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# A SURVEY OF NOISE LEVELS IN A POST-SURGICAL CHILDREN'S WARD

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## 1 INTRODUCTION

There is a growing body of research into the acoustic environment in hospitals with increasing evidence of the detrimental effects of noise on patient and staff well being[1,2], and of a significant rise in hospital noise levels over the past 40 years[3]. However most of the evidence concerning the impact of noise has focused on specialist areas within hospitals, with relatively little information known about noise levels and acoustic conditions in general in-patient hospital wards in the UK.

A collaborative study is currently being undertaken at London South Bank University by the Medical Architecture Research Unit (MARU) and the Acoustics Group, funded by the Engineering and Physical Sciences Research Council (EPSRC) and Arup. The study aims to address some of the gaps in knowledge in the area of in-patient care, in order to provide better understanding of the importance of the acoustic design of hospitals, and its relationship with current hospital management and building design policies. Noise and staff and patient questionnaire surveys are currently being undertaken in a range of hospitals.

This paper presents the findings of the pilot noise measurement study carried out in a post-surgical ward at Great Ormond Street Children's Hospital. Results include comparisons of noise levels measured in a number of ward locations including multi-bed rooms and single bed rooms, and identification of sources of high level noise.

## 2 GREAT ORMOND STREET HOSPITAL

### 2.1 Background Information

Great Ormond Street Hospital for Children (GOSH) was established in 1852, its first building situated at 49 Great Ormond Street, London. With its motto "the child first and always", the hospital has become the leading UK tertiary paediatric hospital, providing the widest range of specialist paediatric services in the country.

As part of an ongoing redevelopment plan for the site focusing on the delivery of a new model of care, the construction of The Octav Botnar Wing was completed early 2006. This building was designed to provide a unique, uplifting environment for both patients and staff by maximising the use of natural light, bright colours, and innovative designs. The Octav Botnar Wing houses a number of specialist centres including an International Patient Centre; Medical Daycare Centre; Orthopaedic Ward and Biomedical Engineering Centre.

The redevelopment team at GOSH are heavily involved with the delivery of each phase of the redevelopment plan and have a particular interest in how buildings perform following their commission. Any feedback from early phase buildings is used to positively inform decision making for subsequent phases. It was felt that the study could yield useful information for the team about the acoustics of the Octav Botnar Wing whose design was heavily influenced by the need for Infection Control, with hard, easily cleanable surfaces.

### 2.1.1 Identification of suitable pilot study ward

Out of the four specialist centres situated in the Octav Botnar building, only the Orthopaedic Ward fitted the study criteria of general in-patient care. Length of stay is generally from one day to two weeks, with patients undergoing a number of different types of operations including limb lengthening procedures, spinal surgery, and hip and foot surgery. Patient ages vary from small babies up to 18 years of age.

The new clinical facilities were designed to provide greater space for patients, more comfortable surroundings for a parent to stay by their child's bedside and more efficient use of space for nursing teams. The ward is built on a "racetrack design" that positions patient rooms on the outer part of each floor and locates the health care resources in the middle. In total there are three 4 bed bays and six single patient rooms – a total of 18 beds. Rooms facing east and south include floor to ceiling glazing looking onto a balcony area (which is not available for use). Rooms facing west have smaller areas of glazing. All 4 bed bays and single rooms have ensuite shower and toilet facilities. Each bed also has a flat screen television, a hoist and a bed for parents to sleep next to the patient (the single rooms have a pull down bed; the 4 bed bays have chairs which convert to beds). This bed can be screened from the patient by a curtain arrangement. All ward furniture and curtain materials are brightly coloured.

The healthcare resources are situated in the centre of the ward and include clean and dirty utility rooms; a plaster room; a sensory room; kitchen; assisted bathroom; equipment store; adolescent room; ward manager's office; and two nurses stations.

The ward manager of Orthopaedic Ward was new to post and was enthusiastic and supportive of the study. He already had some concerns about several systems in place on the ward which he considered to be too loud, and expressed an interest in finding out the noise levels of these systems and how often they were used. It was decided that these concerns could be easily incorporated into the pilot study.

# 3 THE PILOT STUDY

The aim of the pilot study was two fold: firstly to trial the methodology to be used in the main study to ensure that meaningful results could be obtained in line with the research proposal; and secondly to provide useful feedback for the redevelopment team and the ward manager.

In designing the objective part of the study it was important to ensure that the objective measurements would yield enough robust data to build up a picture of the noise climate throughout the ward, and allow for comparisons between different areas to be made.

## 3.1 Study design

To help inform the study design, some time was spent on the ward to build up an appreciation of ward layout, to meet the staff and to make on-the-spot sound level measurements. Several discussions with the ward manager also helped to build up an understanding of the day-to-day running of the ward and any events that may affect the noise levels.

Due to the nature of care in this particular ward, and the timings of operations, staffing levels and ward occupancy are generally at their highest during weekdays. During a weekend, ward occupancy rates drop to 50% or less, staffing levels are lower and often one 4 bed bay and several single rooms may be left empty.

It was decided that measurements made during the weekends would not be representative of typical use of the ward, nor would they not allow for comparisons with other inpatient care facilities (which tend to be at capacity throughout the entire week). In conclusion, analysis would only be carried out on weekday measurements for the pilot study.

Other factors considered in the objective study design were:

- Staff shift patterns and ward rounds
- Cleaning rotas
- Meal times
- Visiting times
- Intrusive medical equipment (equipment with loud alarms)

## 3.2 Ward Locations

The following measurements were made at each location:

| *Position* | *Length of measurement period* |
|---|---|
| Nurses' Station 1 | 2 consecutive weeks |
| Nurses' Station 2 | 1 week |
| Single Patient Room A | 1 week |
| Single Patient Room B | 1 week |
| 4 Bed Bay A | 2 consecutive weeks |
| 4 Bed Bay B | 1 week |

It should be noted that '1 week' is one set of weekday data (Monday to Friday)

## 3.3 Microphone Positioning

Care had to be taken over the positioning of the microphone as the ward was operational and it was important that staff were happy that the location of microphone did not impact on their duties. It was not feasible to position the microphone in the ideal location, close to a bed head, for two reasons: firstly there was too much equipment already situated there; secondly, the ward manager felt that the patient/family would find having the microphone so close intrusive. Also, beds are not permanent and are wheeled in and out of the ward so equipment could easily be knocked if left close to the bed head. Cleaning is another important issue which had to be considered. A microphone placed out of reach is unlikely to be touched and therefore to need specific cleaning for purposes of infection control. Given the sensitive nature of the microphone it was important to ensure it would not be damaged due to contamination by cleaning fluids.

It was decided that to record comparable noise levels it was extremely important to ensure that the microphone could be located in similar positions in similar locations (ie in the two single patient rooms; at the two nurses' stations; and in the two 4 bed bays).

For measurements made in the two four bed bays, the microphone was positioned 2m from the ground on a set of lockers situated towards the rear of the ward. For measurements made in single patient rooms the microphone was located on the pull-down bed housing, approximately 2 m from the ground, facing down towards the patient bed opposite.

Nurses' stations also presented a problem as they are extremely busy places and the equipment could easily be knocked. In both instances the microphone was positioned on a shelving unit, 2.5m from the ground, facing down towards the desk area.

## 3.4 Equipment Used

The following equipment was used throughout the Pilot Study:

- Norsonic 140 Class 1 Sound Level Meter
- Norsonic Sound Calibrator type 1251 (114 dB @ 1000Hz)
- Norsonic Environmental Case with two additional heavy duty batteries
- 5 m microphone extension cable
- Mini microphone tripod

For all long term measurements, the sound level meter (SLM) was placed in an environmental case with two heavy duty batteries. The life of the batteries was such that a full week's worth of data could be collected at each measurement position. A 5 m extension cable allowed the microphone to be placed away from the environmental case on a small tripod, which afforded flexibility regarding the microphone positioning.

## 3.5 Acoustic Measurements

To allow an acoustically robust picture of the noise climate to be obtained, the following parameters were measured: $L_{A\ eq\ (1hr)}$, $L_{AFMAX}$, $L_{AF90}$ and $L_{ZF}$(SPL).

The third octave band spectrum of the sound was also measured.

The SLM used in the study incorporated built in 'trigger' functionality. This trigger functionality works by generating a sound file each time the A-weighted sound pressure level exceeds a set threshold. There are a number of parameters that can be changed to control the length and starting point of this sound file.

The creation of a 'trigger' file enables the source of high level noise to be identified and is invaluable in building up a picture of the sources of high level noise over time.

## 3.6 Presentation of Measurements

Both the World Health Organization[4] and the current acoustic guidelines HTM 08-01[5], list noise levels for day time and night time. Day time is defined as the hours between 07.00 – 23.00 and night time as the hours between 23.00 and 07.00.

For comparison with these guidelines all tabulated results are shown as separate night time and day time values. It will be seen in section 4 that measured levels presented graphically for a 24 hour period clearly show the division between night time and day time.

Average levels presented are the arithmetic averages of hourly A-weighted equivalent continuous sound pressure levels.

# 4 RESULTS

Table 1 shows the average $L_{Aeq}$ levels measured at each position in the ward during day time and night time over a 5 day period (Monday to Friday). It can be seen that levels measured at the nurses' stations and in the 4 bed bays are fairly consistent, while the single room levels are less so. The results from each measurement position are discussed in detail below.

Table 1 Average day and night $L_{Aeq,1hr}$ levels measured over a 5 day week

| **Position in ward** | **Weekday $L_{Aeq,\ 1hr}$ dBA** | |
|---|---|---|
| | **Day 7.00-23.00** | **Night 23.00-07.00** |
| **Nurses Station 1 Week 1** | **57.5** | **46.5** |
| **Nurses Station1 Week 2** | **55.3** | **47.3** |
| **Nurses Station 2** | **58.9** | **49.2** |
| **Single Patient Room A** | **48.8** | **33.8** |
| **Single Patient Room B** | **55.1** | **44.8** |
| **4 Bed Bay A Week 1** | **50.0** | **39.8** |
| **4 Bed Bay A Week 2** | **51.8** | **40.9** |
| **4 Bed Bay B** | **49.9** | **39.0** |

## 4.1 Nurses' stations

The average night and day time $L_{Aeq,1hr}$ levels measured at the two nurses' stations are shown in Table 2 for each day, together with the standard deviations. (Note that the results for nurses' station 1 are averaged over two weeks.)

Table 2 $L_{Aeq,1hr}$ levels measured at nurses' stations

| | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Night | Day | Night | Day | Night | Day | Night | Day | Night | Day |
| **Nurses' Station1** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 50.2 | 58.8 | 45.3 | 54.0 | 44.8 | 55.9 | 47.6 | 56.2 | 46.6 | 57.0 |
| Std Dev P | *± 5.1* | *± 3.3* | *± 2.6* | *± 4.0* | *± 3.1* | *± 3.7* | *± 3.7* | *± 3.3* | *± 3.5* | *± 2.9* |
| **Nurses' Station 2** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 44.5 | 56.2 | 50.2 | 59.1 | 50.4 | 59.6 | 50.3 | 59.8 | 50.7 | 60 |
| Std Dev P | *± 2.8* | *± 3.9* | *± 1.5* | *± 3.2* | *± 1.4* | *± 2.2* | *± 1.9* | *± 3.2* | *± 2.9* | *± 1.8* |

Figure 2 shows the $L_{Aeq,1hr}$ levels over 24 hours, averaged over the five days (Monday to Friday), for each nurses' station.

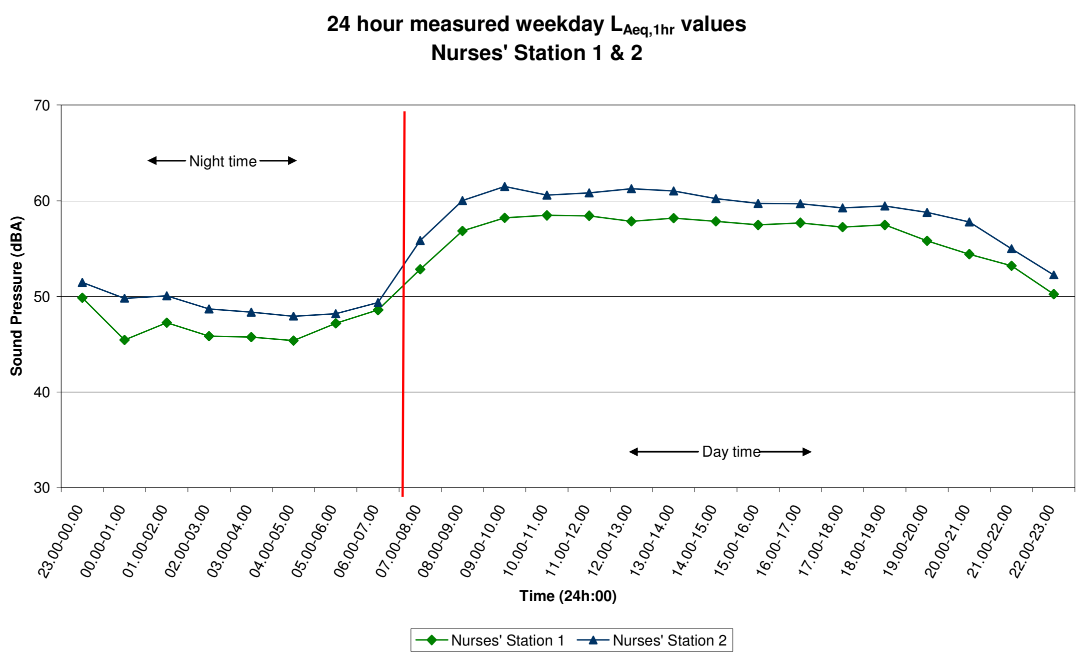


Figure 2 Average $L_{Aeq,1hr}$ levels over 24 hours for nurses' stations 1 and 2

Table 2 and Figure 2 clearly illustrate that the measured levels at the nurses' stations follow a consistent pattern over time and that those measured at the larger nurses' station are generally higher, as would be expected as there are generally more staff located here. The division of night time and day time appears to fit the data well, with an average difference between levels measured during the day and at night of 9.6 dB.

### 4.1.1 Sources of High Level Noise

To build up an accurate picture of the noise climate on the ward it was necessary to identify the sources of high level noise. It was not practical however, to have an observer on site noting down details of each occurrence of high level noise, so the trigger functionality of the SLM was used (see section 3.1.5). After some experimentation with different settings, the most appropriate threshold for capturing identifiable intrusive noise events was found to be 70 dBA.

After an initial analysis it became clear that there would always be a percentage of the 'trigger' files which would be difficult to accurately identify. These were generally related to the everyday bumps and knocks associated with human activity in the measurement area. Examples are general administrative tasks; the wheeling of an object across the floor; an object being placed on the floor.

However, many events could be clearly identified and so are useful in building a picture of the sources of high level noise at the nurses' stations. These include:

- Staff to staff conversation
- Staff talking on the telephone
- Staff talking with patients
- Patients talking
- Ward doorbell
- Nurse call
- Internal telephone ringing
- Patients crying or screaming
- Footsteps
- Laughter
- Furniture scraping on the floor
- Coughing
- Replacing the telephone receiver
- Medical equipment bleeps and alarms
- Mobile phones ringing
- Closing ring binders

For all the events listed, the extensive data captured by the SLM allow for a more detailed analysis of noise levels and frequency content if required.

### 4.1.2 Further analysis of noise sources

The ward manager was particularly interested in capturing occurrences of the nurse call system, internal telephone and the door bell, which were considered to be too loud, especially during the night. It was thought that the nurse call system was designed to have a night setting, but it appeared that this was not working correctly.

Using the trigger functionality of the SLM, each occurrence of these high level noise sources could be identified within the collected data. The maximum levels in dBA (measured on a 'fast' setting) of each type of noise source were arithmetically averaged; the results are shown in Figure 3, and compared with the $L_{Aeq}$ and $L_{A90}$ day and night time levels.

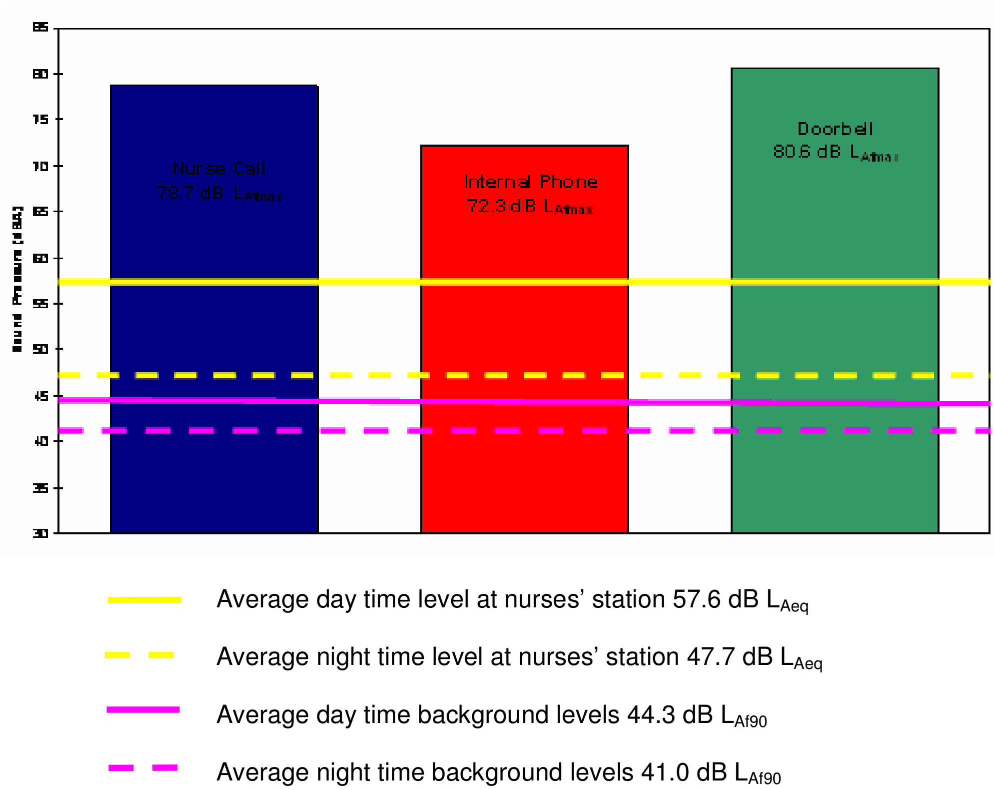


Figure 3 Maximum levels ($L_{Afmax}$) of the nurse call system, internal telephone and ward doorbell

It can be seen that the $L_{Amax}$ levels of the three sources shown exceed the day time $L_{Aeq}$ by between 15 and 23 dBA, and the nighttime $L_{Aeq}$ by between 25 and 33 dBA; and exceed the $L_{A90}$ levels by 28 to 36 dBA (day) and 31 to 39 dBA (night).

## 4.2 Single patient rooms

The average night and day time $L_{Aeq,1hr}$ levels measured in the two single patient rooms are shown in Table 3 for each day, together with the standard deviations.

Table 3 $L_{Aeq,1hr}$ levels measured in single patient rooms

| | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Night | Day | Night | Day | Night | Day | Night | Day | Night | Day |
| **Single Patient Room A** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 31.8 | 47.7 | 33.7 | 47.7 | 32.5 | 48.8 | 37.5 | 49.1 | 33.5 | 50.5 |
| Std Dev P | *± 3.7* | *± 6.7* | *± 6.7* | *± 6.0* | *± 3.8* | *± 4.9* | *± 8.7* | *± 8.0* | *± 6.2* | *± 7.7* |
| **Single Patient Room B** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 41.4 | 52.4 | 48.4 | 57.1 | 49.9 | 61.9 | 39.3 | 50 | 44.7 | 54 |
| Std Dev P | *± 5.9* | *± 3.4* | *± 4.8* | *± 5.8* | *± 6.7* | *± 5.8* | *± 3.8* | *± 6.5* | *± 4.5* | *± 6.1* |

Figure 4 shows the $L_{Aeq,1hr}$ levels over 24 hours, averaged over the five days (Monday to Friday), for each single patient room..

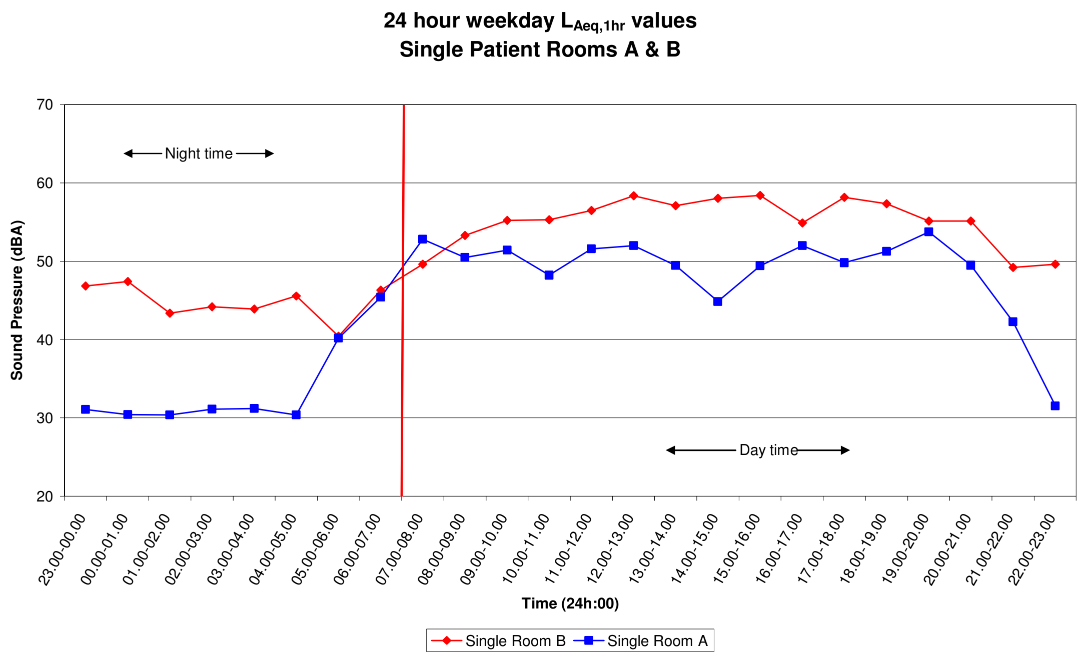


Figure 4 Average $L_{Aeq,1hr}$ levels over 24 hours for single patient rooms A and B

Table 3 and Figure 4 show that, unlike the nurses' stations, the levels for the two single patient rooms vary significantly. The following section looks at the data in detail and attempts to understand why this should be the case.

### 4.2.1 Sources of high level noise

By examining the trigger files captured during the measurement periods it is possible to build up a picture of the numbers and types of high level noise sources.

The overall numbers of triggers files created in each room were very different. There were nearly 2898 triggers files created during the measurement period in room B and only 608 in room A. This can be explained in part by the severity and type of the patient's condition. The patient occupying room B for the majority of the measurement period required a large amount of clinical intervention during their stay which resulted in 1012 (35%) of all trigger files being caused by medical equipment alarms, 458 (16%) by patient procedures (ie. visits by clinicians to provide a level of care) and 340 by conversations between nursing staff and parents (12%).

Figure 5 shows the percentages of trigger events by type for single patient rooms A & B.

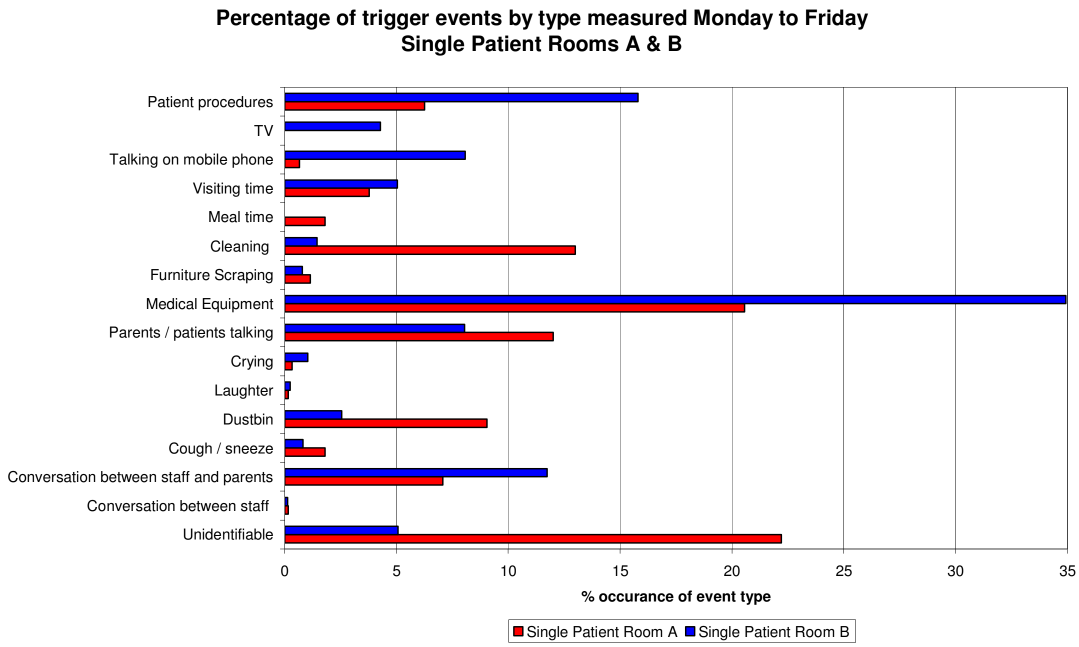


Figure 5 Percentages of triggers events by type for single patient rooms A & B

It can be seen that the percentages of trigger files created by the use of televisions and mobile phones is very different between room A and room B. During the measurement period in room B there were 124 instances (4%) where the television was loud enough to generate a trigger file, and there were 224 instances (8%) where conversations on mobile phones were loud enough to generate trigger files. There were no triggers generated by television usage in room A and only 4 instances (1%) generated by mobile phone usage in room A.

Table 4 provides some examples of the maximum levels ($L_{Amax}$) of some high level noise events that were identified by the creation of trigger files in single patient room A.

Table 4 High level noise sources

| **Event** | $L_{Af,MAX}$ **(dB)** |
|---|---|
| Fluid Pump Alarm | 89.1 |
| Room Cleaning | 79.3 |
| Dustbin | 79.2 |
| Patient Visit | 75.7 |
| Bin Bag Changing | 75.5 |
| Patient Procedure | 81.5 |

## 4.3 4 bed bays

The average night and day time $L_{Aeq,1hr}$ levels measured in the two 4 bed bays are shown in Table 6 for each day, together with the standard deviations. (Note that the results for 4 bed bay A are averaged over two weeks).

Table 5 $L_{Aeq,1hr}$ levels measured in bed bays

| | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Night** | **Day** | **Night** | **Day** | **Night** | **Day** | **Night** | **Day** | **Night** | **Day** |
| **4 Bed Bay A** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 39.0 | 50.9 | 42.7 | 52.2 | 36.8 | 51.2 | 43.5 | 50.8 | 40.0 | 49.5 |
| Std Dev P | *± 5.8* | *± 4.1* | *± 3.7* | *± 4.2* | *± 5.2* | *± 4.8* | *± 6.2* | *± 4.8* | *± 4.9* | *± 4.5* |
| **4 Bed Bay B** | | | | | | | | | | |
| $L_{Aeq}$ (dB) | 38.2 | 47.1 | 39 | 50 | 39.4 | 48.8 | 37.9 | 49.6 | 40.4 | 54.2 |
| Std Dev P | *± 0.7* | *± 5.9* | *± 3.1* | *± 4.3* | *± 1.8* | *± 4.8* | *± 0.4* | *± 4.1* | *± 2.4* | *± 4.5* |

Figure 6 shows the $L_{Aeq,1hr}$ levels over 24 hours, averaged over the five days (Monday to Friday), for 4 bed bay A and 4 bed bay B.

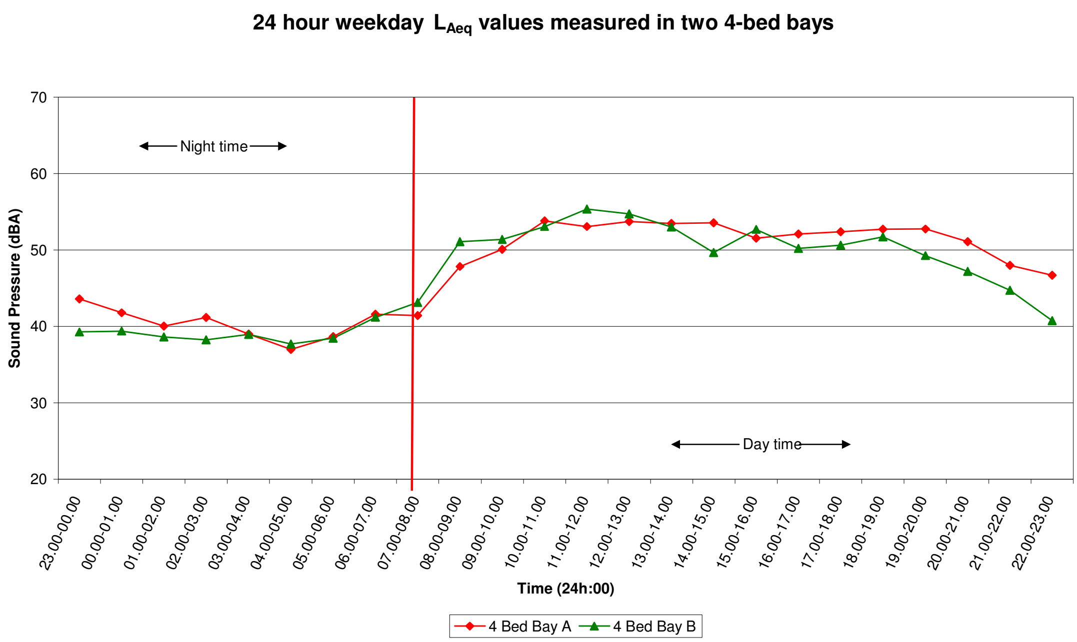


Figure 6 Average $L_{Aeq,1hr}$ levels over 24 hours for 4 bed bays A and B

Table 5 and Figure 6 clearly show that the levels measured in the two 4 bed bays were very consistent over time.

Figure 7 shows the measured levels from the two 4 bed bays and the two single patient rooms. Single patient room B was the highest overall level. As discussed, this may have been partially due to the level of care required by the patient, leading to high numbers of triggers caused by medical equipment alarms, patient procedures and conversations between staff and parents.

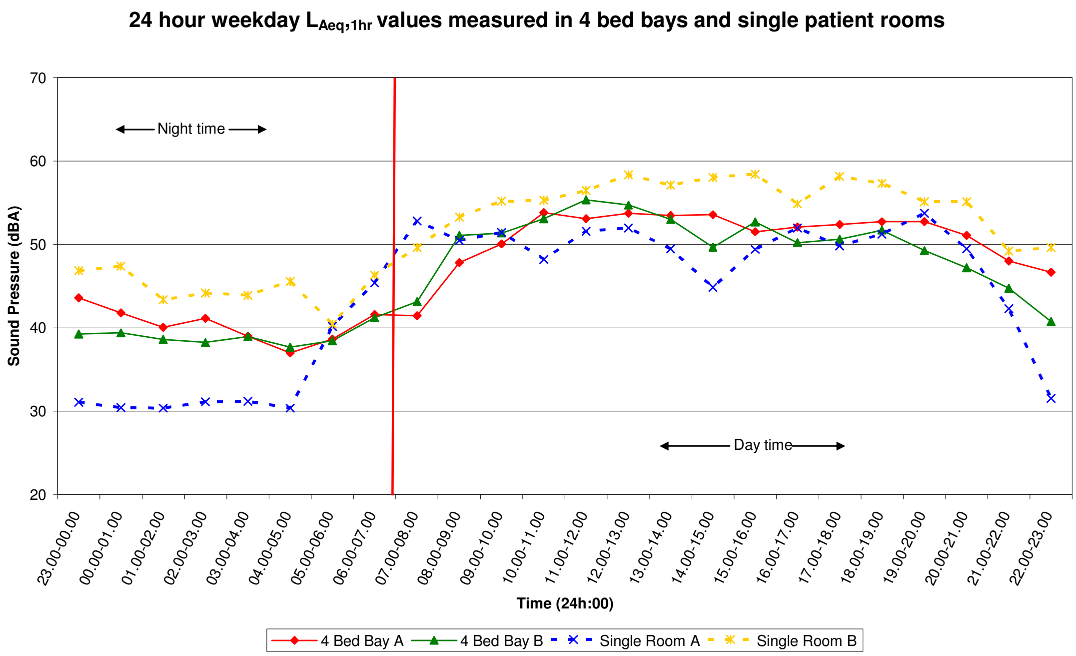


Figure 7 Average $L_{Aeq,1hr}$ levels over 24 hours for 4 bed bays and single patient rooms

### 4.3.1 Sources of high level noise

Although Table 5 and Figure 6 clearly show that the levels measured in the two 4 bed bays were very consistent over time it can be seen in Figure 8 that the sources of high level noise fluctuate from week to week. Large differences can be seen between patient procedures, medical equipment alarms and crying. All these are of course dependent on the severity and type of patient's condition. As patients on this ward undergo different levels of surgery it is not surprising to find largely differing levels in these instances.

In each bay, the microphone was positioned next to the ensuite bathroom door. In 4 bed bay A the door had a loud locking mechanism which caused a large percentage of trigger files to be created over the two week measurement period. The locking mechanism of the ensuite bathroom door in 4 bed bay B did not create any trigger files.

Due to greater activity within the 4 bed bays, it appeared to be harder to accurately identify the source of high level noise. Figure 8 shows percentages of 'unidentifiable' triggers ranging from 22% to 30% for the three measurement periods.

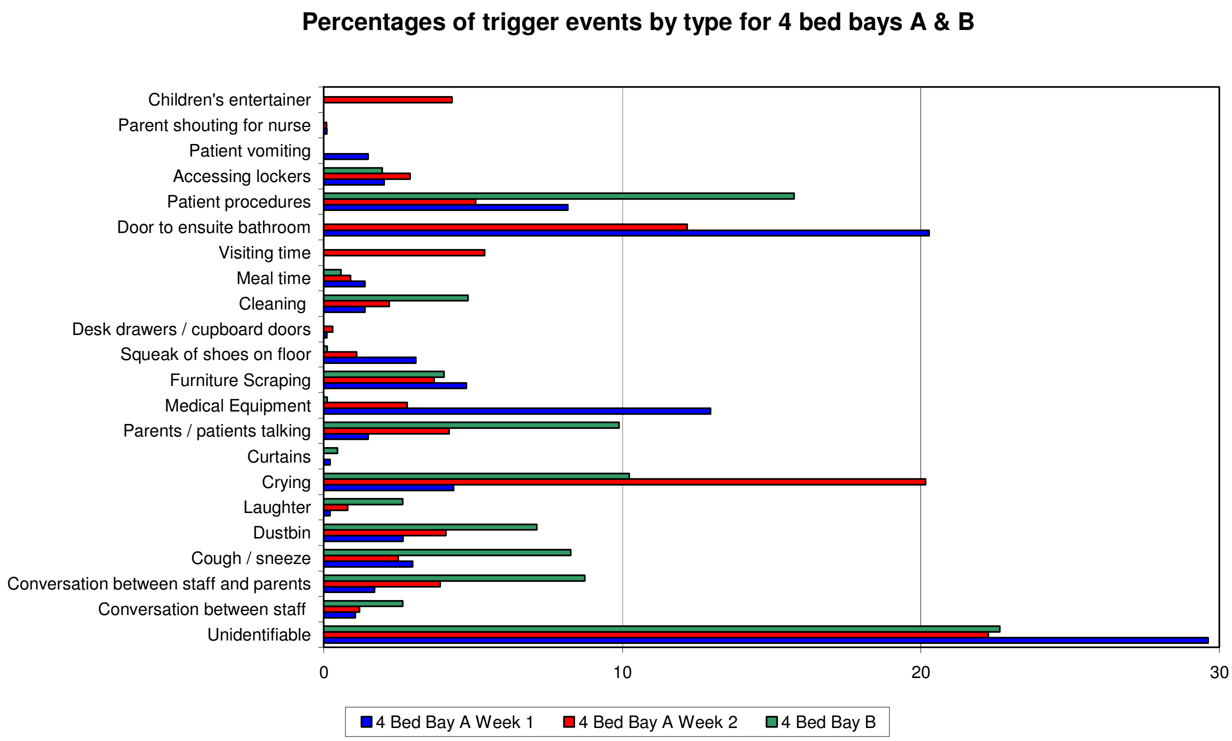


Figure 5 Percentages of trigger events by type for 4 bed bays A & B

# 5 CONCLUSIONS

An extensive pilot study has been carried out in which noise levels have been monitored in various locations in a children's Orthopaedic Ward. In addition to monitoring noise levels, the sources of high level noise have been identified where possible. The survey has shown that it is possible to carry out unobtrusive measurements in a hospital environment without interfering with the activities of staff and the care and comfort of patients, in accordance with infection control policies. However, managing such surveys requires a thoughtful and sensitive approach to issues such as the location of microphones and associated equipment.

Undertaking the pilot study has provided useful insights into how to carry out further surveys in in-patient wards in adult hospitals. It has shown that the use of trigger files to identify dominant noise sources can provide further insight / information into the causes of high level noise without the need for an observer.

The robust data set produced as result of this pilot helps to aid understanding of the acoustic environment within the hospital ward. The identification of high level noise sources on the ward could be used to positively influence noise control or management strategies in the future.

In parallel with the noise level measurements and high level noise source identification, noise questionnaire surveys of staff and patients have been undertaken. The results of these will be analysed and compared with the objective survey results presented here.

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