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Noise annoyance and loudness: Acoustic performance of healthcare buildings in Ibadan city, Nigeria

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ABSTRACT

The acoustic performance of healthcare buildings is frequently overlooked in tropical, low-resource settings, where natural ventilation couples interior soundscapes to intense urban noise. This study identifies the audible noises in two contrasting Ibadan facilities—a private (HC1) and a government (HC2) home—and determines the physical and psychological impacts of loudness and annoyance on frail residents living with dementia. A-weighted sound pressure levels were measured across six interior spaces at three daily intervals in two seasons, and triangulated with a survey of 135 caregivers and a one-year incident review. Levels reached 53.03 dB(A) in HC1 and 67.40 dB(A) in HC2, exceeding the WHO 35 dB(A) guideline throughout. Perceived loudness and annoyance were strongly inter-correlated and associated with agitation, anxiety, wandering, and disturbed sleep; human-related factors outweighed housing-related factors. Traffic, generators, amplified religious broadcasts, and staff conversation were the most undesired sources. The findings support embedding acoustic criteria in tropical healthcare design and policy.

1. Introduction

Sound is an inescapable feature of the built environment, and the way it is managed inside a building is a defining component of indoor environmental quality (IEQ). Alongside thermal comfort [1], indoor air quality, and daylighting, the acoustic environment shapes how comfortable, safe, and restorative an interior space feels [2, 3]. In residential buildings, the acoustic environment is largely a matter of comfort and annoyance; in healthcare buildings it becomes a clinical variable. Excess noise in wards and care settings has been linked to fragmented sleep, elevated stress hormones, longer recovery times, higher rates of delirium, and reduced staff performance [4, 5, 6]. Florence Nightingale's much-quoted observation that unnecessary noise is a cruel absence of care remains, more than a century and a half later, an unmet design objective in most hospitals worldwide [7].

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The seminal residential study by Wang et al. [8] demonstrated that the acoustic performance of buildings in the tropics is routinely neglected by designers, developers, and even occupants, and that traffic and neighbour noise are the most undesired sources in Malaysian dwellings. That study established a replicable framework in which a defined catalogue of audible noises is rated for both loudness (a perceptual, largely physical judgment of magnitude) and annoyance (an affective judgment of disturbance), and in which human-related factors such as job stress and noise sensitivity are modelled alongside housing-related factors. The present study applies and extends that framework to a setting where the stakes are considerably higher: healthcare buildings that house older adults living with frailty and dementia in Ibadan, Nigeria. The relevance of that population is growing sharply—dementia prevalence in sub-Saharan Africa is rising rapidly against a backdrop of minimal specialist infrastructure and predominantly family-based care [9, 10]—so the environments in which affected older adults are cared for are a matter of escalating public-health consequence.

The distinction between loudness and annoyance is central to this work. Two spaces may register identical A-weighted sound pressure levels yet be experienced very differently depending on the source, its meaning, its predictability, and the listener's state [11, 12]. A monotonous 70–80 dB(A) may be tolerable on a moving train, whereas the ticking of a clock at 20 dB(A) can be intolerable in a quiet room [13]. For people living with dementia, whose capacity to interpret, filter, and contextualise sound is compromised, this gap between measured level and perceived disturbance widens further, and unwanted sound frequently manifests as agitation, aggression, wandering, or withdrawal [14, 15].

Nigeria provides a particularly instructive and under-studied context. Ambient noise in its cities substantially exceeds World Health Organization (WHO) limits, driven by dense mixed land use, heavy road traffic, amplified religious broadcasts, commercial activity, and the near-universal reliance on private electricity generators [16, 17, 18, 19]. Within this soundscape, healthcare facilities are seldom acoustically isolated. Ana et al. [16] measured noise levels of 55–77 dB(A) in Ibadan hospital wards and up to 89 dB(A) in operating rooms, well above levels known to interfere with sleep, and identified staff conversation as a major contributor in patient-care areas. Yet acoustic research in Nigerian healthcare remains sparse, and virtually none of it addresses the specific vulnerability of frail, cognitively impaired residents in a tropical climate where windows are opened for ventilation and the external soundscape penetrates the interior.

Recent systematic reviews of IEQ in healthcare confirm both the importance of the acoustic dimension and the geographic imbalance of the evidence base. Ackley et al. [2] and the wider literature consistently find that favourable IEQ shortens hospital stays, reduces patient stress, and improves staff effectiveness, while noting that the overwhelming majority of studies originate in high-income, temperate settings and that tropical, low-resource contexts are markedly under-represented [20, 21]. This study addresses that gap directly.

1.1 Aim and objectives

The aim of this study is to identify the audible noises present in Nigerian healthcare buildings and to determine the physical and psychological impacts of noise loudness and annoyance on occupants across contrasting facility types in a tropical city. The specific objectives are:

(a) to catalogue and categorise the internal and external noise sources audible within two contrasting healthcare facilities;

(b) to measure A-weighted sound pressure levels across interior space types, times of day, and seasons, and benchmark them against WHO and ASHRAE/NC–RC criteria;

(c) to assess occupants' perceptions of loudness and annoyance for each noise type and to model the human- and housing-related factors that shape those perceptions; and

(d) to relate perceived loudness and annoyance to behavioural and clinical outcomes—agitation, anxiety, wandering, falls, and disturbed sleep—among frail and cognitively impaired residents.

1.2 Contribution and research gap

Across four decades of hospital-acoustics research, the evidence base remains overwhelmingly concentrated in high-income, temperate, mechanically ventilated settings; quantitative acoustic assessments of healthcare interiors in sub-Saharan Africa are almost entirely absent, and studies that connect measured sound to the behaviour of frail, cognitively impaired occupants in the tropics are, to our knowledge, non-existent. This study occupies that gap and makes three contributions. First, it provides one of the very few quantitative acoustic characterisations of healthcare interiors in sub-Saharan Africa, extending the residential loudness–annoyance framework of Wang et al. [8] from the domestic setting into the clinical domain, where the affective response to sound carries measurable health consequences. Second, rather than treating objective and subjective data in isolation—a separation that recent reviews identify as a persistent weakness [2]—it integrates calibrated sound-level measurement, occupant loudness and annoyance ratings, and independently recorded behavioural incidents on the same spaces and times, so that the perceptual and clinical consequences of the acoustic environment can be examined together. Third, by comparing a private and a government facility under identical climatic and external-soundscape conditions, it isolates the contribution of building form, servicing, and management to acoustic performance, converting the finding into transferable design and policy guidance for tropical, resource-constrained care settings where such evidence is currently almost wholly lacking.

2. Acoustic performance, loudness, and annoyance in healthcare environments

2.1 From measured level to perceived disturbance

Acoustics concerns how sound is produced, transmitted, and perceived, and acoustic comfort is achieved when a space is sufficiently free of unwanted sound to allow occupants to rest, converse, and be cared for without distraction [22, 11]. Three problems dominate the literature: annoyance, in which noticeable sound disrupts concentration and rest; masking, in which one sound obscures another and impairs speech intelligibility; and, at high exposures, hearing damage. In healthcare, the first two are the more pervasive. A-weighted sound pressure level, dB(A), remains the standard descriptor because it approximates the frequency sensitivity of human hearing, but a growing body of work argues that level alone is a weak predictor of disturbance and that source identity, meaning, predictability, and controllability matter as much as magnitude [23, 12].

This is precisely the loudness–annoyance distinction operationalised by Wang et al. [8]. Loudness is the perceptual correlate of intensity; annoyance is the affective response to an unwanted sound. Their structural analysis of Malaysian dwellings showed that the two constructs, while correlated, are separately predicted: traffic and neighbour noise drove annoyance most strongly, and personal factors—job stress and noise sensitivity—were significant predictors across many noise types, whereas some animal sounds registered as loud but caused little irritation. The present study adopts this separation not as a matter of convention but because it maps directly onto the clinical reality of dementia care, where the affective and behavioural response to sound, rather than its physical magnitude, is the outcome of interest.

2.2 Noise as a clinical variable in healthcare buildings

The evidence that hospital and care-facility noise harms occupants is now substantial and, importantly, convergent. The WHO recommends that average sound levels in patient areas not exceed 35 dB(A), with a night-time maximum near 40 dB(A) [24, 25]. Reviews spanning four decades show that real facilities almost never meet this target: measured ward levels commonly range from 45 to 68 dB(A) by day, with peaks above 80 dB(A) in intensive care, and night-time levels 25–40 dB above guideline [7, 26]. Rather than treat these figures as isolated data points, it is more useful to note what they collectively imply: exceedance is the norm, not the exception, and the problem has worsened over time as buildings have become more mechanised and alarm-dense. Elevated levels are correlated with increased analgesic demand, delirium, disturbed sleep, and elevated cortisol in both patients and staff [4, 6]. Crucially, staff-generated sound—speech, footsteps, equipment handling—is repeatedly identified as a dominant and, in principle, controllable contributor, a finding reported for Ibadan hospitals more than a decade before the current wave of international interest [16].

These physiological effects are the mechanism through which Ulrich's [27, 6] theory of supportive design operates. Ulrich argued that the physical environment reduces stress when it provides perceived control, social support, and positive distraction; uncontrolled noise negates all three, removing the occupant's sense of control and masking the social and restorative cues a supportive environment should provide. Evidence-based design [28] subsequently formalised acoustic control as a core determinant of health outcomes. The theoretical lineage from Ulrich through contemporary IEQ reviews is therefore not merely historical citation but the conceptual spine of this study: noise matters clinically because it dismantles the supportive qualities of the care environment.

2.3 Noise, annoyance, and the person living with dementia

For older adults living with frailty and dementia, the acoustic environment is not a background comfort factor but a driver of the behavioural and psychological symptoms of dementia (BPSD). Because the capacity to interpret sound and connect it to its source is impaired, unfamiliar or unpredictable noise is readily experienced as threatening, producing agitation, aberrant vocalisation, resistance to care, and wandering [29, 15]. The most recent and methodologically strongest evidence comes from soundscape research: Kosters et al. [30], in a cluster-randomised design using the Mobile Soundscape Appraisal and Recording Technology Plus (MoSART+) awareness intervention, showed that raising staff awareness of the auditory environment reduced neuropsychiatric symptoms, while Talebzadeh et al. [14], in a pilot randomised controlled trial, demonstrated that augmenting the soundscape with tranquil natural sounds reduced motor agitation and aggression. Consistent with this, holistic environmental-design interventions that treat acoustics as one lever among several have been associated with reduced agitation in dementia care [31]. The direction of this literature is important for the present study: taken together, these studies establish that the acoustic environment is a modifiable, non-pharmacological lever on behaviour, and they reframe intervention from simple noise reduction toward soundscape management. Reported noise levels in dementia living and dining spaces of 54–67 dB(A) [15] fall squarely within the range measured in the present Ibadan facilities, allowing direct comparison.

What this body of work does not yet address is the tropical, low-resource setting. The soundscape trials cited above were conducted in well-serviced European and North American nursing homes with mechanical ventilation and closed, insulated envelopes. In Ibadan, windows are opened for cooling for much of the year, so the interior soundscape is continuous with a uniquely intense urban exterior, and the mitigation strategies validated elsewhere—sealed envelopes, absorptive finishes, alarm management—are only partially transferable. This is the specific gap the present study occupies.

2.4 The Nigerian and tropical soundscape

Ambient noise in Nigerian cities is well documented and consistently exceeds regulatory limits. Oloruntoba et al. [17] mapped Ibadan's noise surface and attributed high levels to traffic, commercial activity, and the geographic intermixing of incompatible land uses, so that hospitals and schools are frequently sited within high-noise zones in contravention of basic zoning principles. Oyedepo [18] and Osisanya et al. [19] confirmed city-wide exceedances, and characteristic tropical-urban sources—amplified religious broadcasts from churches and mosques, high-amplitude music from record shops, private generators, and grinding machines—recur across the Nigerian literature [32, 33]. Enforcement is weak: although several states have enacted noise-control legislation and some local governments maintain bylaws, there is no coherent federal noise-abatement statute, and personnel shortages undermine what regulation exists [17]. For a healthcare facility, this means the external acoustic load is both severe and effectively unregulated, placing the entire burden of acoustic performance on building design and internal management—the variables this study measures.

3. Methodology

3.1 Study context and design

The study was conducted in Ibadan, the capital of Oyo State and one of the largest cities in West Africa, which lies within a tropical savannah (Aw) climate. In the Köppen–Geiger classification the letter "A" denotes a tropical climate and "w" a dry winter, with precipitation concentrated during the summer months [34, 35]. Ibadan's Aw climate is characterised by a wet season (roughly March–October) and a dry season (November–February), with mean monthly temperatures of approximately 26–30 °C and relative humidity frequently between 50% and 70%. These conditions promote open-window ventilation for much of the year [36], coupling interior soundscapes to the external urban environment. A convergent mixed-methods design was adopted, in which quantitative acoustic measurements and questionnaire data and qualitative incident-report and interview data were collected in parallel and integrated during interpretation [37]. The acoustic dataset reported here forms part of a wider doctoral investigation of indoor environmental quality in tropical dementia-care settings [38], from which the sound-level measurements, facility characterisation, perceptual survey, and behavioural-incident data are drawn.

Institutional elder care remains uncommon in Nigeria, where family-based care predominates and residential facilities of the kind studied here are relatively rare [39]. Two contrasting facilities were purposively selected to represent the principal institutional care models available to older adults in the study area:

HC1 — Private facility: Omisina Memorial Aged People (OMAP) Foundation, a privately operated residential care home. HC1 represents a smaller, better-resourced, purpose-adapted setting.

HC2 — Government facility: Sir Kessington Adebutu Geriatric Rehabilitation Centre, a government-run rehabilitation facility. HC2 represents a larger, publicly funded, higher-occupancy setting.

In both facilities, six interior space categories were assessed: bedrooms (n = 3 per facility), bathroom and toilet, corridor, dining area, and living room/lounge. Garden and outdoor spaces were measured for context but excluded from the analysis of interior acoustic performance. A total of 135 participants—carers, family members, nurses, and social workers—took part in the perceptual survey. In accordance with ethical approval from the relevant institutional review boards, individuals living with dementia were not enrolled as direct respondents; their experience was captured through caregiver report and independently recorded clinical incidents, consistent with established practice in dementia environmental research [29].

3.2 Acoustic measurement procedures

A-weighted sound pressure level, dB(A), was measured with a calibrated hand-held integrating sound level meter (V·RESOURCING, 30–130 dB range, with max/min/hold functions). The measurement protocol followed established field-acoustics practice [40]:

i. the meter was positioned at 0.8–1.4 m above floor level and at least 3 m from major reflective surfaces such as walls;

ii. the instrument was calibrated before each measurement session;

iii. measurements were taken in triplicate at three daily intervals—morning (09:00–11:00), afternoon (14:00–16:00), and evening (18:00–20:00)—to capture the diurnal activity cycle;

iv. each measurement period lasted 15–30 minutes per space, and the triplicate values were averaged;

v. measurements were conducted only on days without precipitation and with minimal wind; and

vi. sampling was repeated in June (wet season) and August to capture seasonal variation, with an accepted tolerance of up to 6 dB regarded as negligible for field evaluation.

Measured levels were benchmarked against two reference frameworks: the WHO guideline of 35 dB(A) average for patient areas [24, 25], and the ASHRAE Noise Criteria/Room Criteria (NC/RC) convention, under which levels below NC/RC 35 do not compromise speech intelligibility while levels at or above this threshold may mask or interfere with speech [41].

3.3 Perceptual survey: loudness and annoyance

Occupant perceptions were assessed through a structured questionnaire administered to the 135 respondents by trained research assistants. The instrument comprised 45 items on a five-point Likert scale and captured three domains: personal data; behavioural and psychological functioning of the resident (dependent variables), assessed with reference to the Neuropsychiatric Inventory–Nursing Home version (NPI-NH) and the Clinical Frailty Scale (CFS); and indoor built-environment (IBE) factors (independent variables), including noise. For each identified noise source, respondents rated both perceived loudness and annoyance, mirroring the dual-rating structure of Wang et al. [8]. Human-related moderators—job stress, individual noise sensitivity, professional role, and whether the respondent was distracted at the time of exposure—were recorded alongside housing-related descriptors of the facility. Internal consistency of the multi-item scales was assessed using Cronbach's alpha.

3.4 Behavioural incidents and analysis

Clinical incident reports documenting agitation, anxiety, wandering, and falls were reviewed over a twelve-month period and coded by location and time, allowing behavioural events to be spatially and temporally aligned with the acoustic measurements. Statistical analysis was performed in SPSS. Spearman's rank correlation (ρ) was used to examine the direction and strength of associations between IBE factors (including noise, denoted by F6) and quality-of-life outcomes, and multiple regression models were developed to predict each behavioural domain, with model adequacy checked using R^2, significance testing at $p < 0.05$, and the Durbin–Watson statistic for autocorrelation. The general regression form was $y = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_m x_m + \varepsilon$, where y is the behavioural outcome and the x terms are environmental predictors. Qualitative incident and interview data were analysed thematically, with recurring constructs such as noise-induced agitation identified inductively and used to interpret the quantitative associations.

Figure 1. Conceptual model linking noise sources, perceived loudness, and noise annoyance to behavioural and clinical outcomes. Indicative path coefficients are shown for illustration; solid arrows denote hypothesised positive associations and the dotted arrow denotes the masking pathway from loudness to speech intelligibility.

4. Results

4.1 Catalogue of audible noise sources

Fieldwork and caregiver report identified a consistent set of audible noise sources across both facilities, spanning external and internal origins. External sources were dominated by road traffic (buses, cars, and motorcycles), amplified religious broadcasts from nearby churches and mosques, commercial and market activity, and—pervasively—private electricity generators operating during frequent grid outages. Internal sources comprised staff conversation and footsteps, the handling of trolleys and equipment, alarms and telephones, doors, sanitary fixtures, and resident-generated sounds. Consistent with both the Nigerian ambient-noise literature [17, 18] and international ward studies [16, 7], traffic and generator noise were the most undesired external sources, while staff conversation was the most significant controllable internal source.

4.2 Measured sound levels

Tables 1 and 2 present the measured A-weighted sound levels by space, time of day, and season for HC1 and HC2 respectively (data from [38]). Column codes denote the measurement occasion: SL.M.J and SL.M.A are morning (June and August); SL.A.J and SL.A.A are afternoon; and SL.E.J and SL.E.A are evening.

Table 1. Field measurement of sound level, dB(A) — HC1 (Private)

Space location	SL.M.J	SL.M.A	SL.A.J	SL.A.A	SL.E.J	SL.E.A	Peak
Bedrooms (mean of 3)	47.60	50.18	39.65	42.98	39.28	40.90	50.18
Bathroom & toilet	41.35	40.83	40.55	38.83	33.68	35.98	41.35
Corridor	43.68	53.03	46.60	41.83	38.60	39.40	53.03
Dining area	50.10	47.15	43.75	44.98	37.83	40.83	50.10
Living room / lounge	45.83	44.13	41.20	40.98	40.15	38.98	45.83

Note. Values ≥ 50 dB(A) are shown in bold amber. All interior values exceed the WHO 35 dB(A) guideline. Peak = highest value across all occasions.

Table 2. Field measurement of sound level, dB(A) — HC2 (Government)

Space location	SL.M.J	SL.M.A	SL.A.J	SL.A.A	SL.E.J	SL.E.A	Peak
Bedrooms (mean of 3)	58.90	52.83	47.65	49.83	44.60	46.83	58.90
Bathroom & toilet	51.60	49.13	45.98	43.98	41.35	42.83	51.60
Corridor	67.40	58.35	54.60	52.83	48.60	50.83	67.40
Dining area	55.83	53.98	50.83	48.98	45.83	47.15	55.83
Living room / lounge	61.90	56.13	52.98	51.83	47.98	49.15	61.90

Note. Values ≥ 50 dB(A) are shown in bold amber. Every interior space and time interval exceeds the WHO 35 dB(A) guideline; the corridor morning value of 67.40 dB(A) is the highest recorded interior level.

In HC1, the three loudest interior locations were the corridor (peak 53.03 dB(A), August), bedrooms (peak 50.18 dB(A), June), and the dining area (peak 50.10 dB(A), June). While these levels exceed the WHO 35 dB(A) average guideline, most fell within a moderate band, and several afternoon and evening readings approached the NC/RC 35 speech-intelligibility threshold rather than grossly exceeding it (Figure 2). In HC2, by contrast, every interior space exceeded 35 dB(A) at every measured time, with the corridor reaching 67.40 dB(A), the living room/lounge 61.90 dB(A), and bedrooms 58.90 dB(A) at their morning peaks (Figure 3). The corridor peak of 67.40 dB(A) is comparable to a running vacuum cleaner and sits at the upper end of the 54–67 dB(A) range reported for dementia living and dining spaces internationally [15].

Figure 2. Measured sound levels, dB(A), by interior space and measurement occasion, HC1 (Private). The dashed line marks the WHO / NC–RC 35 dB(A) reference.

Figure 3. Measured sound levels, dB(A), by interior space and measurement occasion, HC2 (Government). Levels exceed the reference across all spaces and times.

A clear diurnal pattern was evident in both facilities: morning levels were highest, coinciding with peak activity, care routines, and traffic, and declined through the afternoon and evening. A seasonal effect was also observed, with wet-season (June) mornings generally louder than dry-season readings, consistent with heavier open-window ventilation and rainfall-related activity. The facility-type contrast, however, was the dominant effect. Figure 4 compares peak levels space-by-space: HC2 exceeded HC1 in every category, by margins of 8–14 dB(A), indicating that facility form, higher occupancy, harder and more reverberant surfaces, and less controlled circulation in the government setting translated directly into a materially worse acoustic environment.

Figure 4. Peak measured sound levels by interior space, HC1 versus HC2. The government facility (HC2) exceeds the private facility (HC1) in every space category.

4.3 Perceived loudness and noise annoyance

Consistent with the residential findings of Wang et al. [8], perceived loudness and noise annoyance were strongly inter-correlated across respondents but retained distinct predictor structures. Traffic and generator noise were rated both loudest and most annoying, followed by amplified religious broadcasts and staff conversation. Certain sounds diverged from the general pattern: resident-generated and some domestic sounds were rated moderately loud yet comparatively low in annoyance, whereas sudden or meaningful sounds—alarms, raised voices, door slams—were rated disproportionately annoying relative to their measured level, reflecting the affective rather than purely physical basis of annoyance.

Human-related factors were more strongly associated than housing-related factors with both loudness and annoyance perceptions. Respondents reporting higher job stress and greater individual noise sensitivity rated identical environments as both louder and more annoying, and annoyance was heightened when respondents were engaged in concentration-dependent care tasks. This parallels the Malaysian finding that job stress and sensitivity correlate with many noise types, and it has a direct operational implication: staff wellbeing and the acoustic environment are mutually reinforcing, so interventions that reduce staff stress may also reduce reported annoyance, and vice versa.

4.4 Association with behavioural and clinical outcomes

Spearman correlations between the noise factor (F6) and quality-of-life outcomes were location-dependent, underscoring that where noise occurs matters as much as how loud it is. Noise in the communal living/lounge space was positively associated with psychological-health disturbance ($\rho = .29$, $p < .05$), while noise in circulation and outdoor-adjacent zones correlated with physical-health and mobility outcomes. Table 3 summarises the direction of key associations. In the multiple regression models, the noise term contributed to the prediction of agitation, anxiety, and wandering, entering as a significant predictor in several models (for example, unstandardised $\beta \approx 0.66$, $p < .01$ in the physical-health model and $\beta \approx -0.27$, $p < .01$ in the psychological-health model, the sign reflecting the coding direction of the affected item), although its independent contribution to falls was not statistically significant once distance and lighting were accounted for. The overall regression models were statistically significant ($p < .05$), indicating that the indoor environment, of which noise is one component, meaningfully predicts measured levels of agitation, wandering, and anxiety [38].

Table 3. Direction of association between location-specific noise (F6) and resident outcomes (HC1)

Noise location (F6)	Outcome domain	ρ	Direction
Living room / lounge	Psychological health	+.29*	Positive
Dining area	Psychological health	−.27*	Negative
Garden / outdoor-adjacent	Physical health	+.25*	Positive
Bedroom	Physical health	+.21	Positive (ns)
Corridor	Independence / mobility	+.05	Weak (ns)

Note. * $p < .05$; ns = not significant. Spearman's ρ. Signs reflect the coding direction of the underlying NPI-NH / CFS items.

Triangulation with the incident reports reinforced these associations. Agitation and wandering episodes clustered in the morning hours and in the communal and corridor spaces where measured levels and caregiver-rated annoyance were highest, and thematic coding of interviews independently surfaced noise-induced agitation as a recurring construct. The convergence of objective measurement, subjective annoyance, and independently recorded behaviour on the same spaces and times strengthens the inference that the acoustic environment is implicated in these outcomes rather than merely coincident with them.

5. Discussion

This study set out to identify the audible noises in Nigerian healthcare buildings and to determine the impacts of loudness and annoyance on occupants. Three findings warrant emphasis. First, both facilities exceeded the WHO 35 dB(A) guideline, but they did so to very different degrees, and the facility-type gap was the dominant effect. The government facility (HC2) breached the guideline in every space at every time, peaking at 67.40 dB(A), whereas the private facility (HC1) exceeded it more modestly. Because both were measured under identical climatic conditions in the same city, the difference is attributable to building form, occupancy density, surface finishes, servicing, and management rather than to climate or external soundscape. This isolates a practical, actionable lever: acoustic performance in tropical care settings is substantially a design and management outcome, not an inevitability of the environment.

Second, the loudness–annoyance framework transferred cleanly from the residential context of Wang et al. [8] to the clinical setting, but with heightened stakes. As in Malaysia, the two constructs were correlated yet separately predicted, human-related factors outweighed housing-related factors, and traffic was the most undesired source. Unlike the residential case, however, annoyance here was coupled to clinical outcomes—agitation, anxiety, wandering, and disturbed sleep—in a population uniquely vulnerable to it. The finding that annoyance tracked source meaning and predictability more than raw level supports the contemporary reframing of the problem from noise reduction toward soundscape management [23, 14], and it explains why speech and alarms, though not always the loudest sources, were among the most disruptive.

Third, the results locate this work within, and extend, the current IEQ evidence base. Recent systematic reviews conclude that IEQ substantially influences patient recovery, staff performance, and healthcare outcomes, while repeatedly noting the scarcity of studies from tropical regions [2, 21]. By quantifying the acoustic environment of two contrasting tropical facilities and linking it to behaviour in frail, cognitively impaired residents, this study supplies precisely the kind of evidence those reviews identify as missing. The measured 54–67 dB(A) range in communal and circulation spaces aligns with international dementia-care findings [15], suggesting that the behavioural mechanisms established in temperate settings are likely to operate in the tropics—but that the mitigation pathway differs, because open-window ventilation and unregulated external noise constrain the sealed-envelope solutions validated elsewhere.

5.1 Interpretation through supportive-design theory

The pattern of results is coherent with Ulrich's [27, 6] theory of supportive design and its evidence-based-design successors. Uncontrolled corridor and communal noise removes residents' sense of acoustic control, masks the social and restorative cues a care environment should provide, and substitutes negative stimulation for positive distraction—the three mechanisms Ulrich identified as pathways to stress. The clustering of agitation and wandering in the loudest, least controllable spaces is what this theory would predict. Reading the Ibadan data through this lens reframes acoustic underperformance not as a comfort deficiency but as a failure of the environment to support the occupant, with measurable behavioural consequences.

5.2 Practical and policy implications

The findings translate into concrete, climate-appropriate recommendations. At the building scale, siting and zoning matter most: care facilities should be located away from high-noise corridors, and where this is not possible, the acoustic burden falls on the envelope. Passive, low-energy measures suited to a naturally ventilated tropical building—acoustically absorptive ceilings and wall finishes in corridors and communal areas, sound-attenuating but airflow-permitting window and vent detailing, dense planting and boundary treatment to attenuate external sources, and the separation of noisy service zones from resting spaces—are more sustainable and transferable than reliance on sealed, mechanically ventilated envelopes. At the management scale, staff conversation and equipment handling, identified here and by Ana et al. [16] as dominant controllable sources, can be addressed through awareness interventions of the kind validated by Kosters et al. [30] and soundscape strategies shown to reduce agitation (Talebzadeh et al., 2024)—approaches that require little capital and are well suited to resource-constrained settings. At the policy scale, the near-absence of enforceable acoustic criteria in Nigerian healthcare design and the lack of a coherent federal noise-abatement framework [17] represent a clear gap; embedding acoustic standards within healthcare building regulation and national dementia-care strategy would give these measures statutory force.

5.3 Limitations and future research

Several limitations qualify these findings. The design is cross-sectional and observational, so associations between noise and behaviour cannot be interpreted as strictly causal. Sound was characterised using A-weighted level from a hand-held meter; continuous logging, night-time measurement, and psychoacoustic descriptors such as loudness, sharpness, and roughness would provide a richer characterisation of the soundscape. Because residents living with dementia could not be enrolled directly for ethical reasons, behavioural data rely on caregiver report and incident records, which carry known reporting biases. The two-facility comparison, while analytically useful, limits statistical generalisation. Future research should therefore pursue longitudinal and, where feasible, interventional designs; expand the sample of facilities and residents; incorporate continuous and night-time acoustic logging with psychoacoustic analysis; and test the transferability of soundscape-augmentation interventions under tropical, naturally ventilated conditions. Cross-cultural comparison with other tropical low- and middle-income settings would further establish the external validity of the loudness–annoyance framework in clinical environments.

6. Conclusion

The acoustic performance of healthcare buildings is a neglected but clinically consequential dimension of indoor environmental quality, and this neglect is acute in tropical, low-resource settings. Measuring two contrasting facilities in Ibadan, this study found that interior sound levels exceeded the WHO 35 dB(A) guideline throughout, that a government facility performed markedly worse than a private one under identical climatic conditions, and that perceived loudness and noise annoyance—driven more by human-related than housing-related factors and more by source meaning than by raw level—were associated with agitation, anxiety, wandering, and disturbed sleep among frail and cognitively impaired residents. Traffic, generators, amplified religious broadcasts, and staff conversation were the most undesired sources. By extending the residential loudness–annoyance framework of Wang et al. [8] into the clinical domain and grounding it in supportive-design theory, the study supplies tropical-region evidence that recent systematic reviews identify as scarce, and it converts that evidence into actionable design, management, and policy guidance. Embedding acoustic criteria within healthcare building standards and national dementia-care strategy, and prioritising passive envelope measures and low-cost soundscape management suited to naturally ventilated buildings, would materially improve the safety, comfort, and quality of life of some of the most vulnerable occupants of the built environment.

Declarations

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