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Noisy and restless: 24 h in an NHS community hospital ward, a qualitative and quantitative analysis of the patient environment

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ABSTRACT

This case study assesses a hospital patient bay environment in terms of the potential for nurse led interventions to improve the patient experience and possible outcomes. The paper demonstrates where nurses have potential to enhance the environment and where patients contribute most to disruption. A section of an older persons acute-care ward (a patient bay) in an NHS community hospital in the South of England was evaluated by comparing quantitative environmental data (lighting, sound, air temperature, relative humidity, carbon dioxide and patient bed movements) with qualitative observed events, such as patient examinations noted over a 24-h period.

Inferential tests showed a relationship between the movement of patients in their beds and noise levels in the patient bay (a) above 68 dB during the day, (b) above 60 dB at night and (c) above 85 dB across the 24-h period. Staff accounted for 10% of the observed noise events that exceeded 68 dB during the day and 24% of the observed noise events that exceeded 60 dB at night. There was an observed correlation between observed noise events created by staff and the movement of the patients in their beds (a) 49% during the day and (b) 46% during the night, suggesting there is scope for the nursing staff to reduce noise in the patient bay areas and increase patient periods of rest. The introduction of "quiet-time" rest periods during the day and a general reduction of noise in the patient bay during the night is therefore recommended to enhance patient wellbeing.

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NOISY AND RESTLESS: 24 HOURS IN AN NHS COMMUNITY HOSPITAL WARD, A QUALITATIVE AND QUANTITATIVE ANALYSIS OF THE PATIENT ENVIRONMENT

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ABSTRACT

This case study assesses a hospital patient bay environment in terms of the potential for nurse led interventions to improve the patient experience and possible outcomes. The paper demonstrates where nurses have potential to enhance the environment and where patients contribute most to disruption. A section of an older persons acute-care ward (a patient bay) in an NHS community hospital in the South of England was evaluated by comparing quantitative environmental data (lighting, sound, air temperature, relative humidity, carbon dioxide and patient bed movements) with qualitative observed events, such as patient examinations noted over a 24-hour period.

Inferential tests showed a relationship between the movement of patients in their beds and noise levels in the patient bay (a) above 68dB during the day, (b) above 60dB at night and (c) above 85dB across the 24-hour period. Staff accounted for 10% of the observed noise events that exceeded 68dB during the day and 24% of the observed noise events that exceeded 60dB at night. There was an observed correlation between observed noise events created by staff and the movement of the patients in their beds (a) 49% during the day and (b) 46% during the night, suggesting there is scope for the nursing staff to reduce noise in the patient bay areas and increase patient periods of rest. The introduction of “quiet-time” rest periods during the day and a general reduction of noise in the patient bay during the night is therefore recommended to enhance patient wellbeing.

Keywords

Hospital; Indoor environment; Noise; Patients, Nursing staff

INTRODUCTION

Environmental control was one of Florence Nightingale’s main pillars of health, so recognition that the healthcare environment is a key element of patient healing has been understood throughout the history of nursing [1, 2]. A previous NHS Estates commissioned research project concluded the hospital environment has a direct impact on patient treatment and a significant impact on health and wellbeing outcomes [3]. A review of over 600 academic studies found that for staff a healthy hospital environment reduces stress and fatigue whilst improving effectiveness, and for patients a healthy hospital environment reduced stress and increases patient safety whilst improving overall health outcomes [4]. Ulrich et al. [5] concluded there is little doubt that the healthcare environment has an impact on the health and wellbeing outcomes of its users and, as further support to this, [2] concludes that health and wellbeing is increasingly being incorporated into the design and construction of health care facilities.

When considering the hospital environment, the literature broadly refers to four key areas: (1) natural light, (2) noise, (3) temperature, and (4) air quality. Increased natural light has been shown to provide significant health benefits [5], including a reduced stay in hospital [6-8], a reduction in sleep disturbances [9], reduced pain, reduced requests for medication, reduced depression [8] and decreased medical error rates (Ovitt, 1996 cited in [1]). In addition, high quality daylight has been shown to increase patient [6] and staff satisfaction [10, 11].

When noise exceeds comfortable levels it has been reported to have detrimental psychological and physiological effects on both the health of staff and patients, increasing stress levels and disturbing sleep patterns [12, 13]. In contrast, a quiet hospital environment has been shown to reduce the use of sedation and enhances hospital recovery rates [14]. Noise has also been the most reported cause of stress [12, 13] and sleep disturbances [15, 16] in hospitals. It was reported by the Royal College of Nursing in 2012 [15] that noise at night was the primary concern for patients regarding the hospital environment and a study by Park et al. [16] found that 86% of patients surveyed reported having "bad sleep" as a direct consequence of noise on the ward. The Department of Health acoustical technical memorandum provides detailed specifications for noise levels and sources, noting that 'Good acoustic conditions improve patient privacy and dignity, and promote essential sleep patterns. Such conditions are key to healing' [17]. Xyrichis et al. note that noise disruption in UK hospitals is getting worse and 40% of patients now report being bothered by noise at night. The work also notes that education for staff is needed to encourage a culture of noise reduction as an integral part of high quality healthcare delivery [18]. In addition, a patient's subjective wellbeing is specifically influenced by hospital noise from clinical sources (such as monitors, alarms and pumps) which nurses have some control over [19].

Two of the most current challenges for the NHS is an ageing population [20] where care needs are expected to expand by 25% by 2025 [21] and the growth of mental health conditions [22, 23]. Recent studies have reported that loud noises and poor quality soundscapes can have detrimental effects on the quality of life for people with dementia, increase agitation and may trigger Behavioural and Psychological Symptoms of Dementia (BPSD), which often occurs in the more severe stages of dementia [24-26]. Studies have also identified that background speech, reverberant conditions and background noise exacerbate hearing loss in elderly people [27], resulting in communication difficulties [27] and psychological problems, such as loneliness and low self-esteem [28].

Inappropriate temperature in hospitals can have significant effects on the health of patients [29]. It is widely acknowledged that extreme temperatures have a negative impact on human health including heat strokes and hypothermia, which may be fatal [30-32]. Consequently, Pourshaghaghy and Omidvari [33] reported that inappropriate thermal comfort conditions lead to decreased work efficiency and an increased likelihood of the personnel errors.

For cooler climates, it is broadly accepted that air temperature is the most important factor affecting thermal comfort and for hotter climates humidity is of greater importance [32]. This is confirmed by Griffiths [34] who reported that having the 'right temperature' was found to be the most important consideration by people in a user satisfaction survey of UK buildings, closely followed by 'air freshness'. Regardless of the climatic conditions, people generally perceive that high humidity can make an environment feel hotter [35].

Circulated air can relieve heat stagnation and the opening of windows is the most common adaptive behaviour used by people for circulating air and cooling indoor temperatures [36]. In the UK, acute care hospitals have a high ventilation rate of at least six air changes per hour for general wards, which is achieved predominately by mechanical ventilation supplemented by the opening of windows [37].

Ventilation also removes stale air and replaces it with fresh air [38]. The assumption is that ventilation is required to remove the build-up of carbon dioxide (CO_2), which is dangerous to human health [32, 38]. The concentrations of carbon dioxide (CO_2) in normal building conditions are generally harmless and it is the build-up of disagreeable heat, moisture and odours that cause occupants to take action [32, 38, 39].

Whilst the literature highlights the importance of environmental factors on the patient's experience, there remains a gap of in terms of determining the precise sources of disruption and the potential for these to be addressed by nursing staff. This case study assesses ward occupant behaviour gathered from researcher noted observations against environmental monitoring in real time over a 24-hour period on an older-persons acute-care hospital four-bed patient bay environment. The study aims to understand how easily quantitative information can be used to connect observed qualitative events. The study establishes benchmark patient bay conditions in a patient bay environment from which interventions can be developed to improve the patient environment and their experience. This study forms part of a wider project to evaluate the sustainability benefits of running an energy behaviour change intervention with nursing staff in an NHS community hospital.

METHODOLOGY

For this case study, the qualitative data gathered from observations noted by a researcher was analysed against the quantitative data gathered from air temperature, relative humidity, light, sound and CO_2 monitors together with movement sensors on windows and patient beds using R [40]. The study took place over a 24-hour period from 14:30:00 on Thursday 12th October 2017 to 14:30:00 on Friday 13th October 2017 in a four-bed patient bay located near the nurses' station on an older-persons' acute-care ward in a NHS community hospital in the South of England. Ethics approval was granted for the 24h and longer 9-month study by the Health Research Authority, 'Sustainability benefits of behavioural change in NHS Trusts', IRAS 223344, REC 17/HRA/1897. No personal data was collected from patients, the level of patient information was limited to defining if a studied patient bay was male or female. Nurses provided written consent for participation in the qualitative aspect of the study. The starting point was post lunch and so represented a relatively quiet period of the day to start the observations.

2.1 Qualitative Observation Data

The observations noted by a researcher in the patient bay included a timestamp and a description of the observation. The observation protocol was that the researcher should sit and observe the patient bays, taking short breaks as required, but always outside of peak activity periods. To ensure consistency, the observations were categorised into observed events using the criteria shown in Table 1 and were manually noted by the same researcher throughout the 24-hour period. The researcher was present for the entire period, apart from 4 short breaks during quiet periods, which totalled 57 minutes, see Figure 4. There were no nurse interventions reported whilst the researcher was away from the patient bay.

Event category	Criteria	Measurement
Lighting	Observations of the artificial lighting in the following states: ON, OFF, DIMMED. All interventions are manual.	Description and count
Noise	Observations of events that created an audible noise above that considered background noise from the following: alarms, doorbells, people (staff, patients, visitors), doors & cupboards, activities (ablutions, housekeeping, meals & refreshments) and equipment (medical equipment, televisions, radios, metal waste bins)	Description and count
Window movement	Observations of the changes of windows in the following states: OPEN, CLOSED, AJAR. All interventions are manual.	Description and count
Bed movement	Observations of events that created a visible patient movement from the following: patient examinations, bed sitting up / laying down in the bed, getting on / off the bed, turning in the bed.	Description and count
Occupancy	Observations of people in the room and those leaving / coming into the room.	Description and count

Table 1: Categorising observed events noted on an older persons' community hospital patient bay over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

The observations noted by the researcher were transferred into a Microsoft Excel spreadsheet by the researcher before uploading into R Studio programming software. To avoid input error the Microsoft Excel spreadsheet was rechecked by a hospital administrator against the manual list of observations noted by the researcher, as recommended by Marshall and Rossman [41].

Whilst observations noted may be subject to the bias interpretation [41, 42] of the researcher, the observations noted were examined against the quantitative data gathered during the study. The researcher has 7 years' experience managing energy and sustainability for the Trust and so can be considered an expert researcher in this context. Noise events were noted by source, if they occurred concurrently (e.g. nurses and patients) the researcher noted what they perceived to be the dominant source (by volume). Furthermore, whilst a 24h period is reported in detail here, a noise level comparison is made with the entire month showing the 24h studied period is not atypical.

2.2 Quantitative Data

Concurrently to the observed qualitative data, data loggers (Table 2.) were used to collect quantitative data for the identified environmental factors, as outlined in the following subsections. Compared to the qualitative data collection, which occurred only over a 24 hour period, these data loggers were in place from the 1st August 2017 to 30th April 2018 inclusive.

Environmental factor	Sensor	Measurement
Noise level	REED SD4023	Sensor: 0.5” electret condenser microphone Accuracy 31.5Hz ± 3.5 dB, 63 Hz ± 2.5 dB, 125 Hz ± 2.0 dB, 250 Hz ± 1.9 dB, 500 Hz ± 1.9 dB, 1 kHz ± 1.4 dB, 2 kHz ± 2.6 dB, 4 kHz ± 3.6 dB, 8 kHz ± 5.6 dB Resolution 0.1 dB Single measurement every 1 second
Temperature	MadgeTech RHTemp 101a	Sensor: Precision RTD element Accuracy ± 0.5 ºC, Resolution 0.01 ºC Single measurement every 5 minutes
Relative Humidity	MadgeTech RHTemp 101a	Sensor: Internal semiconductor Accuracy ± 3.0 % RH, Resolution 0.1 % RH Single measurement every 5 minutes
Carbon Dioxide	Extech SD800 CO_2	Sensor: dual wavelength non-dispersive infrared Accuracy ± 40ppm (<1000 ppm), Resolution 1 ppm Single measurement every 1 minute
Light level	Silicon photodiode	Sensor: cosine corrected silicon photodiode Accuracy: calibrated against class 1 sensor (1%) Single measurement every 1 minute
Window Movement	MEMS FXLS8471Q	Sensor: 3-axis accelerometers 12.5 samples per second
Bed Movement	MEMS FXLS8471Q	Sensor: 3-axis accelerometers 12.5 samples per second

Table 2: Environmental sensor specifications (accuracy, resolution and sampling rate) for noise, temperature, relative humidity carbon dioxide and light levels.

2.2.1. Air temperature and relative humidity

Air temperature (^oC) and relative humidity (%) levels were quantitatively measured using four miniature MadgeTech RHTemp loggers using the method defined by Amin et al in [43]. A logger was located directly above each patient between the bed and their chair, as shown in Figure 1 (a). The loggers were set to single measurements with a sampling frequency of five minutes.

(a) TEMP: Air temperature and relative humidity sensors in the case study ward.

(b) WINDOW: 3-axis accelerometers on windows in the case study ward

(c) BED: 3-axis accelerometer on the patient's bed in the case study ward. Rear of the headboard shown.

Figure 1: Monitoring of (a) Temp / RH, (b) window status, and (c) patient bed movements.

2.2.2. Carbon dioxide

Carbon dioxide (CO_2 ppm) was quantitatively measured using an Extech SD800 CO_2 monitor as detailed further by Bourikas et al in [44]. The monitor was located on top of a wall-mounted cupboard on the wall furthest from the windows in the patient bay to minimise the direct influence of external CO_2 on the monitor. The monitor was set to single measurements with a sampling frequency of one minute.

2.2.3. Window movement

Window movement was quantitatively measured using five Micro-Electro-Mechanical Systems (MEMS) FXLS8471Q 3-axis accelerometers as detailed further by Bourikas et al in [44]. An accelerometer was located on the bottom left corner of each window in the patient bay, as shown in Figure 1(b). Each accelerometer was set to a range of ±2g, sample rate of 12.5 samples per second and a trigger of 1.5 metres per second per second (m/s/s).

2.2.4. Lighting levels

Lighting was quantitatively measured using a silicon photodiode, calibrated against a class 1 LICOR cosine corrected silicon photodiode. The light sensor and logger were located on the top of a wall-mounted cupboard on the wall furthest from the windows in the patient bay in order to minimise the effect of natural light on the sensor. The logger was set to single measurements with a sampling frequency of one minute.

2.2.5. Noise levels

Noise decibel (dB) levels were quantitatively measured using a Reed SD4023 sound monitor. The sound monitor was located alongside the CO_2 and light monitors. The sensor was set to single measurements with a sampling frequency of one second.

2.2.6. Bed movement

Bed movement was quantitatively measured using four MEMS FXLS8471Q 3-axis accelerometers. An accelerometer was located on the back left-hand or right-hand side of each of the patient's headboard in the patient bay to minimise disturbance to the patients. Each accelerometer was set to a range of ±2g, sample rate of 12.5 samples per second and a trigger of 1.5 m/s/s as per the window accelerometers, see Fig. 1(c).

2.3 Patient Bay schematic

A schematic of the floorplan of the patient bay showing the location of the monitors is shown in Figure 2.

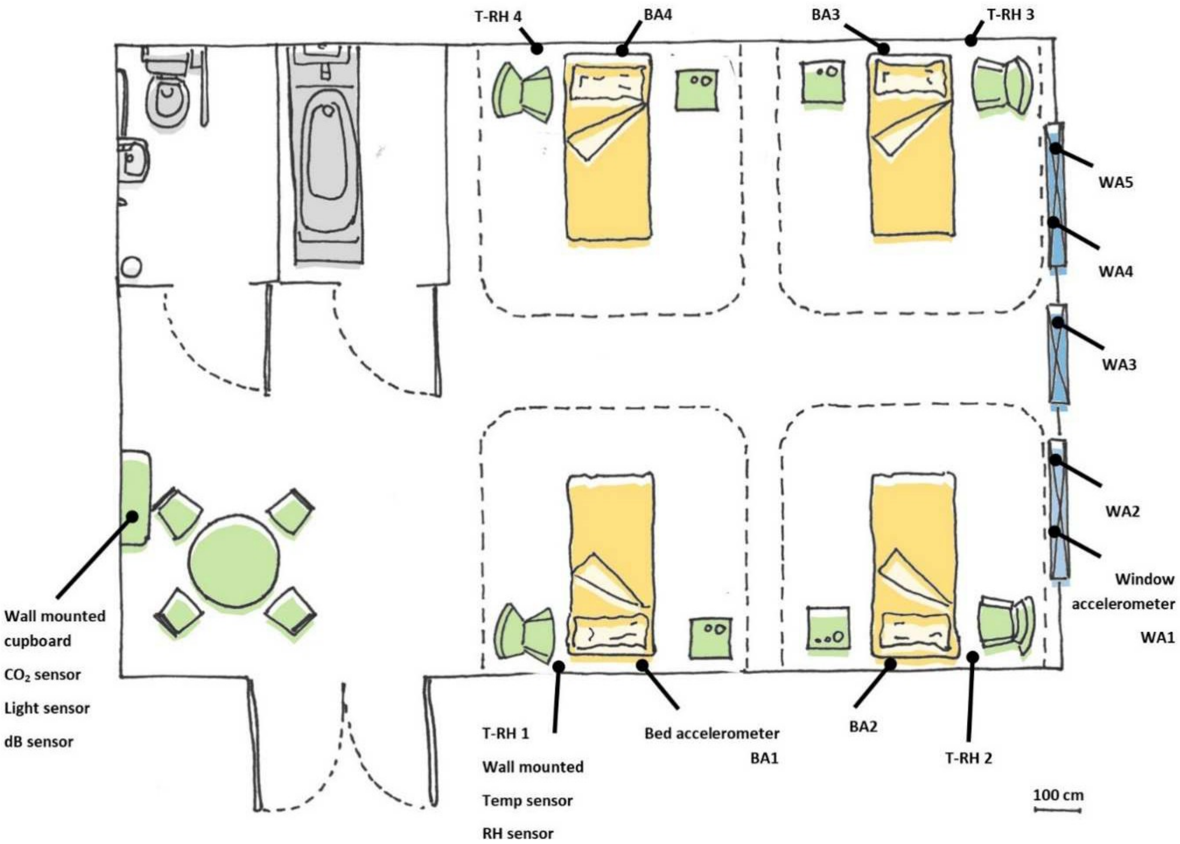

Figure 2: Study patient bay layout and location of measuring equipment used on an older persons' community hospital ward to measure the environment over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. WA1 to WA5 = window accelerometers, BA1 to BA4 = bed accelerometers, T-RH 1 to T-RH 4 = air temperature and relative humidity monitors.

RESULTS

During the 24h period there were no unusual or critical events reported in either the patient bay, the ward or hospital. This was verified by nursing records and senior nursing staff.

3.1. Local weather conditions

Outdoor climate is an important factor affecting indoor climate and thermal comfort [45]. The outside (ambient) air temperature and relative humidity data from the local weather station was compared to indoor air temperature and relative humidity in the patient bay across the 24-hour period, shown in Figure 3, part (i) and (ii). As expected, the ambient air temperature was found to be consistently lower than the internal air temperature. The building is of medium to high thermal mass, which alongside a high ventilation rate, creates a fairly unified temperature across the 24-hour period. The external relative humidity was consistently higher than internal relative humidity. The difference ranging between 20% and 46% was due to the internal relative humidity remaining around 55% as a result of the high ventilation rate and temperature in the patient bay.

3.2. Headline data results

During the 24-hour study period 1442 distinct observations were noted by the researcher of which 268 were observed bed movement events, 18 observed light events, 620 observed noise events, 32 observed patient examinations, 500 observed occupancy events and 4 observed window movement events. 454 observations or 32% of the observations occurred between 22:20:00 and 06:00:00, which was considered to be the night time. During night time no scheduled activity occurred outside of specific patient requirements. Figure 3 shows a summary of the quantitative data findings.

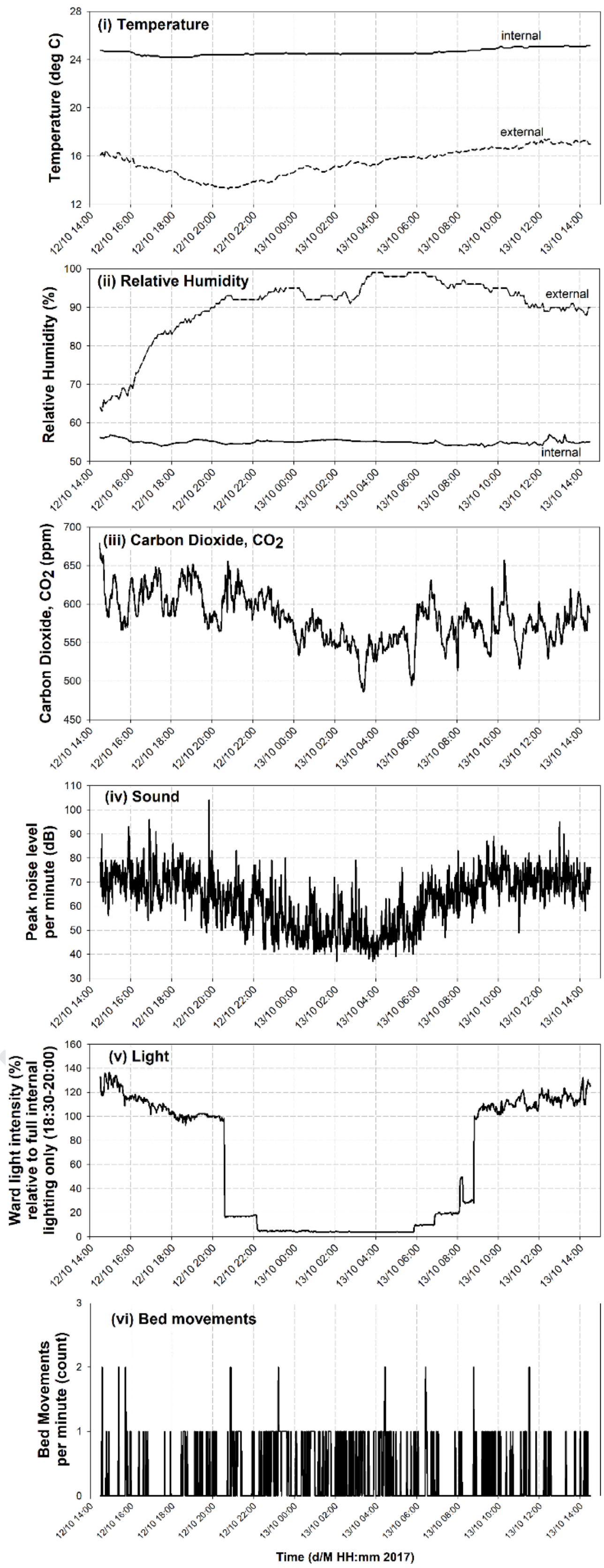

Figure 3: Headline quantitative data findings from an older persons' community hospital patient bay over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. Graphs shown include i) Temperature, internal and external ii) Relative humidity, internal and external, iii) Carbon dioxide, iv) Sound, v) Light, vi) Bed movements.

3.3. Air temperature and relative humidity

Quantitative data gathered from the temperature loggers showed that air temperatures in the patient bay ranged between 23.1^{o}C and 25.1^{o}C, shown in Figure 3 (i). The mean air temperature in the patient bay was found to be 24.0^{o}C, median air temperature was 24.0^{o}C and mode air temperature was 24.7^{o}C. In accordance with BS EN 16798-1: 2019 temperature drift limits, the study area achieved a high level of expected thermal comfort (±2^{o}C) [46].

This 24-hour period was found to be comparable with the patient bay dataset for the month of October, which showed that air temperatures in the patient bay ranged between 21.3^{o}C and 27.5^{o}C, mean air temperature in the patient bay was 24.3^{o}C, median air temperature was 24.4^{o}C and mode air temperature was 25.1^{o}C. The Chartered Institution of Building Services Engineers (CIBSE) recommend air temperatures of between 23^{o}C and 25^{o}C for a general ward in the UK summer (non-heating) period [47]. The case study showed air temperatures on the in the patient bay were within the recommended level for 99% of the time over the 24-hour period, shown in Figure 3(i).

Quantitative data gathered from the humidity logger showed that relative humidity levels in the patient bay ranged between 42% and 62%, shown in Figure 3(ii). The mean relative humidity in the patient bay was found to be 54%, median relative humidity was 56% and mode relative humidity was 61%. This 24-hour period was found to be comparable with the patient bay dataset for the month of October, which showed that relative humidity in the patient bay ranged between 28% and 68%, mean relative humidity in the patient bay was 48%, median relative humidity was 47% and mode relative humidity was 54%. CIBSE recommend internal relative humidity levels between 40% and 70% in the UK [47]. The case study showed relative humidity levels in the patient bay were within the recommended levels 100% of the time across the 24-hour period, shown in Figure 3(ii).

3.4. Carbon dioxide (CO_2)

CO_2 levels in the patient bay ranged between 486 ppm and 679 ppm. The mean CO_2 in the patient bay was found to be 581 ppm, median CO_2 was 580 ppm and mode CO_2 was also found to be 580 ppm. These figures were found to be comparable with the dataset for the month of October, which showed that CO2 in the patient bay ranged between 453 ppm and 895 ppm, mean CO2 on the ward was 553 ppm, median CO2 was 548 ppm and mode CO2 was 587 ppm.

When benchmarked against BS EN 16798-1: 2019 [46] CO_2 concentrations (ppm) and using the average global atmospheric carbon dioxide concentrations during 2017 of 405 ppm [48] as the outdoor CO_2 concentration figure, the CO_2 data was found to be in the high indoor environmental quality range (IEQ_I) for 100% of the time. In this case study, the low CO_2 concentrations observed reflect the high air change rates and associated good air quality.

If we consider the average CO_2 overnight concentration of 546 ppm within the patient bay overnight (01:00-05:00), with the baseline external CO_2 concentration of 405 ppm and a ventilation rate of 6ac/h this would require a CO_2 source (background and people breathing) of 1392 ppm from the ward volume. The CO_2 source at patient bay volume = (7 vol x 546 ppm) – (6 vol x 405 ppm) = 1 vol x 1392 ppm. The 'people breathing' contribution to the ward volume will be 1392 – 546 = 846 ppm. According to Persily and de Jonge [49], 4 males at rest (MET=1), aged 70-80 would each emit 0.0031 L/s CO_2 and 1.5 females aged 20-30 (MET=2) would each emit 0.0063 L/S CO_2. This combined patient, observer and nurse occupancy corresponds to 79L/h CO_2, compared to an estimate of 109L/h from the measured CO_2 values. This confirms the consistency of the CO_2 observations with the stated hospital air change rate and observed occupancy profile.

3.5. Ward occupancy

The patient bay comprised of four patients who remained on the ward 100% of the time and accounted for 67% of the total occupancy over the 24-hour period. The other occupants in the patient bay over the 24-hour period comprised the researcher who accounted for 16%, the staff 12% and visitors 5% of the total occupancy of the patient bay, as shown in Figure 4.

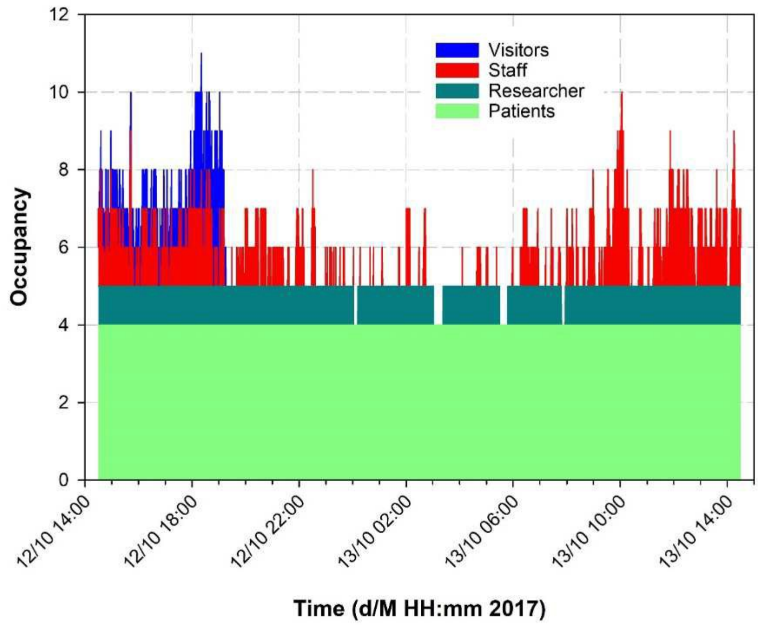

Figure 4: Observed occupancy count on an older persons' community hospital patient bay over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

When the association between day time observed occupancy levels and the movement of patients in their beds was statistically analysed using a logistic regression analysis (95% confidence level), the results showed there was a not significant relationship ($p = 0.613$) between these variables during the day time, suggesting that patient bed movements are not influenced by the level of general activity on the ward during the day time.

When the association between night time observed occupancy levels and the movement of patients in their beds was statistically analysed using a logistic regression analysis (95% confidence level), the results showed there was a significant relationship ($p = 5.64e{-05}$) between these variables during the night time, as would be expected, greater occupancy would reflect an unscheduled nurse led intervention resulting in patient movement.

3.6. Sound

Quantitative data gathered from the sound monitor showed that noise levels in the patient bay ranged between 35dB and 104dB over the 24-hour period. The mean noise level in the patient bay was found to be 49dB, median noise level was 48dB and mode noise level was 37dB. The noise level range was found to be comparable with the dataset for the patient bay for the month of October, which had a noise level range of 35dB to 107dB. During October, the mean noise level in the patient bay was 55dB, median noise level was 56dB and mode noise level was 52dB, therefore the 24-hour period was quieter than typical.

A noise level of 30dB is the target for general wards and single occupancy wards [47, 50] noise levels above 85 decibels (dB) are considered to be harmful to health [51], noise levels exceeding 60dB negatively affect sleep in hospitals [52] and mean background noise levels during the day have typically measured up to 68dB in hospital wards [4] and 55.3dB in care facilities for older people [53]. The case study showed that over the 24-hour period noise levels in the patient bay were above the recommended 30dB noise level for general wards 100% of the time, above the 85dB level considered harmful to health for 0.04% of the time and above the 60dB level that may negatively affect sleep in hospitals for 0.65% of the time. Although, percentage of time is perhaps a somewhat misleading metric as the number of events above a threshold is perhaps a better indicator.

When the observed noise events were mapped to the sound data exceeding 60dB at night, as shown in Figure 5, the findings identified the events that have the potential to wake patients in the patient bay during the night time. Figure 5 shows that 44% of peak noise events (maximum dB level in a one-minute period) exceeding 60dB at night were caused by patients, 25% by medical equipment mainly alarms, 24% by staff and 4% occurred from incidents elsewhere on the ward (noise from outside of the patient bay). 13 of the 55 noise events above 60dB at night were associated with the staff. The source of the peak noise event of each period is shown. When the association between sound data above 60dB at night and patient bed movement events was statistically analysed using a Pearson's Chi-squared test of Independence (95% confidence level), the results showed there was a significant relationship ($X^2(1) = 140.42$, $p < 2.2e-16$) between these variables during the night time.

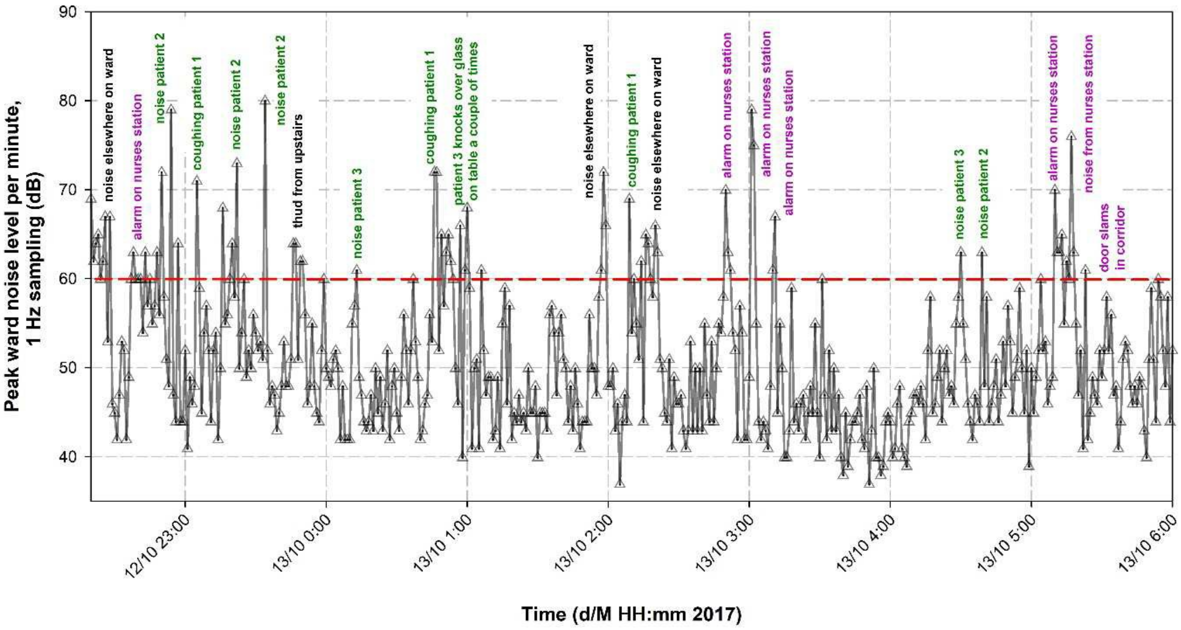

Figure 5: Quantitative noise data at night (22:20:00 – 06:00:00) that exceed the 60dB sleep disturbance level shown against qualitative observed noise events in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017

The staff accounted for 35% (n=72 of 207) of the observed noise events (as noted by the researcher, not considering a dB threshold) at night and 46% of these correlated with a patient bed movement event, suggesting there is scope for the nursing staff to reduce noise on the ward to increase patient rest at night.

Figure 6 maps daytime events that created peak noise above 85dB [4] in the patient bay. A quarter (25%) of the peak noise events above 85dB were caused by staff, 75% by patients. When the association between the sound data above 85dB and patient bed movement events was statistically analysed using a Pearson's Chi-squared test of Independence with a 95% confidence level, the results showed there was a significant relationship ($X^2(1)$ = 955.99, p < 2.2e-16) between these variables across the 24-hour period. When the association between the sound data above 68dB during the day and patient bed movement events was statistically analysed using a Pearson's Chi- squared test of Independence with a 95% confidence level, the results showed there was a significant relationship ($X^2(1)$ = 301.49, p < 2.2e-16) between these variables during the day time.

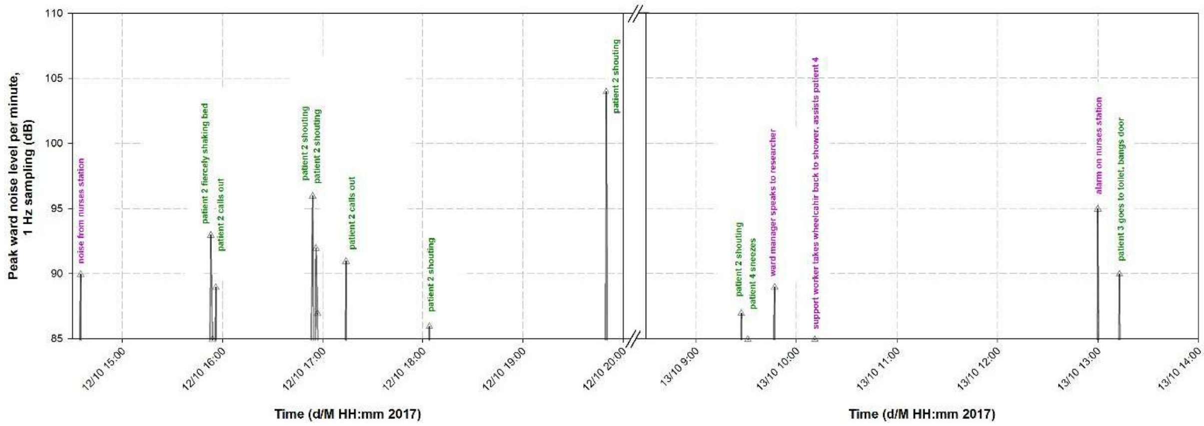

Figure 6: Quantitative noise data that exceed the 85dB peak noise level shown against qualitative observed noise events in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October

The staff accounted for 32% (n=131 of 412) of the observed noise events during the day (as noted by the researcher, not considering a dB threshold) and 32% of these exceeded the 68dB threshold, 49% correlated with a patient bed movement event, suggesting there is scope for the nursing staff to reduce noise on the ward to increase patient rest during the day.

When the association between day time sound data and observed occupancy levels in the patient bay was statistically analysed using a Spearman's rho test (95% confidence level), the results showed there was a significant relationship between these variables during the day time, although the correlation was weak, r_s = 0.14, p = 1.9e-7. When the association between night time sound data and observed occupancy levels in the patient bay was statistically analysed using a Spearman's rho test (95% confidence level), the results showed there was not a significant relationship, r_s = - 0.03, p = 0.48, between these variables during the night time. This is because the major source of high sound level events are the patients at night and the patient occupancy level does not change.

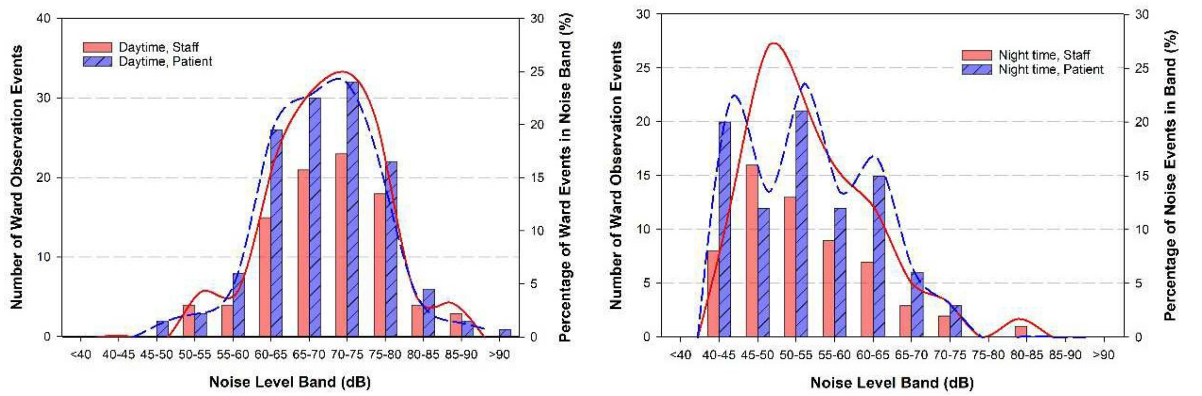

Figure 7: Binned distribution of the number and percentage of patient bay observed noise events and sound level (dB) for (i) LEFT daytime and (ii) RIGHT night time periods relating to Staff and Patients as a source.

Figure 7 compares the contribution of staff and patients to noise events in both the day and night periods. Whilst patients are the major source of noise events in both cases, the distribution of noise events for staff and patients is remarkably similar. At night only 20% of the observed bay noise events are associated with direct intervention with patients. 44% of night time events were directly associated with the activity at the nurses' station located outside of the patient bay (talking, coughs, printer, telephone calls) further suggesting there is scope to reduce night time noise through behaviour change training of staff.

3.7. Light

Light sensor measurements showed a clear pattern of the artificial lighting being fully switched on between the hours of 08:50:00 to 20:30:00, dimmed between the hours of 06:00:00 to 08:50:00 and 20:30:00 to 22:20:00, and fully switched off between the hours of 22:20:00 to 06:00:00, as shown in Figure 8. When the researcher observed light events were mapped to the light data, shown in Figure 8, the light data did not always show changes in local light levels when the staff entered the patient bay with a flashlight at night to check or assist patients. However, Figure 8 did show a clear correlation between the observed light events categorised by the researcher as switched ON, switched OFF and levels changed to DIMMED and the quantitative data from the light sensor.

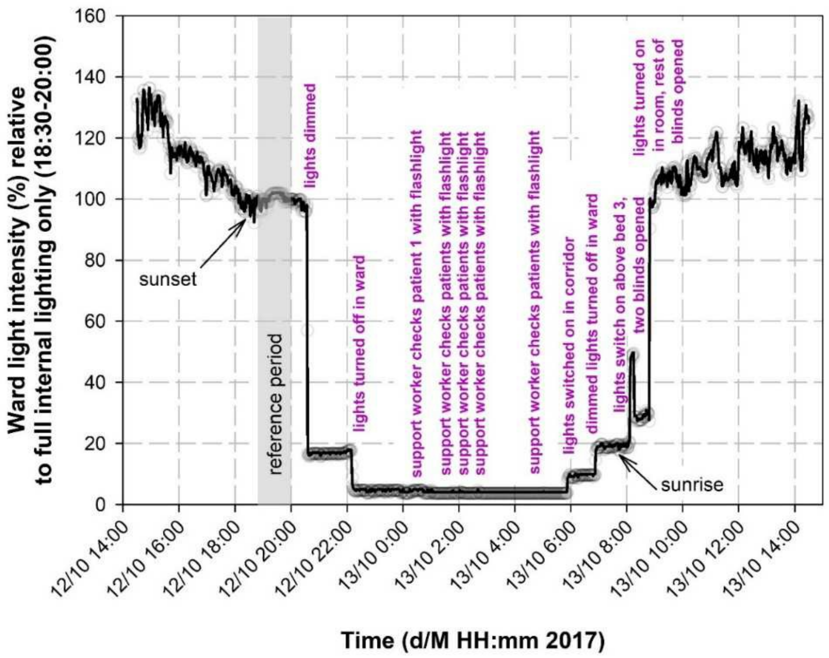

Figure 8: Quantitative light data shown against qualitative observed light events in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October

Lights were dimmed at 20:30:00 hours and fully switched off at 22:20:00 hours on the 12th October for patient comfort. On the 13th October, dimmed lights were switched on at 06:00:00 hours and then fully switched on at 08:50:00 hours. The UK Met Office reported 2.7 daily average hours of sunlight in UK for October 2017 [54], which may explain the reason for the lighting being fully on in the patient bay during the day time. Whilst all the occupants have full access to the controls for the artificial lights in the patient bay, the six lights in the patient bay are controlled simultaneously by one switch that can be switched to off, dimmed or on, consequently the occupants are unable to control individual lights in the patient bay. Whilst the patients had access to a reading lamp above each bed, none of these were used during the 24-hour period and the nursing staff used small torches when checking the patients during the night.

3.8. Bed movement

The quantitative data from the 3-axis accelerometers showed 179 patient bed movements and the researcher noted 268 observed patient bed movement events across the 24-hour period in the patient bay. The difference is associated with (1) the thresholding level set on the accelerometer and (2) false positive observations due to beds with pressure mattresses which re-pressurise and can be falsely interpreted as a patient movement by observation.

When the observed bed movement events were mapped to the patient bed movement data (3 axis accelerometer sensor), shown in Figures 9-12, the findings identified the events in the patient bay that have the potential to disturb patient rest. These figures show that 49% of bed movement events were caused by patient examinations and assistance by nurses, 48% by patients mainly getting in and out of bed and 3% by staff talking to patients. The high noise events (above 85dB) shown in Figure 6 are overlaid across Figures 9-12 as green and a red arrows. A red arrow corresponds to observed patient movement at the same time as the noise event (the patient them self could be the source), a green arrow shows the noise event did not result in patient movement. Of the 10 patient source above 85 dB noise events, 8 were from patient 2, with 1 from patient 3 and 4.

Figure 10 shows that for patient 2, bed movement is observed to occur with above 85 dB noise events only in the case where patient 2 is the source of the noise. In effect this patient is not observed to be disturbed by other noise events, the patient acts as the primary source of disturbance. For the case of patient 1, only 1 sound event bed movement (14:30, 12/10) cannot be associated with another activity in the patient bay, such as the patient talking to a nurse. Figure 11 shows that none of the noise events are observed to impact on Patient 3 in terms of bed movement. Similarly, in the case of Figure 12, other patient activities (such as getting out of bed) are observed to coincide with the >85 dB noise events. There is the possibility that the patient may have chosen, in part, to initiate this activity as a result of the noise disturbance.

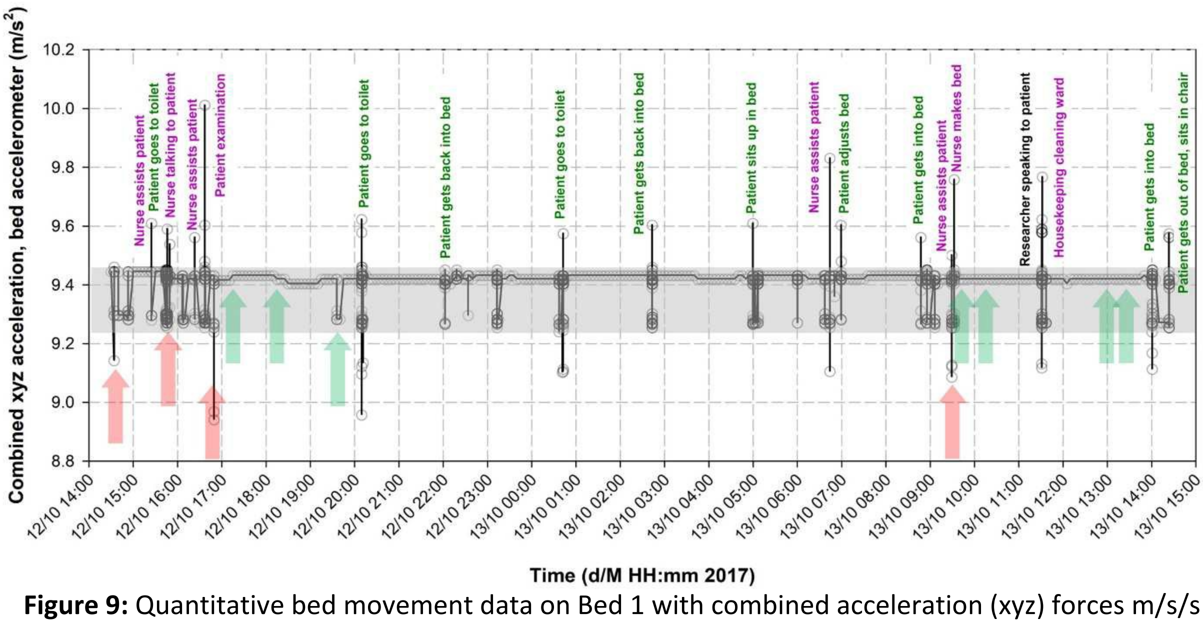

Figure 9: Quantitative bed movement data on Bed 1 with combined acceleration (xyz) forces m/s/s shown against qualitative observed bed events for Bed 1 in a patient bay on an older persons'

community hospital patient ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. Red arrow – patient movement coincides with above 85 dB noise evet, Green arrow – no patient movement observed with above 85 dB noise event.

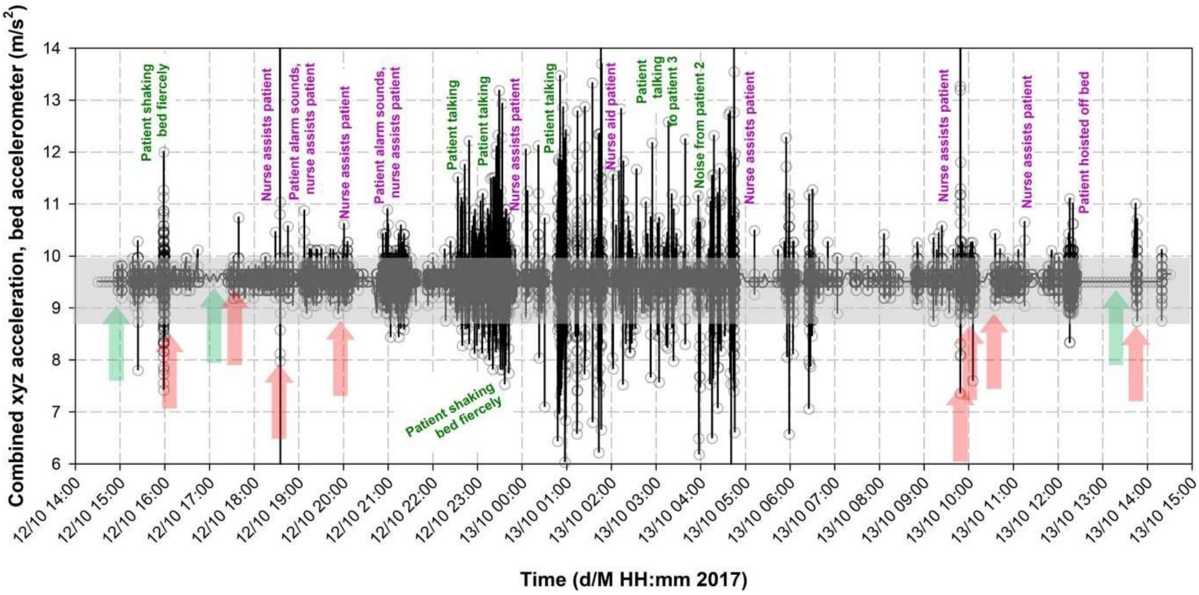

Figure 10: Quantitative bed movement data on Bed 2 with combined acceleration (xyz) forces m/s/s shown against qualitative observed bed events for Bed 2 in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. Red arrow – patient movement coincides with above 85 dB noise evet, Green arrow – no patient movement observed with above 85 dB noise event.

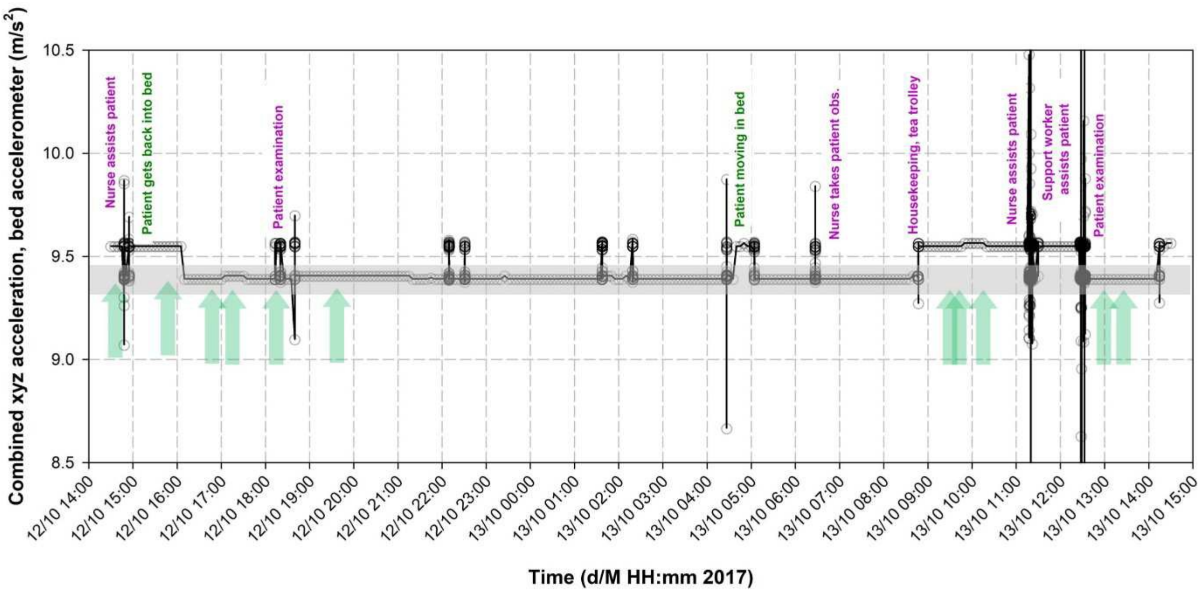

Figure 11: Quantitative bed movement data on Bed 3 with combined acceleration (xyz) forces m/s/s shown against qualitative observed bed events for Bed 3 in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. Red arrow – patient movement coincides with above 85 dB noise evet, Green arrow – no patient movement observed with above 85 dB noise event.

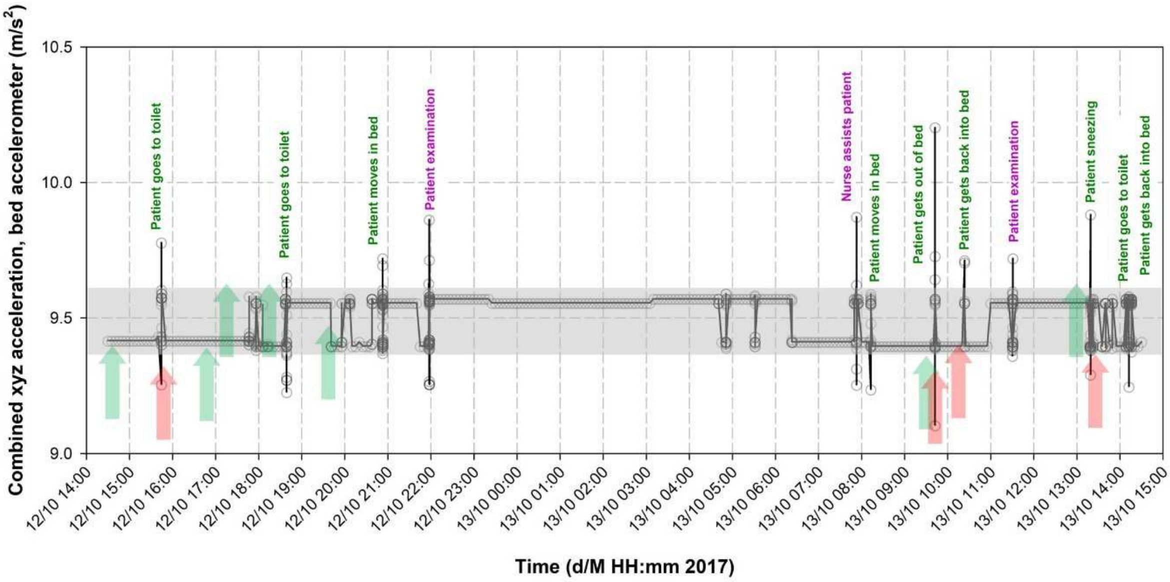

Figure 12: Quantitative bed movement data on Bed 4 with combined acceleration (xyz) forces m/s/s shown against qualitative observed bed events for Bed 4 in a patient bay on an older persons' community hospital ward over a 24-hour study period from 14:30:00 12th October 2017 until 14:30:00 13th October 2017. Red arrow – patient movement coincides with above 85 dB noise evet, Green arrow – no patient movement observed with above 85 dB noise event.

Whilst the quantitative bed data on the whole reflected the qualitative observed bed events for beds 1, 3 and 4, bed 2 was more problematic to match. The patient in bed 2 was reportedly suffering from dementia and was observed talking loudly, calling out and moving in the bed for a significant amount of the 24-hour period, which made it difficult to match the appropriate observations to the quantitative bed data. This highlights that an accelerator based approach does have limitations amongst particular patient groups.

3.9. Window movements

Quantitative data gathered from the 3-axis accelerometers on the windows in the patient bay showed that only one window was open and then closed twice during the 24-hour period and was confirmed by visual observation by the researcher. This low level of window engagement was typical of that the sensor data recorded / observed throughout the month.

DISCUSSION

With the exception of noise, the quantitative data from the study area remained within the recommended environmental standards for the majority of the time (over 71%). Over the 24-hour period, air temperature in the patient bay was within the CIBSE recommend standard (23-25ºC) [47] for 99% of the time. The patient bay environment achieved a high level of expected thermal comfort (±2ºC) [44]. Relative humidity levels in the patient bay were always within the recommended standard for relative humidity (40-70%) [47]. When benchmarked against BS EN 16798-1: 2019 [46] CO_2 concentrations (ppm) in the study area were found to be in the high indoor environmental quality range (IEQ_I) for the whole of the 24-hour period.

Whilst noise levels in the patient bay environment were always above the recommended level (30dB) they generally fell in line with previous studies in UK hospitals that reported background noise levels typically measured 45-68 dB and peak noise levels typically measured above 85 dB [4]. The researcher noted 207 noise events at night, of which 35% (n=72) were by staff, 53% (n=110) by patients and 12% (n=25) by medical equipment. Of the 72 noise events associated with staff, 58 occurred outside of the patient bay (81%), of which 32 (44% of all staff noise events) were noises from staff at the nurses' station, just outside of the patient bay. During the day, 32% of noise events (n=131) were by staff, 41% (n=168) by patients and 27% (n=113) by medical equipment. Of the 131 noise events associated with staff, 40 (31%) were noises from outside of the patient bay, of which 23 (18% of all staff noise events) were noises from staff at the nurses' station. Therefore, there is evidence of scope for the nursing staff to reduce noise and associated disruption on the ward (notably from the nurses' station) across the 24-hour period – this has formed the basis of subsequent extended trialing of interventions.

During the day, people were observed constantly going in and out (n=441) of the patient bay and the background noise was higher during this period (mean = 54dB), however, at night only the nursing staff were observed going in and out (n=59) of the bay, checking on patients and administering medication and background noise was much lower (mean noise level = 39dB). Only those data tests which provide key insight into the patient bay environment are discussed here:

The case study showed there was not a significant relationship between the following variables in the ward:

- occupancy levels and noise levels during the night time, (due to the major source of night time noise being patients whose occupancy number does not change, see Fig. 7.)
- occupancy levels and patient bed movements during the day time (suggesting that patient bed movements are not influenced by the level of general activity on the ward during the day).

The case study demonstrates there was a significant relationship between the following variables in the ward:

- occupancy levels and noise levels during the day time (as would be expected),
- occupancy levels and patient bed movements during the night time (as would be expected, greater occupancy would reflect an unscheduled nurse led intervention resulting in patient movement),
- patient bed movements and noise levels >85dB across the 24-hour period,
- patient bed movements and noise levels >68dB during the day time,
- patient bed movements and noise levels >60dB during the night time.

Patients in care contexts (or domains) often have little, or no control over the local environment and consequently feel a detachment from it [55, 56] and disconnected with attempts to improve it [57]. The bay occupants in this case study were only able to influence the environmental factors air temperature, relative humidity and carbon dioxide in the patient bay by opening windows which they did not do. The occupants only opened one top-pivot window during the 24-hour period between 16:45:00 and 18:45:00 on the 12th October and then again between 06.39:00 to 14:30:00 on 13th October. The top-pivot windows only open a maximum of 5 degrees (11 centimeters) for safety reasons.

CONCLUSION AND RECOMMENDATIONS

During the case study air temperature, relative humidity and carbon dioxide remained within the recommended levels for the majority of the 24-hour period. Whilst noise levels in the patient bay were always above the recommended level (30dB) they generally fell in line with previous studies in UK hospitals that reported background noise levels typical measuring 45-68 dB and peak noise levels typically measuring above 85 dB [4]. Lights were fully switched on between 08:50:00 and 20:30:00, and fully switched off between 22:20:00 and 06:00:00. Only one window was opened and then closed during the 24-hour period.

The inferential tests showed there was a relationship between movements of the patients in their beds and noise levels in the patient bay (a) above 68dB during the day, (b) above 60dB at night and (c) above 85dB across the 24-hour period. As increased noise levels were seen to correlate with increased movements of patients in their beds, the introduction of “quiet-time” rest periods during the day and a general reduction of noise in the wards during the night is recommended to enhance patient wellbeing.

There was an observed correlation between occupancy levels in the patient bay and (a) noise levels during the day and (b) movement of the patients in their beds at night. Staff accounted for 10% of the observed noise events that exceeded 68dB during the day and 24% of the observed noise events that exceeded 60dB at night. There was an observed correlation between observed noise events created by staff and the movement of the patients in their beds (a) 49% during the day and (b) 46% during the night, suggesting there is scope for the nursing staff to examine elements of their practice which can reduce noise on the bay to increase patient rest.

The case study also showed that the occupants in the patient bay, particularly the nursing staff had very little control over air temperature, relative humidity, carbon dioxide and lighting on the ward for which the controls were too limited. The results from this case study have subsequently led to the introduction of a lighter summer uniform for nurses alongside the trailing of a ‘quiet time’ periods (daytime and night time) to enhance the patient environment and their experience.

REFERENCES

[1] Harris, N., Pisa, L., Talioaga, S., and Vezeau, T., 2009. Hospitals going green: a holistic view of the issue and the critical role of the nurse leader. Holistic Nursing Practice, 23 (2), 101–111.

[2] Huisman, E. R. C. M., Morales, E., van Hoof, J., and Kort, H. S. M., 2012. Healing environment: A review of the impact of physical environmental factors on users. Building and Environment, 58, 70–80.

[3] Lawson, B., Phiri, M. and Wells-Thorpe, J., 2003. The Architectural Healthcare Environment and its Effects on Patient Health Outcomes. London.

[4] Ulrich, R., Quan, X., Systems, H., Architecture, C., and Texas, A., 2004. The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity. Designing the 21st Century Hospital Project. Concord.

[5] Ulrich, R. S., Zimring, C., Zhu, X., Dubose, J., Hyun-bo, S., Young-Seon, C., Xiaobo, Q., and Anjali, J., 2008. A review of the research literature on evidence based healthcare design. The Center for Health Design, 1 (3), 61–125.

[6] Agency for Healthcare Research and Quality, 2005. National Healthcare Quality Report. Rockville.

[7] Joseph, A., 2006. The Impact of Light on Outcomes in Healthcare Settings. Concord.

[8] Mathews, M., 2013. I Can Fix That: Manageable Factors in Patient Rehabilitation and Recovery. Undergraduate Research Journal for the Human Sciences, University Research Communitee [online], 12. Available from: http://kon.org/urc/v12/mathews.html.

[9] Bartick, M. C., Thai, X., Schmidt, T., Altaye, A., and Solet, J. M., 2010. Decrease in as-needed sedative use by limiting nighttime sleep disruptions from hospital staff. Journal of Hospital Medicine, 5 (3), 20–24.

[10] Edwards, L. and Torcellini, P., 2002. A Literature Review of the Effects of Natural Light on Building Occupants. Golden, Colorado.

[11] Boyce, P., Hunter, C., and Howlett, O., 2003. The Benefits of Daylight through Windows. Lighting Reasearch Center.

[12] Mazer, S. E., 2012. Creating a Culture of Safety: Reducing Hospital Noise. Biomedical Instrumentation & Technology, 46 (5), 350–355.

[13] Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., and Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. The Lancet, 383 (9925), 1325–1332.

[14] Buxton, O. M., Ellenbogen, J. M., Wang, W., Carballeira, A., Connor, S. O., Cooper, D., Gordhandas, A. J., Mckinney, S. M., and Solet, J. M., 2013. Sleep Disruption due to Hospital Noises Annals of Internal Medicine. Annals of Internal Medicine, 157 (3), 170–179.

[15] Royal College of Nursing, 2012. Going upstream: nursing's contribution to public health [online]. London. Available from: https://my.rcn.org.uk/_data/assets/pdf_file/0007/433699/004203.pdf.

[16] Park, M. J., Yoo, J. H., Cho, B. W., Kim, K. T., Jeong, W.-C., and Ha, M., 2014. Noise in hospital rooms and sleep disturbance in hospitalized medical patients. Environmental Health and Toxicology, 29, e2014006.

[17] Health Technical Memorandum 08-01: Acoustics, Department of Health (2013)

[18] Xyrichis A. et al (2018) Noise pollution in hospitals, BMJ, 363, doi.org/10.1136/bmj.k4808

[19] Cunha M. & Nelio Siva RN (2015) Procedia – Social and Behavioral Sciences, 171, pp 246-252

[20] Appleby, J., 2013. *Spending on health and social care over the next 50 years Why think long term ?* The Kings Fund.

[21] Guzman-Castillo M. et al (2017) Forecasted trends in disability and life expectancy in England and Wales up to 2025: a modelling study, Lancet Public Health; 2: e307-13

[22] The King's Fund, 2015. *Mental health under pressure* [online]. London. Available from: www.kingsfund.org.uk/sites/files/kf/field/field_publication_file/mental-health-under-pressure-nov15.pdf.

[23] NHS Mental Health Taskforce, 2017. Five Year Forward View for Mental Health, One Year On,

NHS, Publications Gateway Reference 06480
[24] Van den Bosch, K.A.; Andringa, T.C.; Ba¸skent, D.; Vlaskamp, C. The Role of Sound in Residential Facilities for People with Profound Intellectual and Multiple Disabilities. J. Policy Pract. Intellect. Disabil. 2016, 13, 61–68.
[25] Van den Bosch, K.A.; Andringa, T.C.; Peterson,W.; Ruijssenaars,W.A.J.J.M.; Vlaskamp, C. A comparison of natural and non-natural soundscapes on people with severe or profound intellectual and multiple disabilities. J. Intellect. Dev. Disabil. **2016**, 1–7.
[26] Aletta, F., Botteldooren, D., Thomas, P., Vander Mynsbrugge, T., De Vriendt, P., Van de Velde, D., & Devos, P. (2017). Monitoring Sound Levels and Soundscape Quality in the Living Rooms of Nursing Homes: A Case Study in Flanders (Belgium). Applied Sciences, 7(9), 874. doi:10.3390/app7090874
[27] Davies WJ, Cox TJ, Kearon AT, Longhurst BJ, Webb CL. Hearing loss in the built environment: the experience of elderly people. Acta Acust United Acust 2001;87:610–6.
[28] Borik, Yuliya, "Social Isolation, Social and Emotional Loneliness, and Self-Reported Hearing Difficulties in Older Adults with Hearing Loss" (2016). CUNY Academic Works., academicworks.cuny.edu/gc_etds/1330
[29] Abrudan, A., Rus, T., and Mare, R., 2016. Thermal rehabilitation influence upon the comfort in hospitals.pdf. In: International Conference on Advancements of Medicine and Health Care through Technology. Cluj-Napoca, Romania, 155–158.
[30] Basu, R. and Samet, J. M., 2002. Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. Epidemiologic Reviews, 24 (2), 190–202.
[31] McMichael, A. J., Woodruff, R. E., and Hales, S., 2006. Climate change and human health: Present and future risks. The Lancet, 367 (9513), 859–869.
[32] Angus, T. C., 1968. The control of indoor climate. Oxford: Pergamon Press Ltd.
[33] Pourshaghaghy, A. and Omidvari, M., 2012. Examination of thermal comfort in a hospital using PMV-PPD model. Applied Ergonomics [online], 43 (6), 1089–1095. Available from: http://dx.doi.org/10.1016/j.apergo.2012.03.010.
[34] Griffiths, I., 1990. Thermal comfort studies in buildings with passive solar features. Field studies. Report to the Commission of the European Community, ENS35 090 UK. London.
[35] Nicol, J. F. and Humphreys, M. A., 2004. A stochastic approach to thermal comfort, occupant behaviour and energy use in buildings. ASHRAE Transactions, 110 (2), 554–568.
[36] Rijal, H. B., Tuohy, P., Humphreys, M. A., Nicol, J. F., Samuel, A., and Clarke, J., 2007. Using results from field surveys to predict the effect of open windows on thermal comfort and energy use in buildings. Energy and Buildings, 39 (7), 823–836.
[37] Department of Health, 2007. Specialised ventilation for healthcare premises. Part A - Design and installation. Health Technical Memorandum 03-01.
[38] Bedford, T. and Warner, C. G., 1939. Subjective Impressions of Freshness in. Journal of Hygiene, 39, 498–511.
[39] Nicol F. et al, (2012) Adaptive Thermal Comfort: Principles and Practice, Routledge, ISBN 0415691591
[40] R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at www.R-project.org/.
[41] Marshall, C. and Rossman, G., 1989. *Designing Qualitative Research*. London: Sage Publications Ltd.
[42] Monhan T. & Fisher J.A. (2010), Benefits of “Observer Effects”: Lessons from the Field, Qual Res. 2010 Jun 1; 10(3): 357–376., doi: 10.1177/1468794110362874
[43] Amin, R., Teli, D., James, P., and Bourikas, L., 2016. The influence of a student’s ‘home’ climate on room temperature and indoor environmental controls use in a modern halls of residence. Energy and Buildings, 119, 331–339. Available from: dx.doi.org/10.1016/j.enbuild.2016.03.028.
[44] Bourikas L. et al (2018) Camera-based window-opening estimation in a naturally ventilated office, Building Research & Information, 46:2, 148-163, DOI: 10.1080/09613218.2016.1245951

[45] de Carvalho, P. M., da Silva, M. G., and Ramos, J. E., 2013. Influence of weather and indoor climate on clothing of occupants in naturally ventilated school buildings. Building and Environment, 59, 38–46.
[46] British Standards Institute, 2019. BS EN 16798-1: Energy performance of buildings — Assessment of overall energy performance.
[47] Chartered Institute of Building Services Engineers, 2015. CIBSE Guide A: Environmental Design. London.
[48] National Oceanic & Atmospheric Administration, 2019. Trends in atmospheric carbon dioxide emissions [online]. Earth Systems Research Laboratory Global Monitoring Division. Available from: https://www.esrl.noaa.gov/gmd/ccgg/trends/global.html [Accessed 22 May 2019].
[49] Persily, A. and de Jonge, L., 2017. Carbon dioxide generation rates for building occupants. Indoor Air, 27 (5), 868–879.
[50] Department of Health, 2015. EnCO2de 2015 – making energy work in healthcare. Part A: Policy & management. Health Technical Memorandum 07-02.
[51] Schneider, E., 2005. Noise in figures. Bilbao.
[52] Hilton, B. A., 1985. Noise in acute patient care areas. Research in Nursing and Health, 8 (3), 283– 291.
[53] van Hout, N. H., Hak, C. C., Suren, S., & Kort, H. S. (2014). Acoustic measurements of sound levels in common rooms and sleeping rooms of care facilities for older adults. Gerontechnology, 13(2), 86-87.
[54] UK Government, 2017. Average daily sun hours and deviations from the long term mean (ET 7.3). [online]. Available from: https://www.gov.uk/government/statistics/energy-trends-section-7-weather.
[55] Bull, R., Lemon, M., Fleming, P. D., Stuart, G., and Everitt, D., 2014. Digitally Engaging and Empowering Employees for Energy Demand Reduction: A New Approach for the Next Generation? In: ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove: American Council for an Energy-Efficient Economy, 7–65.
[56] Dunphy, J. L., 2014. Healthcare professionals' perspectives on environmental sustainability. Nursing Ethics [online], 21 (4), 414–425. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=97190999&site=eds-live.
[57] Mulville, M., Jones, K., Huebner, G., and Powell-Greig, J., 2017. Energy-saving occupant behaviours in offices: change strategies. Building Research and Information, 45 (8), 861–874.