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Sound in Clinical Environments (SILENTS): Overview of a mixed methods intervention to improve acoustic comfort in a hospital ward in London (UK)

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ABSTRACT

An adequate acoustic environment in hospitals is considered crucial for avoiding stress and distraction in staff, and for promoting rest and recovery in patients. These goals are often challenged by design, technical and behavioural factors, even when the awareness of the impact of sounds in hospitals is generally higher than for other spaces. As a response to the high noise levels reported by staff members of the Acute Assessment Unit at Chelsea and Westminster Hospital in London, the ongoing project Sound in Clinical Environments (SILENTS) was created with the aim of improving the experienced acoustic environment. In this paper, we provide an overview of the different stages of the intervention being conducted, which will use qualitative and quantitative methodologies for the evaluation of the situation before and after the intervention. The assessment strategy included long-term SPL measurements through fixed monitoring, personal dosimeters and portable devices, questionnaires for patients and interviews with staff members. Part of the preliminary quantitative results from this assessment are presented and discussed in the context of the specific limitations that can be encountered while undertaking noise analysis and interventions in healthcare environments.

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1. INTRODUCTION

Sound levels in acute clinical environments have been increasing over recent decades [1]. Excessive sound levels in clinical environments can have a significant impact on the wellbeing of both patients [2] and staff [3], and may also increase the risk of medical errors [4,5].Whilst previous studies in this area have documented high sound levels in clinical spaces, few have evaluated the effectiveness of noise reduction measures [6]. Therefore, there is a need to evaluate potential noise mitigation measures within the built environment, in particular measures that can incorporated into a busy working ward with minimum disruption.

In parallel to noise abatement other important qualitative aspects of sound must be considered, such as speech privacy and intelligibility [7], the quality of a soundscape as perceived by patients and staff, and their perceived control over sounds [8]. The diverse sounds that can occur in a clinical space, such as mechanical sounds, anthropogenic sounds and music, all have significantly different impacts on the psychological stress recovery of patients [9], so the collection and analysis of qualitative data is an essential element in any soundscape study.

This project investigates the impact of a series of noise mitigation measures in a ward at Chelsea and Westminster Hospital in London (UK), including the installation of acoustic absorbent ceiling tiles and wall panels, as well as other staff-facing measures. The impact of some of these interventions on overall noise levels will be examined, as will the impact on staff and patient experience.

2. METHODS

This study looks at the effectiveness and feasibility of implementing various noise reduction measures within a busy hospital clinical environment. For this, it was decided to perform an analysis pre- and post-intervention using quantitative and qualitative data collected through a variety of methods.

2.1 Quantitative data

To collect sound pressure level (SPL) in a continuous form during several months, seven Sonitus monitors (AS180 Sonisens) were installed around the ward. This offered valuable long-term data at different times of the day and the year, but limited the allowed possibilities for the positioning of the microphones. The monitors were installed on the wall in relevant spots along the ward's central corridor, within some of the ward's bays, and at the two staff stations (also located within the ward's central corridor). The monitors were positioned to capture sound levels whilst not interfering with the usual activities performed in each space. The closeness to the wall was considered in the interpretation of the measurements by correcting the values provided accordingly. In this case, and as recommended by the Sonitus provider and the literature, the correction consisted in the subtraction of 6 dB to the values obtained by the monitors. This correction, however, does not compensate for the different proximities of sound sources to one or the other measurement locations. Loud repeated sounds such as functional sounds from healthcare monitors, IT equipment, HVAC systems or closing doors that are closer to a measurement location will show increased measured levels in comparison to a further measurement location. This limitation, however, could similarly affect measurements done with other systems registering levels in long-term periods, as well as being a phenomenon experienced by listeners in the specific settings. With this consideration in mind, it was decided to assess approximate discrepancies between the levels captured by the Sonitus monitors and the ones that some of the listeners could experience in the corresponding space. For this, a series of additional measurements using a StudioSixDigital iTestMic microphone attached to a smartphone were done during short periods of time in the same ward areas of each of the long-term wall monitors, but positioned at ear level. These measurements were meant to serve as a reference of the sound levels in more centred spots in each assessed space, as the monitors had to be placed in the walls due to the limitations mentioned. The iTestMic data was averaged across a 5 minutes period, with the purpose of comparing the values with the L_{Aeq} levels obtained by the Sonitus monitors, which are calculated every 5 minutes.

Additionally, several staff members from a mixture of different roles within the ward wore individual Pulsar NoisePen dosemeters for the length of their shift to obtain data on personal noise exposure, with the option to remove them when they leave the ward or if the dosimeter becomes uncomfortable. As with the monitors, these devices measure sound but do not record it, thereby avoiding any breaches of patient confidentiality. In addition, the acquisition of the numerical characterisation of the sound environment in healthcare settings present numerous limitations related to safety and privacy. These limitations were considered with respect to the overall accuracy and representativeness of the data obtained before and after the interventions, and that could affect the final evaluation of the effectiveness of the measures applied.

2.2 Qualitative data

To investigate the impact of noise on patients' experiences and staff work, interviews with 5 staff members were carried out ahead of any intervention, as well as a questionnaire completed by 17 patients. These preliminary qualitative data are summarised below and serve here to describe the kinds of detail which will eventually accompany the quantitative data. Additional interviews and questionnaires are being conducted at the moment of writing this paper to similarly assess the perspectives of staff and patients after the acoustical intervention described in Section 2.3.

This data aims to complement the characterisation provided by the quantitative results with individual accounts of how the sound environment was experienced. The content of the interviews and the questionnaires are being analysed through thematic analysis [10]. These detailed experiences give more information about sound sources, their origin and reasons for their presence, and are therefore helpful in designing possible solutions focused on specific sounds or behaviours that could be overlooked by the quantitative measurements alone. The qualitative exploration of the reported perceptual experiences of the users is also intended to provide a human-centred perspective on the situation pre-intervention and the improvements achieved after the modifications, and that may not be reflected in the post-intervention quantitative data.

Summaries of participants' experiences and preliminary data describing the acoustic environment in the ward are provided below.

2.2.1 Summary of baseline interviews with staff

As mentioned, the conduction and analysis of the data from the interviews to the staff are still ongoing. However, some excerpts from these are given below which indicate some of the most common concerns reported with respect to noise, such as not being able to focus on conversations, or the stress of having to pay attention to all the sounds around in case they need to attend their patients:

"It's very loud. There's a lot of additional noise. For example, today, (which we have probably every day), we had someone cleaning the floors, and I was trying to focus on the consultation and listen to the consultant and the patient, and I couldn't hear a single word of what was being said. There's also a lot of machines going off at the same time. In our office there are lots of people having several different conversations, on the phone, trying to hear what's on the phone, and if you're trying to have a conversation on the phone there's just a lot of noise going on, it's very difficult to hear conversations and focus."

"It's hard to block it out because you need to be on alert for alarms, you need to be on alert for someone screaming and it might be your patient, you need to be on alert for if someone's looking for you."

The exposure to high sound levels and multiple sound sources that cannot be blocked out, while having to perform their medical duties, lead to high levels of exhaustion after long periods of time:

"It is very tiring when you get home after a 12-hour shift, all this noise, all the beeping… it's very overwhelming."

2.2.2 Summary of survey to patients

Preliminary results from the analysis of the surveys done to date show that participants aged 75+ living with presbycusis were more likely to report disruptions to sleep, daytime rest, or communication with staff or visitors as a result of noise on the ward. They also tended to report negative feelings more, including a sense that others (staff and patients) were not always considerate about noise (e.g. talking unnecessarily loud or not putting phones on silent) and feelings of resignation or lack of agency with regards to sound made by other patients or equipment beeping incessantly. Those who had spent most time on the ward (over the course of one or more visits) seemed slightly less likely to report that the sounds they heard were necessary; they were also less likely to identify specific sounds as being noticeable to them. Salient sounds were primarily speech (in decreasing order: other patients, staff, and visitors), with sounds of pain or distress being the next most commonly reported. Equipment beeps, phones ringing, clattering trolleys, squeaky wheels, footsteps, snoring, coughing, and doors closing were also noted. Other sounds included aircraft, infusion pumps, vacuum cleaners, coughing, footsteps, doors, bins, and cutlery. The most common cause of discomfort was the sound of other patients' distress, with one describing the sound as reminding them of their own mother's illness and thus making them cry. Two also highlighted distraction at waiting for an intermittent sound to restart (e.g. infusion pumps), with one describing frustration increasing with the cause being left unaddressed. This, as with phone conversations and noisy visitors, seemed to be perceived as inconsiderate.

Positive feelings relating to sounds were all reported across age, time on ward, and hearing loss groups. These included friendly interactions, kind words, and reassurance from staff, along with family visits (although these could engender feelings of loss for others), the food trolley, quiet conversations with staff, nurses' laughter, camaraderie with other women in the bay, and listening to Radio 4 and a meditation app on headphones.

Changes perceived in the soundscape over time were mixed, with some people perceiving daytimes as noisier than nights, others perceiving nights noisier than days, and visiting hours (described as sounding 'like a fish market') also cited more than once. Shift changeovers, morning rounds, and ambient street sounds (particularly motorbikes) were also described as noticeably varying over time.

When asked what changes they would make to the sound of the ward if they were able to, participants most often mentioned greater use of headphones by other patients, along with increased awareness of the need for quiet (especially in the corridor adjoining the bays, with doors typically open or no doors), separate spaces for staff conversations, such as a staff room, staff exerting greater control over noisy patients and equipment, and the provision of earplugs or headphones. Limiting visiting hours; moving equipment more quietly; moving distressed, shouting, or coughing patients elsewhere; and further separating or reducing the size of bays were also mentioned (the bays in the ward have 4, 5 and 6 beds). Modifications to make equipment quieter were also mentioned, such as fixing squeaky wheels or adjusting door closers. While some participants requested background classical music, more expressed a keenness to avoid adding new sounds or recommended headphones for music provision.

The accounts from staff and patients suggest that a significant improvement could be experienced with measures such as the use of quieter cleaning equipment or adequate maintenance and use of building elements such as doors and bins. Some behavioural factors could facilitate the reduction of overall background noise and also annoyance due to the perception of higher levels of consideration from staff, patients and visitors. For example, promoting the use of headphones by patients and visitors who want to listen to music or watch videos could have a positive effect on other patients' rest.

While the use of earplugs and noise cancelling headphones can be useful to help patients rest and sleep, it is important to ensure that noise levels are adequate for both, patients and staff, reducing the level and types of noise sources when possible, and increasing the awareness of the impact of noise among all users.

2.3 Noise mitigation actions

From the experiences collected from the staff members and the investigators visiting the ward, one of the problems identified was the lack of sound absorption in the most problematic spaces, which affected the perception of the sound environment and speech intelligibility, leading users to increase the volume of their voice to be able to communicate. To address this, it was decided to install high-performance acoustic ceiling tiles and wall panels in the ward's central corridor. It was not possible, however, to perform typical measurements such as reverberation times, as that would have interfered with the clinical activity in the ward. To make the wall panels more aesthetically pleasant, the project collaborated with the local artist Bella Gomez to produce artworks that were printed on to the panels prior to installation.

The team will also explore possible further actions oriented to reduce noise levels, including working with staff to increase awareness around noise in clinical environments.

Ethical approval was granted by North West - Haydock Research Ethics Committee (reference 22/NW/0166).

RESULTS AND DISCUSSION

Preliminary results from Sonitus monitors

The data reported here correspond to preliminary results of the analysis being carried out by the investigators following the ceiling tile and wall panel interventions. Ranges between minimum and maximum LAeq levels pre intervention, mean LAeq levels pre and post intervention, and evolution of the LAeq levels across 24 hours pre and post intervention are presented below.

The ranges of sound levels registered by the monitors show a considerable difference between the maximum and minimum levels, especially in the bays, where it can be quieter at some hours during the night and louder from people or devices during the day. Fig. 1 shows the ranges between the minimum and maximum LAeq levels before the intervention (corrected, averaged over periods of 5 minutes) for a whole month in six of the spaces being monitored.

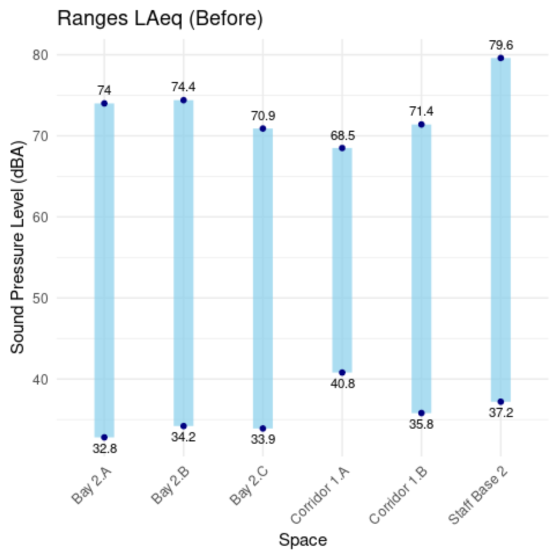


Figure 1. Ranges between minimum and maximum L_{Aeq} levels registered before the intervention during one full month in six of the spaces monitored.

Preliminary analysis of the data being obtained after the interventions show a significant impact on the sound levels. As shown in Table 1, the mean LAeq levels in both corridors present a reduction of 5 and 7 dB respectively during the day, and of 3.8 and 6.5 dB during the night, in the data obtained for two comparable weeks before and after the intervention (Week 3 in 2024 and 2025). There is also a reduction in the mean levels at Staff Base 2 during the day and night, as seen in the ranges of maximum and minimum LAeq values. Measurements from the bays, where there were no direct interventions, show light reductions of the mean LAeq values (with the exception of the levels in Bay 2.A, that presents a 0.5 dB increase in the mean values for the night). Although these reductions could be the result of casual differences in the events taking place during the two different periods being compared, it is also possible that there was an indirect effect of the acoustical

interventions implemented, as well as some behavioural factors due to a higher awareness about the impact of noise after the intervention and the qualitative investigations.
These preliminary results showing a reduction of 4-7 dBs are in agreement with what was expected based on similar interventions using acoustic absorbers in hospital wards [11]. Both day and night mean levels are, however, still over the recommended levels indicated in the WHO guidelines (LAeq of 35 dBA in patient treatment and observation rooms, and 30 dBA in ward rooms [12]).

Table 1. Mean L_{Aeq} levels (corrected) during one full week before and after the interventions for six of the spaces monitored (three in the central corridor where the intervention took place, and three in adjoining bays where there was no intervention). Day levels correspond to the logarithmic average of the hourly levels between 8am and 10pm, while night levels correspond to levels between 10pm and 8am. L_{Aeq} levels were calculated over periods of 5 minutes, averaged for each hour of the day, and then for day and night periods.

Space	Mean L_{Aeq} Day (dBA) Before	Mean L_{Aeq} Day (dBA) After	Diffe-rence (dB)	Mean L_{Aeq} Night (dBA) Before	Mean L_{Aeq} Night (dBA) After	Diffe-rence (dB)
Corridor 1.A	59,0	54,0	*-5,0*	52,6	48,9	*-3,8*
Corridor 1.B	57,9	50,9	*-7,0*	52,6	46,2	*-6,5*
Staff Base 2	57,5	52,2	*-5,2*	51,9	46,2	*-5,8*
Bay 2.A	54,2	52,1	*-2,1*	50,4	50,9	*0,5*
Bay 2.B	57,0	56,2	*-0,8*	52,5	49,1	*-3,4*
Bay 2.C	55,5	54,9	*-0,6*	49,4	48,7	*-0,7*

The profile of the L_{Aeq} levels (corrected, averaged over 5 minutes periods) obtained in the Staff Base 2 during seven consecutive days before and after the intervention are presented in Fig. 2. It can be observed that in both cases there are considerable differences between day and nighttime levels, with post-intervention levels being lower for both periods.

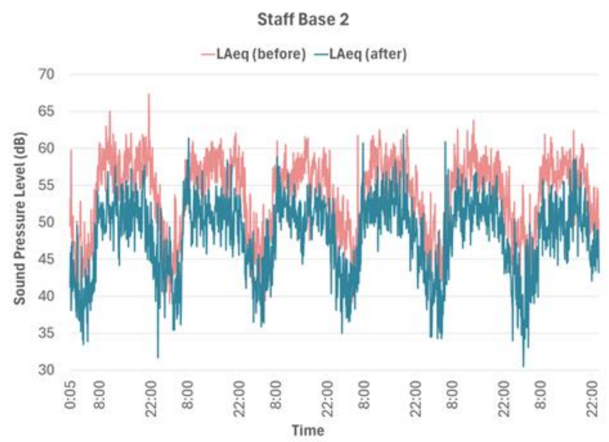
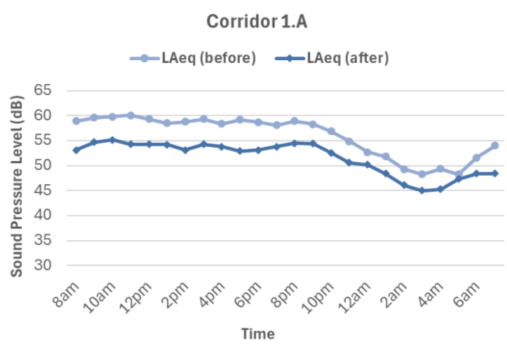


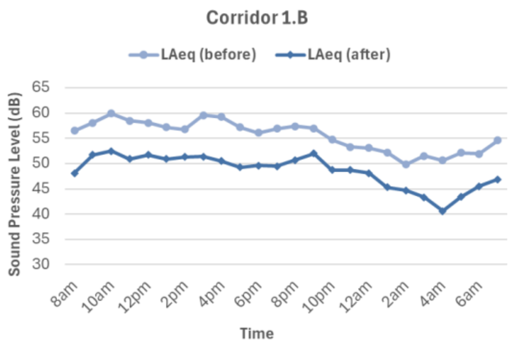
Figure 2. L_{Aeq} levels for Staff Base 2 during seven days before and after the intervention.

Comparisons across different times of the day before and after the intervention also show a consistent decrease in sound levels in the spaces where the absorbent material was installed. Fig. 3 presents the LAeq levels corresponding to the logarithmic average of the hourly levels across a seven day period pre and post intervention in these spaces (Corridor 1.A, Corridor 1.B, and Staff Base 2). The levels of reduction observed range from 1 dB at 5 am in Corridor 1.A to 10 dB at 4 am in Corridor 1.B, with average differences of 4.4 dB for Corridor 1.A, 7 dB for Corridor 1.B, and 5.2 for Staff Base 2.

a)



b)



c)

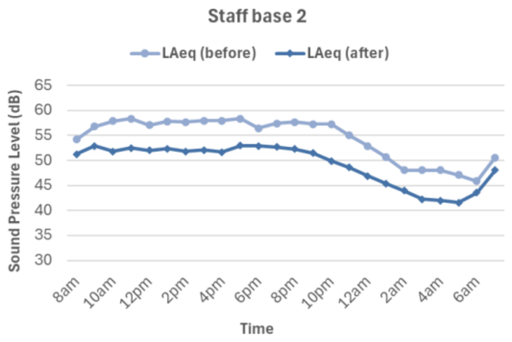


Figure 3. Averaged L_{Aeq} levels for (a) Corridor 1.A, (b) Corridor 1.B, and (c) Staff Base 2, for each hour of the day calculated over a seven day period pre and post intervention.

2.4 Dosemeters and iTestMic

A total of five staff members wore the dosemeters for a shift in the ward. However, only three of the shifts had valid, complete data. Two of these were day shifts and one was a night shift. The average recorded noise exposure for these staff members is presented in Table 2.

Table 2. Measurements obtained with the personal dosemeters.

Shift	L_{Aeq}	L_{AFmax}
1 (8am – 6pm)	75.9 dB	120.0 dB
2 (8am – 6pm)	74.1 dB	101.1 dB
3 (7.45pm – 8.15am)	71.9 dB	111.7 dB

With respect to the measurements done with the iTestMic, there were mixed results. In some of the spaces, there were some important discrepancies obtained between the levels registered with the iTestMic and the corrected levels obtained with the Sonitus monitors for the same 5 minutes periods, with the corrected levels being lower than the levels from the iTestMic system. The differences ranged from 0.1 dB at Staff Base 2, 0.6 dB at Bay 2.A or 1.6 dB at Corridor 1.B, to 5.6 dB at Bay 2.C or 13.7 dB at Bay 2.A. These differences were somewhat expected, especially in larger spaces such as the bays, where the Sonitus monitors could be far from certain noise sources. As noted in the previous section, the limitations introduced by the necessity of situating the monitors in positions that are not ideal for the acquisition of accurate sound levels at all times were taken into account from the early stages of the project. It was considered by the investigators that the opportunity to obtain long-term measurements from spaces before and after different acoustical intervention could still provide relevant information about their effect, and also about the acoustic profile of the different spaces in both scenarios. It is also worth considering that, with respect to real exposure to noise, averaged levels calculated through a series of measurements from different positions in a space may also present different degrees of discrepancies with what different patients and staff end up hearing, especially in larger spaces. We believe this circumstance presents opportunities for future development of accurate methodologies optimised for settings with similar requirements with respect to physical space, privacy, and health and safety considerations.

3. CONCLUSIONS

This paper presents an overview of an ongoing mixed methods study aimed at the improvement of the acoustic comfort for patients and staff in a hospital ward. The study includes the characterisation of the acoustic environment before and after a series of noise reduction measures including an acoustical intervention, the evaluation of the improvement that these types of interventions can represent in such settings, and the qualitative exploration of the soundscape and the experiences of the users of the space. The preliminary results show a consistent decrease in sound levels in the spaces where the absorbent material was installed. Considerations are provided on the particular technical challenges for the positioning of the measurement instrumentation and acoustic treatment, challenges that can be common in healthcare environments.

4. ACKNOWLEDGMENTS

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