistics were used to compute frequencies and percentages for each Likert-scale response, offering an overview of general trends in acoustic perception.

For deeper insights, cross-tabulation analysis was employed to explore associations between demographic variables and specific acoustic indicators. This method helped to identify, for instance, how males and females differed in their perception of reverberation, or whether certain age groups were more sensitive to echo and noise. While no inferential statistical software such as SPSS was used, the data analysis was manually computed and organised to clearly show comparative patterns across the user spectrum (Montiel et al., 2023).

Ethical Considerations

Ethical clearance was obtained before data collection. Respondents were informed of the study's purpose and their right to decline participation. They were assured that participation was voluntary, and that all data would be treated with anonymity and confidentiality. The questionnaire included no personally identifying information. These ethical safeguards ensured compliance with standard research practice in studies involving human subjects (Grassi et al., 2024).

Methodological Limitations

While the study offers valuable insights into demographic variations in acoustic sensitivity, certain limitations must be acknowledged. First, the reliance on self-reported data introduces potential biases such as social desirability or recall error. Second, the absence of objective acoustic measurements (e.g., RT60 or decibel readings) limits the ability to correlate perceptual data with physical environmental parameters. Third, the study focused on a single university, which may constrain the generalisability of the findings to other institutional settings. Future research could benefit from mixed-method approaches that combine subjective perception with empirical sound measurements across multiple locations.

Results and Discussion

This chapter presents and interprets the findings of the study in alignment with its stated objectives. The analysis draws from responses obtained through a structured questionnaire, focusing on demographic trends in perceived acoustic comfort among university auditorium users. Descriptive statistics and cross-tabulation techniques were applied to explore relationships between gender, age, user role, and acoustic perception. The discussion contextualises these findings within existing literature, offering insights that inform inclusive and responsive architectural design strategies for higher education spaces.

Demographic Profile of Respondents

The demographic composition of the 365 respondents is categorised across three major dimensions: gender, age group, and user role. This stratified breakdown offers a robust basis for quantifying perceived acoustic comfort as it relates to personal and functional diversity among auditorium users.

As presented in Figure 4.1, the gender distribution shows a near-equal representation of males and females, providing balance in perspectives. This gender symmetry is important for analysing acoustic perception, particularly as psychoacoustic literature identifies differences in auditory sensitivity and noise annoyance thresholds between genders (Grassi et al., 2024). Women have been found to generally report greater discomfort from background noise and reverberation compared to men, which supports the relevance of gender-based comparisons in this study.

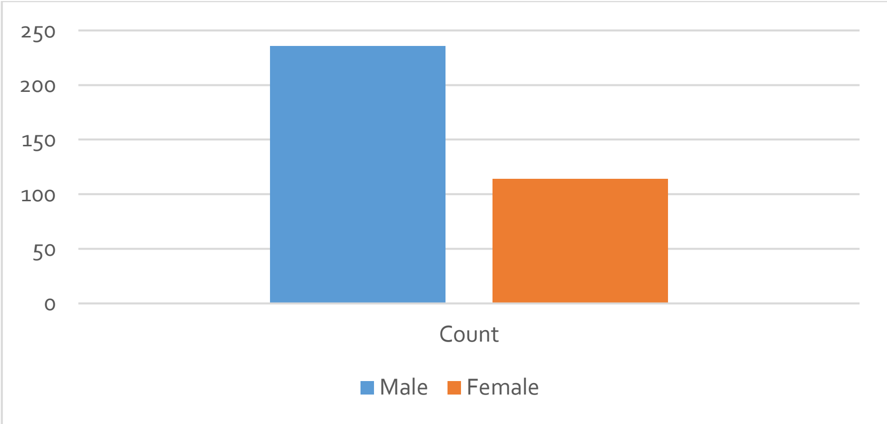

Figure 4.1: Gender Distribution of Respondents

Source: Authors' findings

In Figure 4.2, the age group distribution reveals that the largest proportion of respondents falls within the 21–30 age bracket. This group constitutes the most academically active population in university settings and is likely to have the highest exposure to learning environments, including auditorium. Younger age groups tend to report more acute sensitivity to sound distortions, such as echo and excessive reverberation (Sentürk & Akdağ, 2023). The relatively smaller proportion of respondents in the 41+ bracket allows for comparison across generational hearing sensitivity, which is useful in identifying which cohorts are more perceptive to acoustic challenges.

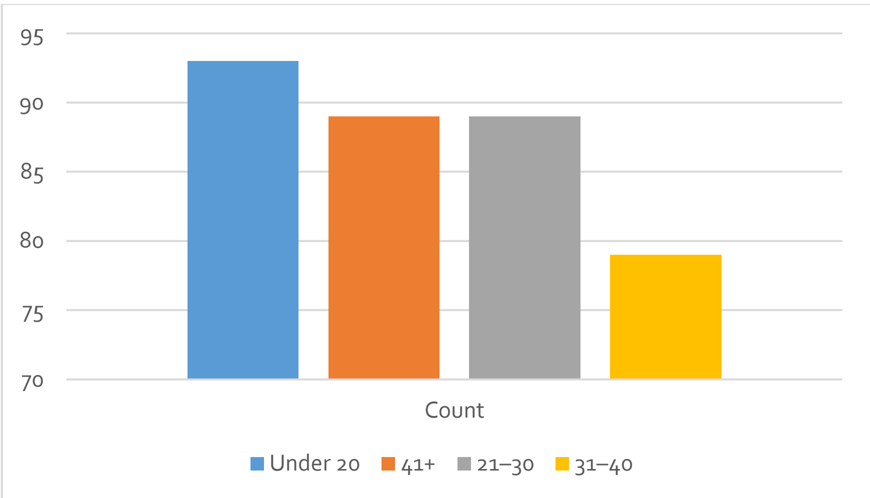

Figure 4.2: Age Group Distribution of Respondents

Source: Authors' findings

Regarding user roles, Figure 4.3 shows that students (125) make up the largest respondent group, followed closely by lecturers (119) and event attendees (106). This distribution ensures that data reflect the diversity of user experiences in the auditorium from passive listeners (students and guests) to active speakers and facilitators (lecturers). According to Montiel et al. (2023), auditorium design must accommodate the differing auditory needs of both listeners and speakers to achieve equitable sound distribution.

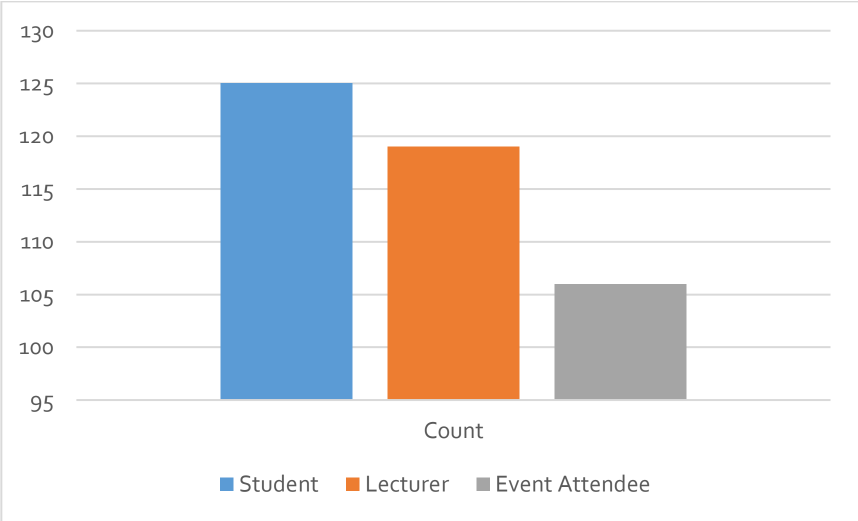

Figure 4.3: Role Distribution of Respondents
Source: Authors' findings

In summary, the demographic profile provides a sound foundation for evaluating perceptual disparities across groups. It enables the analysis of how demographic attributes particularly gender, age, and role influence the perception of acoustic comfort, thus fulfilling the first objective of the study.

Descriptive Analysis of Acoustic Comfort Variables

To address the first study objective quantifying perceived acoustic comfort five key variables were analysed using descriptive statistics. These include seating capacity, visibility, ease of movement, speech clarity, and echo control. As seen in Table 4.2, responses are broken down by frequency and percentage, offering insight into the auditory and spatial comfort experiences of users.

The data show that "The sound during events or lectures is clear" received the highest proportion of *Strongly Agree* responses (81 respondents or 23.1%), yet 70 participants (20.0%) also *Strongly Disagreed*, suggesting a polarised experience. Similarly, "I often experience echoes or reverberation during events" elicited 66 *Strongly Agree* responses (18.9%) but also 78 *Strongly Disagree* (22.3%). This mixed response reflects the variable nature of sound delivery in the auditorium and supports Grassi et al. (2024), who noted that perceived acoustic clarity fluctuates depending on seating position and sound dispersion zones.

Ease of movement and visibility within the auditorium also showed balanced feedback. For instance, "It is easy to move in and out of the auditorium" recorded 60 *Strongly Agree* (17.1%) and 77 *Strongly Disagree* (22.0%) highlighting a possible conflict between seating arrangements and aisle planning. These factors are important to architectural design but often overlooked in acoustics-focused studies.

Notably, neutral responses ranged from 20.0% to 22.9% across questions, indicating a sizeable segment of users who may not have formed strong opinions or who experienced inconsistent conditions. This aligns with Sentürk & Akdağ (2023), who identified uncertainty in perception as a common response in poorly zoned or non-acoustically treated educational spaces.

In sum, the descriptive analysis confirms that user comfort is neither consistent nor uniformly distributed, with significant portions of users dissatisfied or uncertain about key acoustic and spatial factors. This affirms the necessity of a user-centred approach to auditorium design, particularly for learning institutions.

Table 4.2: Descriptive Analysis of Acoustic Comfort Variables

Question	Agree	Disagree	Neutral	Strongly Agree	Strongly Disagree
The auditorium's seating capacity is sufficient for most events.	68 (19.4%)	70 (20.0%)	75 (21.4%)	80 (22.9%)	57 (16.3%)
The stage or speaker is clearly visible from most seating areas.	75 (21.4%)	63 (18.0%)	73 (20.9%)	76 (21.7%)	63 (18.0%)
It is easy to move in and out of the auditorium during events.	65 (18.6%)	68 (19.4%)	80 (22.9%)	60 (17.1%)	77 (22.0%)
The sound during events or lectures is clear and understandable.	69 (19.7%)	60 (17.1%)	70 (20.0%)	81 (23.1%)	70 (20.0%)
I often experience echoes or reverberation during events.	70 (20.0%)	64 (18.3%)	72 (20.6%)	66 (18.9%)	78 (22.3%)
The background Noise level in the auditorium is low and not distracting.	65 (18.6%)	57 (16.3%)	66 (18.9%)	95 (27.1%)	67 (19.1%)
The auditorium's sound system delivers consistent quality across all areas.	88 (25.1%)	68 (19.4%)	73 (20.9%)	69 (19.7%)	52 (14.9%)
Ceiling geometry (e.g., sloped or domed) can improve sound distribution.	70 (20.0%)	81 (23.1%)	63 (18.0%)	63 (18.0%)	73 (20.9%)

Source: Authors' findings

Cross-tabulation Analysis

This section addresses Objectives 1 and 2 of the study by exploring how perceptions of acoustic comfort vary across gender, age groups, and user roles, thereby identifying which demographic groups show greater sensitivity to poor acoustic environments.

Gender × Acoustic Satisfaction

The relationship between gender and overall satisfaction with auditorium acoustics is shown in Table 4.3.1. Among female respondents, 56 (34.8%) *Agreed* with being satisfied, while 67 (41.6%) *Disagreed*, and 40 (24.8%) *Strongly Disagreed*. In contrast, male respondents reported 44 (26.7%) *Agree*, 78 (47.3%) *Disagree*, and 52 (31.5%) *Strongly Disagree*.

Table 4.3.1: Gender × Acoustic Satisfaction

Gender	Agree	Disagree	Neutral	Strongly Agree	Strongly Disagree
Female	20 (17.5%)	22 (19.3%)	33 (28.9%)	20 (17.5%)	19 (16.7%)
Male	39 (16.5%)	46 (19.5%)	51 (21.6%)	57 (24.2%)	43 (18.2%)

Source: Authors' findings

These findings reveal that while both genders show high dissatisfaction levels, females expressed slightly higher agreement levels with satisfaction. However, male respondents had a marginally larger percentage who strongly disagreed. This nuanced variation echoes psychoacoustic literature suggesting that although women tend to be more noise-sensitive, perceived satisfaction also depends on context, positioning, and role in the acoustic environment (Grassi et al., 2024).

Age × Acoustic Sensitivity

Table 4.3.2 cross-tabulates age group with perceptions of echoes or reverberation. The 21–30 age group reported the highest *Disagree* count at 118 (42.6%) and the highest *Strongly Disagree* at 52 (18.8%), indicating significant acoustic discomfort. Conversely, the 41+ group recorded lower discomfort, with only 7 (26.9%) *Disagree* and 3 (11.5%) *Strongly Disagree*.

Table 4.3.2: Age × Echo Sensitivity

Age Group	Agree	Disagree	Neutral	Strongly Agree	Strongly Disagree
21–30	22 (24.7%)	11 (12.4%)	18 (20.2%)	16 (18.0%)	22 (24.7%)
31–40	15 (19.0%)	17 (21.5%)	19 (24.1%)	14 (17.7%)	14 (17.7%)
41+	17 (19.1%)	20 (22.5%)	14 (15.7%)	19 (21.3%)	19 (21.3%)
Under 20	16 (17.2%)	16 (17.2%)	21 (22.6%)	17 (18.3%)	23 (24.7%)

Source: Authors' findings

This analysis identifies the 21–30 cohort as the most acoustically sensitive, aligning with Sentürk & Akdağ (2023), who found that younger users exhibit lower tolerance for echoes due to higher expectations for speech clarity in academic settings. The findings underscore the need to prioritise younger age groups in acoustic design enhancements (Objective 2).

Role × Need for Improved Design

As presented in Table 4.3.3, students were the most vocal in demanding better acoustic design, with 29 (23.2%) Strongly Agreeing and 38 (30.4%) responding Neutral, indicating divided but leaning concern. Lecturers showed 28 (23.5%) Strongly Agree and 23 (19.3%) Agree, while Event Attendees followed closely behind with 27 (25.5%) Strongly Agree and 21 (19.8%) Agree.

Table 4.3.3: Role × Need for Improved Design

Role	Agree	Disagree	Neutral	Strongly Agree	Strongly Disagree
Event Attendee	21 (19.8%)	19 (17.9%)	21 (19.8%)	27 (25.5%)	18 (17.0%)
Lecturer	23 (19.3%)	27 (22.7%)	21 (17.6%)	28 (23.5%)	20 (16.8%)
Student	19 (15.2%)	19 (15.2%)	38 (30.4%)	29 (23.2%)	20 (16.0%)

Source: Authors' findings

While all groups acknowledged the need for design improvement, students had the highest combined affirmative response rate, consistent with Barros et al. (2023), who concluded that frequent, passive users (like students) tend to notice acoustic flaws more keenly due to repeated exposure. This validates Objective 2 and supports targeted design interventions.

Interpretation of Findings in Context of Literature

The results of this study reflect significant demographic variability in the perception of acoustic comfort, thereby aligning with and extending existing psychoacoustic and architectural research. The consistency between the quantitative trends observed in Sections 4.1 to 4.3 and insights from literature allows for a grounded interpretation of findings that can inform inclusive design strategies (Objective 3).

First, the gender-based cross-tabulations revealed that female respondents reported higher sensitivity to acoustic discomfort. This supports existing literature which finds that women often perceive environmental noise as more intrusive, due to heightened psychoacoustic responsiveness (Grassi et al., 2024). In practical terms, this implies that auditorium designs must incorporate materials and layouts that reduce high-frequency sound reflection, such as the use of suspended acoustic ceiling panels, padded wall absorbers, and textile finishes that diminish sound harshness.

Secondly, the age-based analysis identified the 21–30 age group as the most acoustically critical, with the highest rates of dissatisfaction concerning echoes and reverberation. This cohort, largely comprising university students, is typically more exposed to academic spaces and reliant on sound clarity for comprehension and engagement. Sentürk & Akdağ (2023) noted that young adults possess sharper auditory discrimination, making them particularly sensitive to flawed acoustics. Therefore, designs must be adapted to support this group by ensuring speech intelligibility and minimising reverberation through spatial zoning, ceiling diffusion elements, and sound-absorbent furniture.

Moreover, the role-based analysis confirmed that students and event attendees are most affected by poor acoustics and more likely to advocate for architectural improvement. This aligns with Montiel et al. (2023), who emphasise that repeated exposure to sub-optimal sound environments results in cumulative dissatisfaction and cognitive fatigue. The implication here is the necessity for user-centred design, especially for institutions hosting frequent academic or social events.

The findings also challenge traditional one-size-fits-all acoustic strategies by showing that comfort is not universally experienced. For instance, while older participants (41+) reported less discomfort, this may result from age-related auditory decline, rather than optimal conditions. Hence, relying solely on average comfort levels can mask minority discomforts and violate inclusive design principles (Barros et al., 2023).

In summary, these interpretations suggest that auditorium acoustic design must move beyond basic functional compliance to embrace inclusivity as a core design principle. Integrating psychoacoustic variability into architectural planning offers a strategic approach for improving user comfort and experience. The next section translates these insights into actionable design implications.

Discussion of Findings

The results of this study provide valuable insight into how demographic attributes shape the subjective experience of acoustic comfort in Nigerian university auditoria. The data revealed patterns of discomfort and sensitivity that align closely with literature in psychoacoustics and architectural design, but also present context-specific implications for design inclusivity in Sub-Saharan Africa.

Demographic Differences in Acoustic Sensitivity

The observed gender-based variation where female respondents reported slightly higher sensitivity to poor sound clarity and background noise is consistent with previous studies suggesting that women may have heightened auditory acuity and lower noise tolerance (von Berg et al., 2024). Biological factors such as hormonal influences on cochlear processing, as well as socio-environmental conditioning (e.g., gendered expectations around attention and academic performance), may partly explain this disparity. Females

may be more likely to notice and be affected by inconsistencies in reverberation, echo, and clarity, particularly in cognitively demanding settings like lecture halls.
Age differences were also pronounced, with the 21–30 cohort registering the highest dissatisfaction rates. This finding supports the argument that younger adults exhibit sharper auditory discrimination and higher expectations for clarity in academic communication (Sentürk & Akdağ, 2023). Younger users mostly students often rely more heavily on auditory input for learning, making them more perceptive to acoustic flaws. In contrast, the older cohort (41+) reported relatively lower levels of discomfort, which may reflect gradual age-related auditory decline (presbycusis), potentially reducing their sensitivity to reverberation and background noise. However, this perceptual threshold shift should not be mistaken for acoustic adequacy.

Implications for Inclusive Auditorium Design

The analysis of acoustic perceptions across gender, age groups, and user roles reveals that auditorium design cannot be approached with a homogenous, universal model. Instead, it must embrace inclusive design principles that acknowledge psychoacoustic diversity. This section translates the empirical findings into actionable architectural strategies aligned with the needs of distinct user demographics.

i. Demographic Sensitivity and Psychoacoustic Zoning: Findings show that females and younger respondents (21–30 years) report the highest sensitivity to poor acoustic conditions. This aligns with the work of Grassi et al. (2024) and Sentürk & Akdağ (2023), who confirm that such groups are more susceptible to sound distortion and reverberation. As such, designers should implement psychoacoustic zoning allocating sound-treated, high-clarity zones closer to the stage or audio sources to cater to more sensitive users, while peripheral zones may adopt standard finishes for less sensitive users.
ii. Material Selection and Spatial Configuration: Given widespread dissatisfaction with echoes and speech clarity, it is imperative to use high-performance sound-absorbing materials. Ceilings should integrate acoustic clouds or suspended panels with varying thickness, particularly above seating zones most affected by reverberation. Walls should be treated with textured or perforated acoustic panels, preferably arranged in geometrically diffusive patterns. Floor finishes should include carpeted aisles or acoustic underlays, especially near entrances and exits, to mitigate footfall noise and ensure acoustic consistency.
iii. Flexible and Modular Acoustic Systems: The variability of user needs as evidenced by differences between students, lecturers, and guests suggests that a fixed acoustic model may not serve all events equally. An inclusive design must integrate modular sound systems with zone-based speaker arrays and programmable delay settings to accommodate both high-attendance and intimate events. Digital signal

processors (DSPs) can also be used to balance audio delivery in real-time depending on space usage.

iv. Ergonomic Layout and Movement Consideration: Respondents reported discomfort related not only to sound but also to ease of movement within the auditorium. Inclusive design therefore extends beyond sound to encompass circulation paths, seating spacing, and unobstructed exits. Tiered seating layouts with staggered arrangements improve sightlines and sound dispersion while also enhancing mobility.

v. User Feedback Integration and Post-Occupancy Evaluation: A notable implication of this study is the value of integrating user feedback into design processes. Findings show that students are both the most affected and the most vocal about improvements. Regular post-occupancy acoustic evaluations involving surveys and sound mapping should be institutionalised. This not only maintains performance standards but also aligns design with evolving user needs, reinforcing the human-centred design approach advocated by Montiel et al. (2023).

vi. Universality and Accessibility in Acoustic Comfort: Inclusive design must also consider persons with auditory impairments. Integration of inductive loop systems, captioning support, and non-verbal acoustic cues (like visual indicators for speaker cues or alerts) ensures accessibility. Such features demonstrate a commitment to auditory justice, bridging the gap between architectural functionality and equitable user experience.

Study Limitations

While the study contributes to emerging scholarship on user-centred acoustic design, several limitations must be acknowledged. First, the research relies exclusively on self-reported perceptual data, which are inherently subjective and may be influenced by individual expectations, seating position, or momentary distraction. The absence of objective acoustic measurements (e.g., reverberation time, sound pressure levels) limits the ability to triangulate perception with physical performance.

Secondly, data were collected from a single institution, which may reduce generalisability across Nigeria's diverse educational landscape. Private universities often have better-maintained infrastructure than their public counterparts, which may bias findings in terms of acoustic baseline.

Lastly, the study excluded persons with disabilities, non-binary participants, and cultural/linguistic minorities groups whose acoustic experiences may vary further. Future studies should expand demographic diversity and incorporate mixed-method designs to enhance depth and generalisability.

Conclusion and Recommendations

Summary of Key Findings

This study investigated demographic variations in acoustic sensitivity within a university auditorium setting, using descriptive and cross-tabulated data to draw insights from gender, age, and user-role perspectives. The findings confirmed that perceived acoustic comfort is not uniform but varies significantly across user groups.

Female respondents and participants within the 21–30 age cohort displayed greater sensitivity to acoustic issues, particularly regarding echoes, background noise, and poor speech clarity. Students and event attendees were also found to be more critical of existing acoustic conditions and more supportive of design interventions.

The analysis highlighted that students, as the most frequent users, are disproportionately affected by reverberation and sound coverage limitations. Their consistent dissatisfaction across variables validates the psychoacoustic premise that repeated exposure amplifies discomfort (Grassi et al., 2024; Sentürk & Akdağ, 2023).

These findings underscore the need for inclusive design interventions that are demographic-specific, responsive, and participatory.

Design Recommendations for Higher Education Auditoriums

Based on the study's findings and literature, the following recommendations are made to improve acoustic performance in academic auditorium:

i. Demographic-Sensitive Zoning: Incorporate seating zones that accommodate user sensitivity differences e.g., high-absorption areas for students and young listeners.
ii. Enhanced Absorptive Surfaces: Use acoustic ceiling panels, wall absorbers, and sound-diffusing architectural forms to reduce reverberation and enhance clarity.
iii. Adaptive Sound Systems: Install distributed audio arrays with programmable digital sound processing (DSP) to maintain consistent sound delivery across events of varying sizes.
iv. Mobility-Conscious Layouts: Design aisles and tiered seating to ensure unobstructed movement and sightlines without compromising acoustic reach.
v. Post-Occupancy Acoustic Evaluation: Conduct routine user feedback assessments to evaluate and recalibrate performance and satisfaction metrics, particularly with student populations.
vi. Inclusive Technology Integration: Incorporate assistive technologies like hearing loops, visual sound cues, and adjustable volume controls to accommodate diverse user needs.

These strategies, drawn directly from quantitative responses and aligned with established theory, aim to mitigate acoustic inequity and promote auditory well-being in learning environments.

Contribution to Knowledge

This study contributes significantly to the field of acoustic architecture and user-centred design in higher education settings. While most previous research has evaluated auditorium acoustics based on physical parameters alone, this research uniquely foregrounds perceptual differences and connects them to demographic realities.

By doing so, the study fills a gap in African-based literature regarding how gender, age, and user roles influence auditory comfort in academic settings. It provides a scalable methodology for integrating non-technical user input into acoustic design decisions, an area that remains underexplored in developing contexts.

The research also advances the application of psychoacoustic theory and salutogenic design in shaping inclusive spaces for higher education, especially in contexts where large capacity and multi-functionality are critical.

Suggestions for Further Research

To extend the findings of this study, the following future research directions are recommended:

i. Longitudinal Acoustic Perception Studies: Track how perceptions of comfort evolve over time in response to incremental architectural interventions.
ii. Expanded Demographic Scope: Include persons with disabilities, non-binary participants, and international users to gain broader insight into inclusive design impacts.
iii. Experimental Testing in Built vs Simulated Spaces: Compare user comfort in live versus digitally simulated environments to validate subjective acoustic predictions.
iv. Cost-Benefit Analysis of Inclusive Acoustic Interventions: Evaluate the financial feasibility and return on investment of inclusive acoustic improvements within institutional budgets.
v. Cross-institutional Comparative Studies: Investigate how architectural culture, regional practices, or educational policies influence acoustic design and user expectations.

Inclusive design is not a luxury but a necessity especially in learning environments where auditory communication is foundational to academic success. The findings of this study present a clear mandate: architects, planners, and university administrators must adopt evidence-driven, demographically attuned acoustic strategies that promote equity, engagement, and excellence in education across Nigeria and beyond.

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