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This is the Published version of the following publication

Jonescu, Emil, Mackintosh, Gary, Uylaki, Talia J, Ramanayaka, Chamil Erik, Farrell, Benjamin, Hunter, Helen, Blagden, Gary, Olatunji, Oluwole A and Ullah, Fahim (2026) Baseline indoor environmental quality in a residential aged care facility prior to replacement. *Facilities*, 44 (15-16). pp. 42-62. ISSN 0263-2772

The publisher's official version can be found at
<https://doi.org/10.1108/f-12-2025-0238>

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Baseline indoor environmental quality in a residential aged care facility prior to replacement

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Abstract

Purpose – This study aims to establish a baseline of indoor environmental quality (IEQ) and perceived indoor environmental conditions in an older ward-style residential aged care facility prior to demolition, providing a benchmark for evaluating a purpose-built replacement in a companion study. In this study, “baseline” refers to minute-resolution distributions of real-world environmental exposure (typical ranges, exceedance proportions and peak frequencies) measured within the existing facility, rather than a single target value.

Design/methodology/approach – A 14-day monitoring campaign (September–October 2024) was conducted in Perth, Western Australia, across a bedroom, lounge, activity room and corridor. Continuous measures of noise (dB(A)), illuminance (lux) and temperature (°C) were recorded using calibrated loggers (IC-NSRT calibrated acoustic dataloggers; HOBO MX2202 combined light and temperature dataloggers). Results were evaluated against WHO night-noise guidance (recommended night-time limits for sleep protection), AS/NZS 2107:2016, pragmatic circadian-light targets (=1000 lux daytime; =10 lux night) and literature indicating diurnal thermal variation = 2°C. Parallel surveys co-developed with facility stakeholder perceptions (including staff and resident/proxy respondents) of noise, lighting and thermal comfort (staff: 23; residents/proxies: 24).



Findings – Night-time bedroom sound levels exceeded WHO guidance for most monitored minutes, with intermittent peaks above 55 dB(A). Communal lounges exceeded the 45 dB(A) daytime guideline during most monitored periods. Daytime bedroom illuminance rarely achieved =30 min at =1,000 lux, while night-time exceedances above 10 lux occurred because of corridor spill. Temperatures were generally stable with limited day–night variation (<2°C) in most spaces. Survey responses aligned with measured noise patterns but tended to normalise lighting conditions that fell short of circadian-supportive targets; thermal comfort was rated positively.

Practical implications – The findings identify actionable priorities for redevelopment and interim operations, including acoustic buffering of bedrooms and corridors, daylight/circadian-supportive lighting provision, night-time spill control and more dynamic thermal zoning or scheduling.

Originality/value – This study provides a rare pre-replacement baseline integrating continuous IEQ monitoring with stakeholder perceptions in residential aged care, enabling defensible same-site benchmarking against a purpose-built facility.

Keywords Facilities management, Residential aged care, Indoor environmental quality, Post-occupancy evaluation, Building performance benchmarking, Acoustic comfort, Lighting performance, Thermal comfort

Paper type Research paper

Background and problem statement

Residential aged care facility design and environmental quality

The quality of the built environment in residential aged care facilities directly influences the health, well-being and daily experiences of residents and staff. International evidence links poor acoustic control to increased sleep disturbance, cognitive decline, cardiovascular stress and reduced social engagement among older adults (Hahad *et al.*, 2022; Johnson *et al.*, 2020). Lighting conditions that fail to provide adequate circadian stimulus can disrupt sleep–wake cycles, exacerbate cognitive impairment and reduce daytime alertness (Figueiro and Pedler, 2016; Blume *et al.*, 2019). Thermal environments lacking diurnal variability can impair circadian rhythm entrainment, contribute to discomfort and exacerbate agitation in residents with dementia (Okamoto-Mizuno and Mizuno, 2012; Tartarini *et al.*, 2017a, 2017b). Together, acoustic, lighting and thermal conditions constitute key dimensions of indoor environmental quality (IEQ) in residential aged care facilities.

While many Australian residential aged care facilities were constructed before contemporary evidence-based standards emerged, these ward-style buildings with large, shared spaces and limited environmental zoning provide valuable insight into environmental performance under earlier design paradigms. Documenting such conditions establishes a foundation for evaluating the acoustic, light and thermal improvements made possible by purpose-built facilities.

Policy and demographic context

Australia's aged care sector is facing rapid demographic shifts. As of 2023, 16.4% of the population is aged ≥65 years, with projections exceeding 21% by 2070 (AIHW, 2024). More than half of residential aged care residents are aged 85 years or older, with a high prevalence of dementia and sensory impairments. Policy reform, driven in part by the Aged Care Royal Commission (Pagone and Briggs, 2021), has prioritised dignity, autonomy and evidence-based care environments. However, capital investment cycles mean that many residents will continue to live in older facilities during transition phases. These environments, therefore, present opportunities for targeted operational

refinements and provide important reference points for assessing the value of new capital projects.

The case for pre-relocation baseline evaluation

A pre-relocation “pre-occupancy baseline evaluation” (PrBE) of environmental quality provides a baseline against which to measure the success of new-build interventions. These baseline exposure profiles are compared against formal standards where available and against pragmatic health-relevant targets (e.g. circadian-supportive lighting and diurnal temperature variation) where prescriptive standards are limited. Unlike narrative accounts or anecdotal feedback, PrBE offers quantified evidence of environmental performance under real-world conditions. This evidence is essential not only for benchmarking design improvements but also for identifying interim operational measures to improve resident outcomes in facilities awaiting replacement. A rigorous PrBE enables clearer attribution of improvements in subsequent post-occupancy studies and strengthens the evidence base for design strategies that support resident comfort and well-being.

Accordingly, this Phase 1 study aimed to establish a baseline environmental performance profile for an ageing ward-style residential aged care building prior to demolition. The objectives were to:

- quantify noise, illuminance and temperature exposures in representative bedrooms, communal spaces and transitional areas;
- compare observed conditions with established health-relevant thresholds and recommendations; and
- assess alignment between objective measurements and stakeholder perceptions to identify feasible operational and low-disruption improvement opportunities.

This baseline provides the benchmark for a companion Phase 2 evaluation of the purpose-built replacement facility. Stakeholders were defined as staff and residents/proxies, reflecting those most directly exposed to, and affected by, indoor environmental conditions in daily care and living activities.

Environmental quality and health in aged care

The design and operation of residential aged care environments exert a profound influence on resident well-being, particularly among populations with heightened sensory or cognitive vulnerabilities. Empirical evidence demonstrates that noise, light and temperature act as key mediators of sleep quality, mood and cognitive function in older adults ([Jonescu et al., 2025](#); [Sagha Zadeh et al., 2018](#); [Delaney et al., 2017](#); [Litton et al., 2017](#)).

Older individuals frequently experience presbycusis, a progressive decline in the ability to perceive high-frequency sounds, often accompanied by diminished sensitivity to low frequencies from middle age onwards ([National Institute on Deafness and Other Communication Disorders, 2023](#)). In people with dementia, these auditory changes are compounded by neurodegenerative impacts on cognitive auditory processing, leading to auditory agnosia, disorientation and impaired speech comprehension ([Johnson et al., 2020](#)). Environmental noise in such contexts can trigger anxiety, elevate cardiovascular markers and impair balance, thereby increasing fall risk ([Uylaki et al., 2024](#); [Wunderlich et al., 2024](#)). Conversely, well-designed acoustic environments can elicit feelings of safety and familiarity, supporting reminiscence and orientation ([Talebzadeh et al., 2024](#)).

The implications for residential aged care facilities are significant. Both short-term and chronic exposure to unregulated noise are associated with ischaemic heart disease, cognitive

impairment, tinnitus and mental health decline (Hahad *et al.*, 2022). In facilities with open-plan communal spaces and limited acoustic zoning, steady-state heating, ventilation and air-conditioning (HVAC) noise, intermittent equipment alarms and conversational activity can cumulatively exceed recommended thresholds (Standards Australia and Standards New Zealand, 2016; Berglund *et al.*, 1999), potentially disrupting sleep architecture and reducing restorative rest.

Lighting and circadian regulation

Lighting in aged care is often designed with a focus on safety, preventing falls and enabling visual tasks rather than optimising circadian health; this emphasis is particularly pronounced given age-related changes in visual acuity and contrast sensitivity, which increase illuminance requirements for older adults. Yet the circadian clock regulates behavioural and physiological processes, including sleep–wake cycles, alertness, mood, hormone secretion and core body temperature (Konis *et al.*, 2018). For residents with dementia, circadian disruptions are common, manifesting as night-time wakefulness, increased agitation and caregiver burden (Figueiro and Pedler, 2016).

Exposure to high illuminance levels early in the day can improve sleep consolidation and cognitive performance in this population (Yang *et al.*, 2021). Konis *et al.* (2018) demonstrated that regular access to morning daylight in close proximity to windows significantly increased circadian-effective light exposure in dementia care settings. Because spectral data were not available, illuminance thresholds were used as pragmatic proxies for circadian-supportive exposure, acknowledging that lux does not fully represent melanopic stimuli. Night-time exposure above 10 lux can suppress melatonin, delaying sleep onset (Blume *et al.*, 2019; Richardson *et al.*, 2018). Therefore, facilities with inadequate daylight penetration, overuse of cool-white lighting and uncontrolled corridor spill may compromise circadian entrainment.

Thermal environment and comfort

Thermal conditions in residential aged care settings must balance comfort, health and circadian considerations. While thermal comfort standards such as ANSI/ASHRAE (2013) and ISO 7730:2005 primarily target healthy adults, ISO 28803:2012 addresses individuals with special requirements, including the elderly, recommending avoidance of cooler temperatures at the lower end of the thermal spectrum. Evidence suggests that a diurnal variation of at least 2°C supports circadian rhythm regulation, while constant warm conditions (>22°C) may impair thermoregulation and contribute to restlessness in dementia care (Okamoto-Mizuno and Mizuno, 2012; Tartarini *et al.*, 2017a).

Ma *et al.* (2023) found that low humidity, elevated temperatures and poor air quality in nursing homes were associated with discomfort symptoms such as thirst, headaches and dizziness, driving residents to seek relief in outdoor or semi-outdoor spaces. In older facilities with centralised HVAC and minimal zoning, thermal monotony is common, reducing opportunities for personalised comfort control.

The gap addressed by this study

Most post-occupancy evaluations in aged care focus on newly built or recently renovated facilities, with limited empirical data on environmental performance in older buildings prior to replacement on the same site and by the same cohort (Phase 2 was reported separately). The Phase 1 facility studied has a ward-style configuration with carpeted floors, low ceilings and mixed communal/private areas, providing a unique opportunity to document baseline environmental conditions using industry-standard monitoring prior to its demolition. By

integrating sensor data with occupant conditions, the study aimed to identify both design-driven and operational factors contributing to environmental burden, generating actionable insights for facilities in similar pre-replacement stages.

Methods

This study formed the first phase of a sequential, mixed-methods evaluation of environmental quality in a residential aged care facility in Perth, Western Australia. Phase 1 is a PrBE of an ageing ward-style building scheduled for demolition; Phase 2 (reported separately) evaluates the purpose-built replacement on the same site.

Data processing and summary metrics

Environmental data were recorded and analysed at 1-minute resolution unless otherwise stated. Acoustic exceedances are reported as the percentage of 1-minute intervals exceeding guideline thresholds (L_{aeq} for background levels; L_{max} for transient peaks). Where exceedance results are summarised “by night”, a night is classified as exceedance-positive if at least one 1-minute interval exceeds the relevant criterion. Illuminance metrics are reported as the percentage of night-time minutes exceeding 10 lux and as total minutes per day achieving $\geq 1,000$ lux. Diurnal temperature variation (ΔT) is defined as the difference between the mean daytime temperature (07:00–21:59) and the mean night-time temperature (22:00–06:59) over the monitoring period. Across Phase 1, approximately 672 space-hours of monitoring were captured across four monitored locations, with $\geq 98\%$ data completeness for all loggers.

Facility monitoring locations

Two monitoring deployments were conducted across a 14-day study (24 September–9 October 2024). Monitoring focused on purposively selected “representative” locations across three primary space types (private bedrooms, communal areas and transitional spaces). “Representative” refers to typical, frequently used spaces expected to capture day-to-day environmental exposure patterns, selected in consultation with facility management based on occupancy, care routines and access constraints, to capture typical patterns of environmental exposure rather than statistical sampling across all rooms. The facility accommodated 44 residents and approximately 100 staff (Figure 1), and all monitored rooms were fitted with standard window coverings consistent with typical facility operation and comparable to those in the replacement facility. Measurements were undertaken under normal occupied conditions, without attempting to control or standardise curtain position, exterior lighting operation or occupant behaviour. This approach reflects real-world exposure rather than experimental conditions. Interior lighting systems in the monitored spaces were not dimmable.

The Phase 1 facility bedrooms were primarily single-occupancy with en-suite bathrooms and were arranged along double-loaded corridors adjacent to communal lounges and activity rooms. Interior finishes in the old facility included carpeted concrete floors, plasterboard walls and flush ceilings of approximately 2.5 m, with acoustic treatments limited to certain communal spaces. HVAC was provided by wall- or ceiling-mounted split systems, with no mechanical zoning at the room level.

Instrumentation

Each monitored space was instrumented with a single logger mounted at a fixed height for the duration of the deployment; reported mean, maximum and minimum values therefore

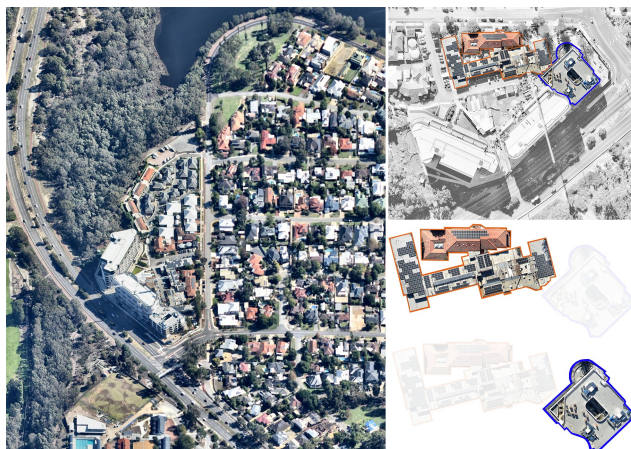


Figure 1. Co-location of old (since demolished) Phase 1 facility (orange outline), part of a ward-style model and a new purpose-built, resident-focused facility (blue outline) and Phase 2 (reported separately), into which residents and staff transitioned

Source: Nearmaps 2025 (modified by Authors 2025)

reflect within-room time-series data rather than averages across multiple sensor heights or locations.

Environmental monitoring targeted three IEQ parameters: noise, light and temperature, which were selected for their known impact on resident sleep, circadian regulation and comfort (Sagha Zadeh *et al.*, 2018; Okamoto-Mizuno and Mizuno, 2012; Blume *et al.*, 2019). Noise levels were recorded in A-weighted decibels [dB(A)] using IC-NSRT acoustic dataloggers, capturing 1-minute equivalent continuous sound levels (LAeq), maximum fast-time-weighted sound levels (Lmax[F]) and minimum sound levels (LAmin). Benchmark thresholds were drawn from the WHO Guidelines for Community Noise (Berglund *et al.*, 1999), which recommend LAeq ≤ 35 dB(A) and Lmax ≤ 55 dB(A) at night, and from AS/NZS 2107:2016 (Standards Australia and Standards New Zealand, 2016), which specifies ≤ 40 dB(A) for hospital ward bedrooms and ≤ 45 dB(A) for lounges during the day.

Reverberation time (RT60) was measured in a representative bedroom using a Brüel and Kjær handheld analyser, in accordance with ISO 3382–2:2008. Balloon-burst impulse responses were used as the excitation source, with four decay measurements recorded and averaged. Balloon bursts provide a brief broadband acoustic impulse that excites a wide frequency range, allowing reverberation time (RT60) to be estimated from the subsequent sound–energy decay curve. Four decay measurements were recorded and averaged to reduce event-to-event variability. Because of occupancy constraints, RT measurements were not undertaken in the communal lounge or activity spaces. These areas could not be cleared and held sufficiently quiet for the duration required to obtain valid decay measurements without disrupting resident activities, care routines and normal operations; intermittent conversation, staff movement and service activity would have biased RT estimates.

Illuminance was measured in lux using HOBO MX2202 loggers, positioned at approximately 1.4 m above finished floor level to approximate seated head height. Daytime circadian-supportive targets were defined as $\geq 1,000$ lux for at least 30 min per day, with ≤ 10 lux at night to prevent melatonin suppression (Blume *et al.*, 2019; Figueiro *et al.*,

2016; Richardson *et al.*, 2018). The same devices recorded temperature in °C, with thresholds informed by Okamoto-Mizuno and Mizuno (2012), who recommended avoiding continuous operation above 22°C and maintaining a diurnal variation of at least 2°C to support circadian entrainment.

Deployment 1 (24 September–1 October 2024) involved monitoring in a private bedroom (GB3) and a communal lounge (GL1). GB3 featured a north-facing window (1.9 × 1.2 m) with a roller blind, carpet flooring, flush plaster ceiling and an inactive ceiling fan and wall-mounted A/C during the monitoring period. GL1 was situated between two high-activity lounges, approximately 16–20 m from fully glazed elevations, with carpeted flooring and an acoustic grid ceiling.

Deployment 2 (2–9 October 2024) monitored a transitional corridor (GC1) and an activity room (GA1). GC1 was a 1.7 × 12.3 m space with a plasterboard ceiling and carpeted floor, while GA1 had carpet flooring, flush plaster walls, a 2.7 m ceiling and a recessed skylight with shade cloth. Logger placement heights ranged from 0.9 to 2.25 m above finished floor level, with positioning chosen to avoid direct sunlight, HVAC discharge and obstruction (see Figure 2 composite explanatory diagram for deployment locations. For large-format individual floor plans, see Supplementary files S2–S4).

All loggers were factory-calibrated within the previous 12 months and synchronised prior to deployment to ensure temporal alignment of data sets. After retrieval, the data were downloaded and cleaned. Cleaning comprised removal of obvious device artefacts (e.g. gaps during retrieval/handling) and retention of all plausible environmental readings; staff annotations were used for contextual interpretation rather than exclusion of observations. For each monitored space, analyses included percentage of time within or exceeding thresholds; daily mean/minimum/maximum values; exceedance counts for $L_{max} > 55$ dB(A) and light > 10 lux at night; and diurnal temperature variation.

Survey

Surveys were completed by 23 staff and 24 residents or proxies during Phase 1. The resident cohort was predominantly aged over 80 years, with a high prevalence of mobility and sensory impairments, reflecting the demographic profile typical of long-established residential aged care populations. Staff respondents represented a broad cross section of care roles, including registered and enrolled nurses, personal care assistants, allied health professionals and administrative staff.

Perceptions were assessed using a seven-point Likert scale. Statements were tailored to respondents' experience as residents (or proxies) or staff. Participants rated their agreement with each statement from 1 (strongly disagree) to 7 (strongly agree): 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neither agree nor disagree, 5 = somewhat agree, 6 = agree, 7 = strongly agree.

Seven-point Likert-scale surveys were developed in consultation with the residential aged care executive team, clinical leads and operational managers to ensure relevance, clarity and appropriateness for the residential aged care context. Domains included perceived noise levels and sources; lighting adequacy and glare; thermal comfort and control; and the impact of environmental factors on sleep and daily activities. Surveys were made available in both paper format and electronically via a QR code linking to a Microsoft Forms version to maximise accessibility and respondent convenience. Questions were framed in experiential rather than technical terms and reviewed informally with staff prior to deployment to confirm comprehension and therefore did not require respondent training or technical qualification.

Staff completed the survey by self-administration. Resident and proxy surveys were completed via a combination of direct participation and interviewer-supported

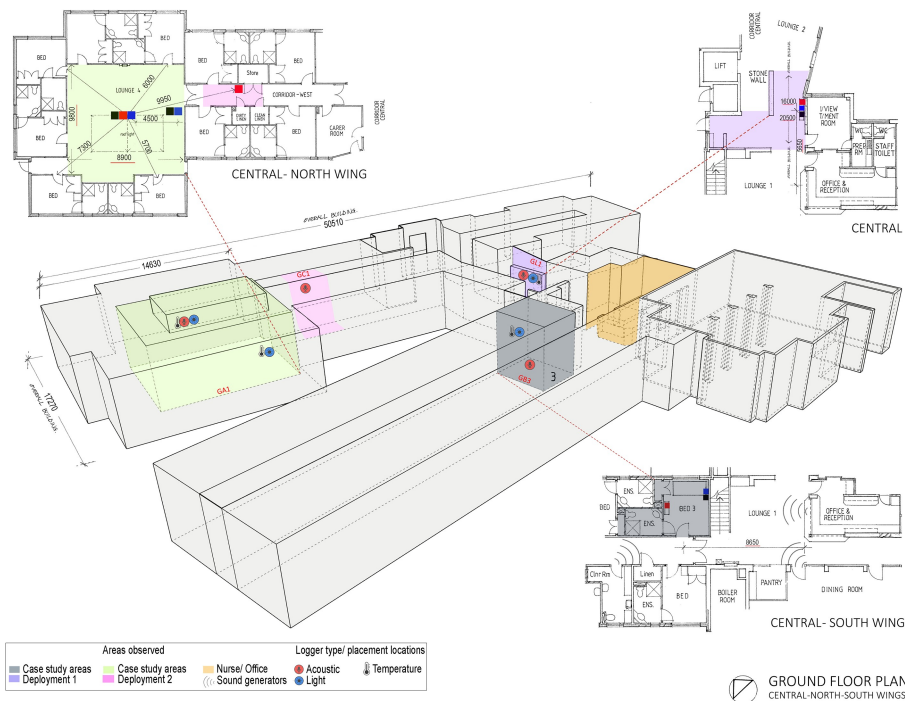


Figure 2. Phase 1 facility (now demolished). The diagram and legend show Phase 1 logger locations and types (acoustic, light and temperature) in bedroom (GB3), communal spaces (GA1 and GL1) and transition space (GC1). The building followed a ward-style rectilinear layout, double-loaded corridors lined with resident rooms and other functions and central staff stations

Note(s): Larger format individual floor plans are provided (see Supplementary files S2–S4)

Source: Authors (2025)

administration, with approximately half of resident responses facilitated by a research assistant to accommodate cognitive, sensory or fatigue-related limitations. The full staff and resident/proxy survey instruments are provided in Supplementary file S1.

Participation was voluntary, responses were anonymous, results were reported in aggregate and data were handled in accordance with institutional ethics approval. A proxy was defined as a legally authorised representative or next-of-kin who responded on behalf of a resident when cognitive capacity, fatigue, or communication limitations restricted direct participation. Of the 24 resident/proxy surveys completed, [$n = 14$] were completed directly by residents and [$n = 10$] by proxies. Given the modest sample size and ordinal nature of Likert responses, survey items are reported primarily using medians and modes, with means (SD) included for comparability with prior post-occupancy evaluation (POE) literature. No inferential tests were performed. Qualitative free-text comments were thematically coded for contextual interpretation; themes informed the discussion and recommendations but are not reported as standalone findings.

Example survey items included “The noise level in the aged care home distracts me from conversations with staff or family members”, “It is not easy for me to rest or sleep due to the

noise level in the aged care home”, “The temperature in my room is comfortable”, “The temperature in my room affects my ability to sleep”, “The brightness of the lighting in my room during the day is appropriate” and “The lighting in my room affects my ability to sleep”. All items were framed in experiential rather than technical terms to ensure accessibility for respondents.

Survey data were analysed using IBM SPSS Statistics (Version 28), while environmental monitoring data were processed using Microsoft Excel. Figures were prepared using Adobe InDesign and Adobe Photoshop.

Data analysis

No inferential statistical tests were performed. The study was designed as a pre-replacement baseline characterisation with modest, operationally constrained sample sizes and primarily ordinal Likert-scale outcomes. Analyses therefore emphasised descriptive distributions (medians, modes and variability) rather than hypothesis testing, to avoid over-interpretation of statistically underpowered comparisons.

Ethics considerations

Ethics approval for this study was obtained from the Human Research Ethics Committee of a Western Australian university (Approval #2024-XXXXX). Oral informed consent was obtained from all participating staff and from residents or their legally authorised proxies. Interviewer-administered protocols were used where required to facilitate participation, and all data were de-identified prior to analysis. The study was conducted in accordance with national guidelines for research involving human participants.

Results

Environmental performance by space and type

Results are presented by environmental domain and space type using the summary metrics defined in the Methods section.

Sound levels

Sound level monitoring in the Phase 1 facility provided useful baseline information for understanding acoustic conditions prior to redevelopment. In the monitored private bedroom (GB3), LAeq ranged between 42 and 75 dB(A). The WHO night-time guideline of ≤35 dB(A) was exceeded during approximately 99% of night-time minutes. Transient peaks above 55 dB(A) were observed on 20.5% of night minutes, most often linked to corridor activity, door movement or trolley use.

In communal areas, the lounge (GL1) recorded daytime LAeq levels above the AS/NZS 2107:2016 guideline of 45 dB(A) during approximately 60% of daytime minutes. The transitional corridor (GC1) exhibited high daytime LAeq (Table 1), reflecting frequent staff circulation and service traffic, with additional peaks during logistics and care routines. The activity room (GA1) demonstrated a wide range of conditions, shifting from relatively quiet intervals to elevated levels during structured programmes (see Table 1). In the measured bedroom, octave-band RT60 values ranged from approximately 0.37 to 0.51 s across the 125–4,000 Hz frequency bands, indicating moderately reverberant conditions for a furnished residential bedroom.

Table 1. Phase 1 daytime acoustic performance (LAeq) by space

Building	Space	Average daytime Leq	Reference criterion (daytime LAeq)	Exceedance (yes/no)	Standard deviation of daytime Leq (daily)
Phase 1 building	Lounge GL1	56 dB(A)	≤45 dB(A) (AS/NZS 2107:2016, lounge/day)	Yes	3.4–6.1
	Corridor GC1	59 dB(A)	≤45 dB(A) (treat as circulation/communal)	Yes	3.6–6.9
	Bedroom GB3	52 dB(A)	≤40 dB(A) (ward/bedroom/day)	Yes	3.5
	Activity Rm GA1	60 dB(A)	≤45 dB(A)	Yes	4.2–7.6
Note(s): Values report the daytime mean LAeq (07:00–21:59) across the monitoring period, with the standard deviation (daily) calculated from 1-minute LAeq on each monitored day (late Sep–early Oct 2024). Bedroom (GB3) has a relatively stable with lower variability, while communal spaces (lounges, dining rooms and activity rooms) naturally have greater dynamic range and higher variability					
Source(s): Authors (2025). Reference criteria are drawn from AS/NZS 2107:2016 for hospital ward bedrooms and communal areas during daytime periods					

Light

In the monitored bedroom (GB3), no day reached the threshold of ≥ 30 min at $\geq 1,000$ lux, with only 19 min recorded across the entire week, including 5 min in the 1,000–2,000 lux band. In the communal lounge (GL1), the weekly total reached 29 min $\geq 1,000$ lux, with 6 min in the optimal band, while the activity room (GA1) showed similarly limited daytime stimulus.

Night-time light monitoring demonstrated space-specific patterns. In GB3, only 2.6% of night minutes exceeded 10 lux, typically associated with corridor activity during rounds, while in GL1, 33% of night minutes were above this threshold because of corridor and external lighting spill.

Temperature

Thermal monitoring provided a benchmark of conditions in the Phase 1 facility, highlighting stable setpoints and limited diurnal cycling. In the monitored bedroom (GB3), the mean temperature was 22.9°C (day 23.0°C, night 22.7°C), with a day–night difference of only 0.35°C. In the communal lounge (GL1), the mean temperature was slightly higher at 24.5°C (day 25.2°C, night 23.3°C), yielding a diurnal variation of 1.82°C. Continuous operation above 22°C was common, with GB3 above this level for approximately 73% of readings and GL1 for approximately 93%.

Space-specific differences highlighted the influence of building configuration and HVAC operation. In the activity room (GA1, near the piano), mean daytime and night-time temperatures of 24.4°C and 21.0°C, respectively, produced a diurnal difference of 3.4°C. The skylight logger in GA1 showed a smaller swing (22.9°C day, 21.8°C night; $\Delta = 1.05^\circ\text{C}$), consistent with more stable setpoints (see [Figure 3](#)). [Table 2](#) highlights the percentage of time or days each monitored space exceeded established environmental thresholds.

Surveys*Noise perceptions*

Staff identified alarms as the primary noise source ($M = 4.96$), followed by ancillary services such as deliveries and waste removal ($M = 4.39$). Interpersonal communication ($M = 3.65$) and resident activities ($M = 3.70$) were rated as moderate contributors, while visitors were least disruptive ($M = 3.04$). Staff generally agreed that facility design supports task performance ($M = 4.65$) and enables communication without disturbing residents' sleep ($M = 4.91$). Staff also reported concerns about noise affecting residents' sleep ($M = 4.74$) and staff well-being ($M = 4.17$), likely reflecting alarms and service-related activity. Moderate agreement was reported for noise interfering with communication ($M = 3.17$), care delivery ($M = 3.43$), work quality ($M = 3.57$) and staff–resident connection ($M = 3.74$); staff also agreed that quieter environments would improve connection ($M = 4.57$). Standard deviations (1.32–1.99) indicate variability in staff responses across items.

Resident and proxy responses suggested a lower perceived impact of noise overall. Across four items, the highest mean rating was 3.58/7 (background noise affecting ability to hear staff), which is below the neutral midpoint (4). Ratings for noise affecting conversations with staff or family were 3.25, relaxation 2.88 and sleep/rest 2.42. Medians and modes were 2 or 3 for all items, indicating that most respondents reported low-to-moderate noise-related impact, although standard deviations (1.41–2.01) indicate heterogeneous experiences.

Lighting perceptions

Staff perceptions of lighting were generally positive. The highest ratings were for lighting supporting interactions at night and in lounge/group spaces (both $M = 5.70$), as well as during



Figure 3. Potential for solar gains near skylight area GA1 (near piano) in the Phase 1 facility (now demolished). The diagram and legend show Phase 1 logger locations and types (acoustic, light and temperature) in bedroom (GB3), communal spaces (GA1 and GL1) and transition space (GC1)

Note(s): The GA1 skylight position #2 recorded a smaller swing (day 22.89°C; night 21.83°C; $\Delta = 1.05^\circ\text{C}$), consistent with more stable set points and reduced internal gains. Where HVAC set points were held constant, thermal monotony was evident, with day–night differences $<1^\circ\text{C}$ (see Table 2)

Source: Authors (2025)

the day ($M = 5.65$), indicating agreement that lighting supports care and social engagement. Brightness in residents' rooms during the day was also rated favourably ($M = 5.65$), while lighting for night-time care activities was slightly lower ($M = 5.17$). Staff reported moderate agreement that lighting affects residents' sleep ($M = 5.13$) and their own well-being ($M = 4.13$), with greater variability for staff well-being ($SD = 2.10$).

Residents' and proxies' perceptions of lighting were similarly positive in relation to adequacy. Daytime brightness in rooms received the highest rating ($M = 6.04$), while lounge spaces ($M = 5.25$), night-time brightness in rooms ($M = 5.42$) and perceived consistency of lighting across the day ($M = 5.50$) were also rated favourably. In contrast, lighting was rated as having little impact on sleep ($M = 2.50$) or overall well-being ($M = 2.79$). Perceived influence on comfort during interactions was lower and more mixed, both at night ($M = 3.63$) and during the day ($M = 3.04$), indicating diverse experiences for interaction-related items.

Thermal comfort perceptions

Staff perceptions of thermal comfort were generally positive. Comfort in lounge/group spaces ($M = 5.87$) and residents' rooms during care provision ($M = 5.83$) was rated highest, indicating agreement that temperatures were appropriate. Seasonal adjustment was also rated favourably ($M = 5.78$), while consistency of room temperature throughout the day received moderate agreement ($M = 5.17$). Staff expressed some concern about temperature affecting residents' sleep ($M = 4.91$), with high variability ($SD = 2.09$), suggesting differing

Table 2. Phase 1 facility

Location	Metric	Measured value	Reference criterion	Exceeds criterion
GB3 – Bedroom	Mean temperature (°C)	22.87	≤22°C	Yes
	Day mean temperature (°C)	23.04	≤22°C	Yes
	Night mean temperature (°C)	22.69	≤22°C	Yes
	Maximum temperature (°C)	32.52	≤22°C	Yes
	Minimum temperature (°C)	19.82	—	No
	Diurnal temperature ΔT (°C)	0.35	≥2°C	Yes
	Time >22°C (min)	7,410	—	Yes
	Mean night-time light (lux)	90.65	≤10 lux	Yes
	Maximum light (lux)	20,208	—	—
	Night-time minutes >10 lux	403	≤10 lux	Yes
	Minutes ≥1000 lux (day)	5	≥30 min/day	No
	Minutes ≥1000 lux (night)	0	≥30 min/day	No
GL1 – Lounge	Mean temperature (°C)	24.47	≤22°C	Yes
	Day mean temperature (°C)	25.15	≤22°C	Yes
	Night mean temperature (°C)	23.33	≤22°C	Yes
	Maximum temperature (°C)	33.25	≤22°C	Yes
	Minimum temperature (°C)	21.19	—	No
	Diurnal temperature ΔT (°C)	1.82	≥2°C	No
	Time >22°C (min)	9,422	—	Yes
	Mean night-time light (lux)	48.14	≤10 lux	Yes
	Maximum light (lux)	39,976	—	—
	Night-time minutes >10 lux	2,489	≤10 lux	Yes
	Minutes ≥1000 lux (day)	6	≥30 min/day	No
	Minutes ≥1000 lux (night)	0	≥30 min/day	No
GA1 – Activity room	Mean temperature (°C)	22.7	≤22°C	Yes
	Day mean temperature (°C)	24.39	≤22°C	Yes
	Night mean temperature (°C)	20.99	≤22°C	No
	Maximum temperature (°C)	29.26	≤22°C	Yes
	Minimum temperature (°C)	19.26	—	No
	Diurnal temperature ΔT (°C)	3.4	≥2°C	No
	Time >22°C (min)	5,061	—	Yes
	Mean night-time light (lux)	120.87	≤10 lux	Yes
	Maximum light (lux)	746.24	—	—
	Night-time minutes >10 lux	462	≤10 lux	Yes
	Minutes ≥1000 lux (day)	0	≥30 min/day	No
	Minutes ≥1000 lux (night)	0	≥30 min/day	No

Note(s): Percentage of time or days each monitored space exceeded established environmental thresholds. Built from Lux/Temp loggers (GB3 bedroom, GL1 lounge and GA1 activity spaces) and an acoustic logger (GL1 lounge). Lighting thresholds: <1,000 lux (day, non-compliance) and >10 lux (night); temperature thresholds: >22°C (time-based) and ΔT <2°C (day–night, daily). Day = 07:00–21:59; night = 22:00–06:59
Source(s): Authors (2025)

experiences. Ratings indicating the home was too hot (M = 3.61) or too cold (M = 2.91) were comparatively low, suggesting these were not major concerns.

Residents’ and proxies’ perceptions of thermal comfort were also favourable. Mean ratings were highest for room temperature comfort (M = 5.67) and lounge spaces (M = 5.42), with consistency throughout the day slightly lower but still positive (M = 5.00). Median and mode values for these items were 6, reinforcing overall agreement on comfort. In contrast, temperature was rated as having minimal impact on sleep (M = 3.00) and comfort during interactions (M = 3.04), both below the neutral midpoint. Standard deviations for these items (SD = 1.79–1.88) suggest variable experiences regarding temperature-related disruptions.

Across items, both staff and residents/proxies reported favourable ratings for thermal comfort, with high scores for rooms and lounge spaces and little indication that the environment was generally too hot or too cold. Staff perceived temperature-related impacts on residents' sleep more strongly ($M = 4.91$) than residents/proxies ($M = 3.00$), again suggesting a perceptual gap.

Overall comfort and well-being

When asked about the overall impact of environmental conditions, residents most often cited safety, familiarity and general comfort as positives. Occasional references to sleep disruption from noise or light were made but framed as manageable aspects of daily life. [Figure 4](#) illustrates the percentage of respondents selecting “Agree” or “Strongly agree” to environment statements relating to noise, lighting and temperature impacts on sleep.

Discussion

Summary of principal findings

This evaluation of the Phase 1 ward-style facility established a detailed baseline of environmental quality across noise, light and temperature domains. Accordingly, the baseline provides an empirical reference for both standards-based interpretation and same-site comparison with the purpose-built replacement in Phase 2. Monitoring confirmed that bedrooms and communal areas frequently operated above contemporary acoustic thresholds, that daytime illuminance often fell short of circadian-supportive targets, and that diurnal temperature variation was limited in many rooms. These findings are consistent with the environmental affordances of ward-style buildings designed before current evidence-based standards ([van Hoof et al., 2010](#)). Note, where results are expressed “by night”, a night is counted as “exceedance-positive” if at least one 1-minute interval exceeds the criterion.

Survey responses complemented the monitoring, showing both convergence and divergence between measured outcomes and perceptions. Staff more frequently reported that noise and lighting affected residents' sleep and well-being, whereas residents and proxies

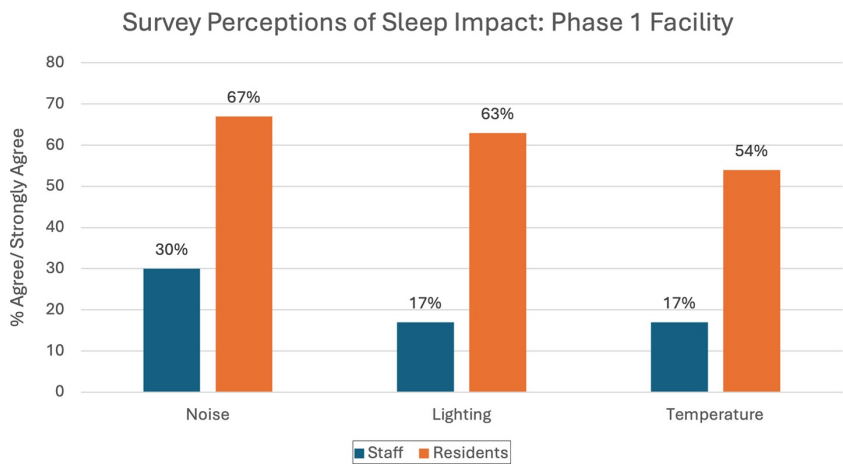


Figure 4. Perceived environmental impacts on sleep: Phase 1 surveys. Percentage of respondents selecting “Agree” or “Strongly agree” to statements on noise, lighting and temperature impacts on sleep

Source: Authors (2025)

generally rated these impacts below the neutral midpoint, in spite of monitoring indicating exceedances and circadian-light shortfalls. Thermal comfort, by contrast, was generally rated positively by both groups, even where monitoring indicated limited variability. These patterns reflect the adaptation and normalisation of exposure common in long-term care environments and emphasise the importance of combining quantitative and qualitative approaches.

Noise and acoustic control

In the monitored bedroom (GB3), night-time LAeq exceeded 35 dB(A) for the majority of 1-minute intervals ($\approx 99\%$ of night minutes), indicating a persistently elevated baseline relative to WHO guidance. Transient peaks above 55 dB(A) were also common ($\approx 20.5\%$ of night minutes), consistent with corridor movement and predictable operational activities. Limited RT measurements in the representative bedroom suggest that reverberant decay may have contributed to the acoustic character of the Phase 1 facility, particularly when combined with operational noise sources. While RT testing was not feasible in occupied communal areas, the findings establish a baseline and reinforce the importance of absorptive finishes and spatial buffering in reducing overall acoustic burden in future facilities. Equivalent RT measurements in bedrooms of the purpose-built replacement facility will be reported as part of the Phase 2 evaluation to enable pre- and post-relocation comparison.

Acoustic conditions in communal areas reflected socially active environments, where elevated background noise may be tolerated or even expected, yet still warrant design attention to minimise unnecessary stressors or fatigue in vulnerable residents. Peaks were often linked to group activities, mealtimes or audiovisual equipment, illustrating how acoustic exposure in communal areas is shaped as much by social engagement as by building fabric. Staff surveys confirmed this pattern, identifying dining areas and lounges as the most acoustically active spaces, while residents described these environments as both “lively” and occasionally “loud”.

Comparisons between surveys and measured data showed partial alignment. Both groups acknowledged the challenges posed by communal areas, where measured LAeq levels exceeded the 45 dB(A) daytime benchmark during the majority of monitoring periods. Importantly, however, in bedrooms, objective monitoring identified night-time exceedances ($L_{max} > 55$ dB(A) occurring during approximately 20.5% of night-time minutes) that were less frequently acknowledged by staff, who often assumed private spaces remained undisturbed. It also underscores the adaptive capacity of residents, many of whom described conditions as “quiet” or “calm” in spite of elevated measured levels. Moreover, the findings suggest that operational assumptions can shape perceptions, reinforcing the value of combining monitoring and surveys to establish a comprehensive baseline for evaluating the impact of design improvements in new facilities.

Taken together, these findings demonstrate that while the Phase 1 facility reflected the acoustic limitations of ward-style layouts, it also provided a valuable benchmark for evaluating future improvements. The data point to clear opportunities for design strategies such as acoustic separation, sound-absorptive finishes and corridor buffering, combined with operational protocols (Jonescu *et al.*, 2024) to minimise activity peaks during sensitive periods.

Lighting and circadian health

Lighting measurements in the Phase 1 facility provided a clear baseline for circadian performance. In the monitored bedroom (GB3), illuminance $\geq 1,000$ lux was achieved for

only 19 min across the week, compared with the ≥ 30 min/day guideline (Figueiro and Pedler, 2016).

Communal lounges performed better than bedrooms, reaching 29 min $\geq 1,000$ lux, but still fell short of targets. These findings reflect the limited daylight penetration of ward-style layouts and establish a benchmark for evaluating the glazing and orientation strategies of the new facility.

Night-time exposures above 10 lux were space-dependent. In GB3, exceedances were relatively infrequent ($\approx 2.6\%$ of night minutes), typically corresponding to staff rounds and corridor spills. In GL1, exceedances were substantial ($\approx 33\%$ of night minutes), consistent with spill from adjacent circulation and external lighting. Where summarised “by night”, the metric refers to whether any exceedance occurred during that night. Staff emphasised night-time light’s role in safety, highlighting the need for strategies that balance visibility and circadian protection. Survey respondents often described lighting as “adequate”, underestimating shortfalls detected by monitoring, which aligns with evidence that subjective adequacy can mask physiological insufficiency (Blume *et al.*, 2019).

Both staff and residents rated lighting adequacy favourably, with residents rating daytime brightness in rooms slightly higher ($M = 6.04$) than staff ($M = 5.65$). Staff perceived a stronger link between lighting and sleep/well-being (sleep: $M = 5.13$; well-being: $M = 4.13$) than residents/proxies (sleep: $M = 2.50$; well-being: $M = 2.79$), indicating a perceptual gap.

Overall, the results highlight both the baseline challenge of daylight penetration in older facilities and set a clear reference point for assessing improvements in daylight access, corridor lighting control and circadian-supportive electric lighting in the new modern RAC environment in Phase 2.

Thermal environment and circadian cues

Thermal monitoring in the Phase 1 facility established a stable comfort baseline. Average bedroom temperatures were 22.9°C (day 23.0°C, night 22.7°C), while the lounge averaged 24.5°C (day 25.2°C, night 23.3°C). Diurnal variation $\Delta T \geq 2^\circ\text{C}$ was observed in a minority of monitored logger positions, with some rooms showing minimal fluctuation because of centralised HVAC setpoints. Although this limited cycling, it provided consistent comfort, a feature valued by many residents and staff.

Survey responses supported these findings: residents generally described conditions as “comfortable”, with some preferring slightly cooler nights or warmer afternoons. Staff noted that HVAC settings were usually kept stable to avoid complaints, confirming the balance between operational simplicity and comfort. These patterns provide an important baseline for assessing whether the new facility’s zoning, operable openings and programmed HVAC schedules deliver greater circadian-supportive variation while maintaining perceived stability.

Together, these findings suggest that while baseline conditions were generally perceived as satisfactory, the underlying lack of dynamic variation represented an opportunity to enhance circadian-supportive thermal cycling. The surveys thus provide important context for interpreting the monitoring data, emphasising how perceived stability and actual environmental variety can differ, and establishing a clear reference point for evaluating the new facility’s ability to balance both comfort and circadian health.

Alignment and divergence between perceptions and measurements

This divergence highlights the importance of pairing objective measures with subjective perceptions, as noted in previous POE studies (van Hoof *et al.*, 2010). Survey responses complemented monitoring, showing both convergence and divergence between measured

outcomes and perceptions. Staff more frequently reported that noise and lighting affected residents' sleep and well-being, whereas residents/proxies generally rated these impacts below the neutral midpoint, in spite of monitoring indicating exceedances and circadian-light shortfalls. This pattern is consistent with adaptation and with the limits of subjective "adequacy" for physiological targets (van Hoof *et al.*, 2010; Lee *et al.*, 2021). The comparison reinforces the importance of pairing objective monitoring with stakeholder feedback to ensure that assessments of acceptability are evidence-based and not reliant solely on subjective impressions.

These patterns indicate a divergence between staff and resident/proxy perceptions (for example, alarms $M = 4.96$; ancillary services $M = 4.39$), indicating greater concern, whereas residents' and proxies' ratings were lower (highest $M = 3.58$), suggesting minimal perceived disruption. This divergence indicates a perceptual gap between staff and resident/proxy experiences, with variability in both groups implying that impacts are not uniform.

Implications for older residential aged care facilities awaiting replacement

While formal standards provide minimum compliance thresholds, they do not capture the temporal variability, cumulative exposure, or lived experience of occupants; the baseline, therefore, complements standards by documenting real-world operational conditions. For older residential aged care facilities awaiting redevelopment or replacement, the findings indicate scope for meaningful improvements in resident comfort and well-being through modest, low-disruption environmental interventions that are feasible within operational constraints and supported by prior evidence.

From an acoustic perspective, targeted measures such as localised sound-absorptive treatments in communal lounges, improved sealing of bedroom doors and scheduling logistics activities outside rest periods may reduce intrusive sound exposure and improve sleep continuity.

Lighting interventions offer a similarly feasible pathway. Portable high-intensity morning lighting in bedrooms may support circadian entrainment, while time-of-day lighting strategies in communal areas and reduced corridor spill at night can better balance safety with circadian protection.

Thermal strategies can be implemented within existing systems through modest day–night temperature differentials ($\approx 2^{\circ}\text{C}$ – 3°C) and controlled use of operable windows during mild conditions, where clinically appropriate.

Staff observed that greater environmental adaptability, including improved noise control, adjustable lighting and more flexible temperature zoning, would further support residents with specific sensory or cognitive needs. Together, the survey results demonstrate how residents and staff experienced the Phase 1 facility as broadly familiar and comfortable, while also highlighting clear opportunities for targeted improvements.

Together, these findings suggest that relatively modest environmental adjustments, supported by staff awareness, can enhance sleep and well-being even in facilities approaching the end of life (Figueiro *et al.*, 2020; Blume *et al.*, 2019).

Broader significance

This study provides rare, minute-resolution evidence of environmental conditions in an older residential aged care facility and establishes a pre-relocation benchmark for the same cohort prior to transition into a purpose-built household-model facility. Sequential PrBE/POE studies of this kind remain uncommon yet are critical for evaluating whether new buildings deliver meaningful environmental change beyond design intent.

Limitations

Several limitations should be considered. Monitoring was conducted during spring and therefore does not capture seasonal extremes; however, the aim of Phase 1 was to establish a like-for-like pre-replacement baseline for subsequent comparison rather than to characterise annual daylight availability. Although monitored spaces were representative of private, communal and transitional areas, coverage was constrained by equipment availability and operational considerations and may not reflect all conditions across the facility. Detailed audits of building materials, products, furnishings and lighting system specifications were not undertaken, as the study focused on observed environmental exposure and stakeholder perceptions under normal operational conditions rather than material-level performance attribution.

Survey responses were subject to recall bias and adaptation effects, particularly among long-term residents, while staff responses may have been influenced by operational priorities. The cross-sectional design limits causal inference; however, the integration of objective monitoring and stakeholder perceptions strengthens interpretive validity.

Illuminance (lux) was used as a field-appropriate proxy for circadian-relevant light exposure; spectral or melanopic metrics were not measured; the study focused on illuminance-based exposure under real-world conditions rather than detailed circadian-effective lighting analysis, and results should be interpreted as indicators of exposure opportunity rather than physiological effect. Surface reflectance properties (e.g. light reflectance values of finishes) were not measured, as the study prioritised observed illuminance exposure under normal operational conditions rather than modelling lighting performance based on material properties.

Finally, while RT measurements were limited to representative spaces, they provide useful contextual information regarding acoustic character.

Conclusions

This pre-relocation baseline evaluation of an older residential aged care facility established a detailed quantitative and qualitative baseline of environmental conditions. The findings suggest that sound levels in communal areas often exceeded guidelines, daytime illuminance in bedrooms rarely reached circadian-supportive thresholds and diurnal temperature variation was limited. Importantly, some of these conditions were not recognised by residents or staff, which underscores the value of combining monitoring with perception surveys.

Although the facility was nearing the end of its operational life, the patterns observed are likely representative of many older residential aged care environments in Australia and internationally. Even without major capital investment, targeted improvements in acoustics, lighting and thermal control, together with operational adjustments, can meaningfully enhance comfort and well-being.

Most importantly, this study provides a methodologically consistent benchmark for comparison with the new purpose-built household-model facility on the same site. By documenting baseline indoor environmental exposure under real operational conditions, this study provides a practical evidence base to inform design, refurbishment and operational decision-making in residential aged care and establishes a methodological framework for paired pre- and post-replacement evaluation. The forthcoming Phase-2 evaluation will offer an uncommon same-site comparison of how architectural and operational innovations influence environmental performance in aged care. Sequential PrBE and POE studies of this kind can inform not only future capital works but also interim operational strategies in facilities that continue to house residents during redevelopment cycles.

Acknowledgements

The authors would like to thank Adventist Care and its staff for facilitating this study.

Authors' contributions

Emil E. Jonescu: Conceptualisation (equal), Data Curation (equal), Formal Analysis (equal), Investigation (co-lead), Methodology (equal), Project Administration (lead), Resources, Supervision (equal), Validation (equal), Visualisation (equal), Writing – Original Draft Preparation (co-lead). Gary Mackintosh: Co-conceptualisation (equal), Project Administration (shared), Supervision, Review and Editing. Talia J. Uylaki: Visualisation (equal), Surveys Coordination, Writing – Review and Editing (equal). Chamil Erik D. Erik Ramanayaka: Data Curation, Formal Analysis (equal), Validation (equal). Benjamin Farrell: Data Curation, Formal Analysis (equal), Resources, Validation (equal), Visualisation (equal). Gary Blagden: Co-conceptualisation (equal), Supervision (equal), Methodology (equal), Supervision (equal), Validation (equal). Helen Hunter: Co-conceptualisation (equal), Project Administration (shared), Supervision (equal), Methodology (equal), Supervision (equal), Validation (equal). Oluwole A. Olatunji: Co-conceptualisation, Methodology. Fahim Ullah: Co-conceptualisation; Methodology.

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Supplementary material

The supplementary material for this article can be found online.

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