Improved perception of sound environments through room acoustic interventions

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According to research, noise levels in hospitals worldwide are perceived to be very high. At the same time, the awareness of the negative effects of noise on patients and healthcare staff has grown. Standards and policies are a great help to manage or eliminate noise in hospitals. An overview of international standards will be presented, showing various parameters and angles of approach, e.g. based on activity or room type. To further optimize the content, and stimulate the use of the standards, some countries have even defined healthcare specific standards. These can support the planning and the evaluation of the sound environment in those premises. New insights from research and case studies, as well as emerging laws, provide opportunities or even force us to improve the existing content of standards to meet future demands. Suggestions for that are based upon the subjective experience of people and could include the use of additional room acoustic parameters, such as reduction of sound pressure level and parameters addressing privacy. Finally, revision of standards provides opportunities for all stakeholders in the building project to understand the importance of room acoustics in relation to the quality of care and the well-being of patients and staff in health care environments.

1 Summary

Noise in hospitals is among the top complaints of medical staff. Negative effects of high sound levels on staff include burnout and depression, increased number of medical errors and increased chances of hearing loss. Occupational Health servants have a challenge in characterizing hospital noise and to find effective noise control approaches. Building codes and standards are generally either unavailable or show shallow content. However, case studies on the effects of room acoustic interventions show valuable information to be used to encounter the noise. One particular case at a Thorax ICU in Sweden shows how the use of sound-absorbing material improved working conditions.

2 Introduction

Healthcare not only is stressful for patients but also is a physically and emotionally demanding service to deliver. Negative effects of high sound levels on staff include burnout and depression, increased number of medical errors and increased chances of hearing loss. Creating or refurbishing an environment, to enable staff to perform to their best abilities, requires good planning. Several investigations and research projects have pointed out clear links between sound levels and the quality of care. The World Health Organization guideline values for continuous background noise in hospital wards are 35 dB, with night time peaks not to exceed 40 dB. However, many studies have shown that background noise levels in hospitals are much higher. According to researchers at Johns Hopkins, noise in hospitals throughout the world has been increasing by about 0.4 decibels per year since 1960. Background noise levels are typically 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB.(1-7) However, many noise sources are not easy to do anything about, such as mechanical and building noise. Involving acoustical engineers, architects and building experts is the best way of addressing the planning of renovations as well as the design of new facilities. Interventions that have proven particularly effective for reducing noise and improving acoustics in hospital settings include:

- Installation of high-performance, sound-absorbing ceiling tiles
- Elimination or reduction of noise from equipment
- Layout and zoning

Especially the room acoustic interventions appear to contribute drastically to improve working conditions. Studying this example helps give guidance for improvements after evaluation and reviewing processes of existing working environments.

3 Background

In consultation with Locum AB and the Work Environment Authority in Stockholm, Ecophon performed a case study at the Thorax ICU at the Karolinska University Hospital in Solna, Sweden. The purpose has been to clarify how room acoustics in a patient ward affect the staff's perception of the noise situation in that ward. Another purpose has been to develop a better understanding of how a set of requirements for room acoustics should be formulated in order to include the demands that a tenant makes regarding the working and the patient environment. The initiative was taken after discussions with the Work Environment Authority in Stockholm, which had conducted an inspection of the Thorax ICU in 2005. In connection with the inspection it was declared (Inspection Notice AIST 2005/51166) that the staff complained about the sound environment in ward 5. Subsequently Ecophon suggested that it could be of interest to evaluate how the environment would be affected if more sound absorbing material was installed.

In order to evaluate the change in the sound environment, the following measures were performed:

A. A group interview with two staff groups (2x5 people) to record how the sound environment was perceived.

B. Measurement of room acoustics to illustrate the acoustics in ward 5 before and after the changes.

C. Reconstruction of the ceiling with change of absorbers.

D. Group interview with two staff groups (2x5 people) to record how the reconstruction was subsequently perceived. 20 June 2006.

4 Description of the activities and the environment

The following is how the staff described the activities at the Thorax ICU (THIVA) during the first interview. High-tech specialist care is performed in the department, which is part of the Thorax Clinic of KS. The majority of the patients come to THIVA after having had open heart surgery as part of a care plan. The purpose of their stay is to be monitored at THIVA after their operation (post-operative care).

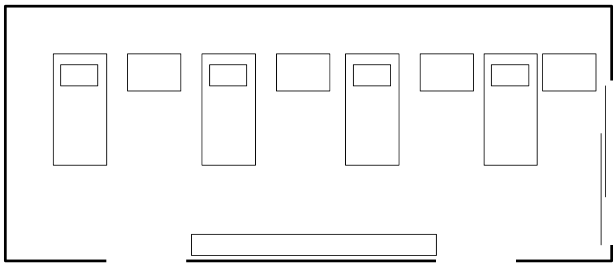

Image 1. General outline of ward 5 of THIVA. Ward 5 has four intensive care beds. The ward has two doors leading to a corridor and a sliding door (on the right) into a single room.

At best, the care period is approx. 24 hours, but certain patients remain for up to one month. The typical patient is elderly (often over 70) and frequently has undergone a bypass operation or a cardiac valve replacement. In the department and ward 5, the patients may either be under sedation or be sitting up in bed, fully awake.

Image 2. The corridor outside ward 5

Image 3. Each bed is surrounded by many different types of medical-technical equipment.

5 Group interview 1: Recording the noise problem

Following comments were gathered from the different staff groups on how the noise at their workplaces was perceived and what effects the noise had on their work and their wellbeing.
The environment/department is under considerable strain on account of equipment noise, visitors, cramped conditions and noise from general activity. The environment around the patient plays an important role. The time when a person is in need of peace and quiet is instead characterised by sensory stress in the form of noise and light, and the constant presence of other people. This has been linked to intensive care psychosis:

"After just 2-3 days in this environment, patients can enter a psychotic state due to lack of sleep and considerable stress."

Around the patient and each bed there are many different types of medical-technical equipment: pumps, pressure monitors, respirators, carbon dioxide monitors – and all of these have alarms for warning if a patient's condition changes:

"The carbon dioxide monitor and the respirator are the worst sources of noise. I think there are almost 30 different alarm signals linked to each bed, and learning to distinguish them and understand what they mean takes time. Because of this, hearing is an important tool in our work."

"The amount of medical-technical equipment increases constantly. Technical developments mean that we can save and treat far more patients now than we could beore. The disadvantages of this is that the equipment takes up space and the noise levels increase.

"More and more mobile phones are now included in the immediate patient environment, which also contributes to an increase in the sound level."

"Some of our colleagues are dependent on hearing aids. They notice a definite difference between ward 5 and ward 2." (Note: Ward 2 has another type of acoustic ceiling.)

"The working environment is intensive; it is demanding work, with patients who are frail. This means that you have to have a large number of staff in the room, which causes a considerable amount of noise. This in itself (apart from the noise from equipment) means that an excessively high noise level develops - too high to be considered satisfactory for the patient or for those who work in the room. All of this is particularly noticeable in ward 5."

"The noise situation means that you have to raise your voice when you talk and that you automatically feel that you make more noise. It is also difficult then to hear what the patients are saying, which means that they have to raise their voices."

"Communication with elderly patients is more complicated, since they are harder of hearing."

"In rooms with fewer patients, the situation is better and it is easier to work with quieter methods."

"Work is carried out in wards with 3-4 beds to save on staff. Single rooms and double rooms have meant that you have to employ more people and then costs increase."

Staff feel that what happens out in the corridor affects the noise level in the room.

"We try to keep the door shut but it's difficult since we have to move around a lot in our work."

Other symptoms of noise that the staff of ward 5 show, apart from the way the noise affects the immediate work situation, are that after work they feel tense, have headaches and ringing noises in their ears. This is most noticeable after having worked on ward 5. Most of the staff are quite definite that ward 2 is quieter than ward 5.

5 Conclusions from Interview 1

As is apparent from the comments above, ward 5 of THIVA is not organised in a way that is suitable for its purpose: the patients are close to each other, there are many staff, and the patients are in great need of care and of medical-technical equipment. A complete solution to the noise problem should probably include an initiative on a wide front or, possibly, new premises. In this case, we are interested in evaluating how the ceiling surface affects people's perception of the sound environment, although the final solution has many more aspects to it than this. The focus for the physical measurements that were performed within the framework of this project was on evaluating how the "acoustic response" altered. This gives information on how the room's surfaces contribute to building up the noise level in the room. This can be interesting information since the sound sources that were mentioned as being disturbing have many different aspects (equipment and noise from activity) and can be difficult to limit.

6 Acoustic measures

The change that was made in the premises involved increasing the amount of sound absorbing material in the room, thus altering the room's acoustics. The room, in the initial phase, was given a suspended ceiling (perforated plaster) with panels measuring 600x600mm. The room was otherwise well filled with furniture and equipment, which contributes to rapid sound energy decay in the room.

On the manufacturer's website the ability of the ceiling surface to absorb sound is described by presenting lab test results as per ISO 354. The absorption factor for the product is presented in Diagram 1 (orange line).

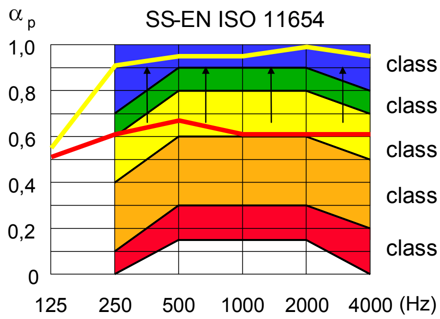

Diagram 1. The ability of different acoustic ceilings to absorb sound. The orange line shows the existing ceiling's ability to absorb sound in the frequencies 125-4000 Hz. The yellow line shows the performance of the new ceiling that was installed in order to influence the sound environment. According to the classification standard SS-EN ISO 11654, the lower product (orange line) is classified as a class C absorbent and the upper one (yellow line) as a class A absorbent.

The ceiling products that were used can be described on the basis of the method described in SS-EN ISO 11654 (see Diagram 1). The product that was already installed was in the Class C category and the product that was later installed is Class A. A surface that absorbs 100% of the incident sound has an absorption factor (α p) of 1.0. Using the test method that is used internationally (ISO 354), the ability of the surface to absorb sound of different frequencies is gauged. The following is the absorption performance in the field 125-4000 Hz.

Image 4. The picture on the left shows the ceiling in the initial phase. The picture on the right shows the ceiling surface after reconstruction. The reconstruction meant that the existing ceiling panels had to be replaced to as great an extent as possible with panels with a higher absorption performance.

On the basis of the ceiling that there was in ward 5, it was obvious that the environment could be improved by changing to a ceiling surface that had a higher absorption performance. To achieve this, an acoustic ceiling from Ecophon was chosen (Ecophon Hygiene Performance 40mm) on the basis of the demands placed by the activities in question, and this maximised the absorption (expressed in m2 Sabine). The acoustic performance of the new ceiling is illustrated before in diagram 1 (yellow line).

7 Acoustic measurement and change and change of sound environment

At the time the reconstruction was being carried out, a number of acoustic measurements were performed in order to determine how the ceiling surface could change the sound environment in the ward. It was also possible to assess the acoustics of the room without any kind of suspended ceiling. On the basis of the time that could be allocated for acoustic measurements, involving interrupting the use of the premises, the following measurements were made:

- Reverberation time T60 in seconds
- Noise level reduction (dB(A)) of a constant noise
- Sound propagation of a constant noise source in the room (the sound pressure level along the propagation path 3.8-10 metres).

The measurement technique and equipment are described in a report dated 28 April 2006 by Erling Nilsson Akustik AB.

8 Acoustic measurement and change and change of sound environment

The acoustic measurements were expected to give a picture of what the added absorption (in the form of a new ceiling) meant for the acoustics of the room. This, in turn, would indicate how the overall sound environment in ward 5 would be perceived.

Reverberation time

The measurement provided a picture of how the reverberation time of the room was affected by the change. The results are presented in the following diagram.

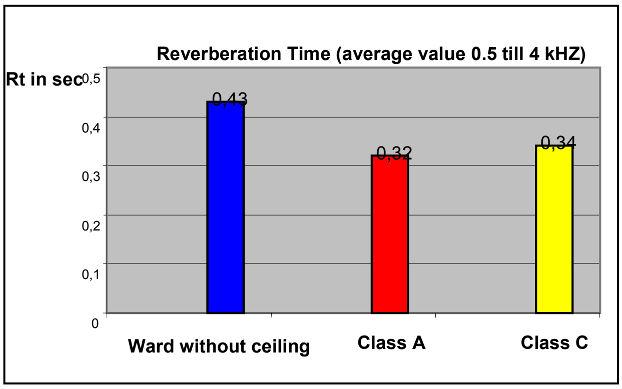

Diagram 2. Room acoustics. The columns show the reverberation time measured in seconds (average 500 Hz to 4000 Hz) for the different situations: the ward without an acoustic ceiling, the new ceiling (class A) and the original conditions (class C).

It is interesting to note that the measurement demonstrated that the room's reverberation time was not particularly affected by the extra absorption. It is also worth noting that the room's reverberation time without an acoustic ceiling (framework of cement) was relatively short, approx. 0.4 seconds.

Sound propagation and noise level reduction

In order to evaluate how the sound absorbing ceiling could contribute to reducing the noise level in the room (sounds from equipment, voices, activities, etc.), a measurement was taken with the help of a constant sound source (MLS signal), which produces broadband noise in the premises. The effect of the sound combined with the acoustic response from the room is registered by a sound level meter which is placed at different points in the room (in order to reach an average). For this purpose, the main interest was in examining the difference in sound level between the two cases, class C and class A.

The result showed a difference in sound level of 3.1 dB(A), which can be regarded as a considerable reduction. A reduction of the background level by about 3 dB(A) in a speech/communication situation has a significant effect on speech comfort, often resulting in the people speaking reducing their voice level and thus further reducing the noise level in the room.

Sound propagation

In ward 5 there are 4 beds along the length of the room. Looking at privacy and reduction of sound pressure levels it is interesting to evaluate the sound propagation in the room.

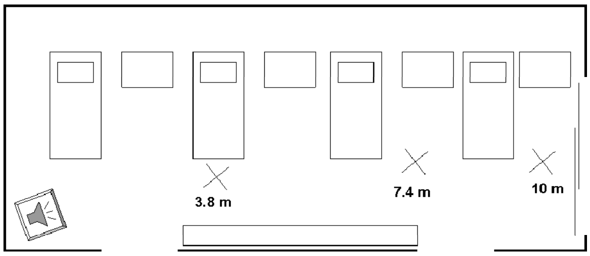

Image 5. The sound propagation was evaluated along the length of the room at distances of 3.8, 7.4 and 10 metres from the sound source.

The difference between the different situations is illustrated in the diagram below. It is clear that the added absorption in the form of class A absorbent contributes to muffling the propagation of sound in the room. The difference between C and A is about 3 dB(A) here as well.

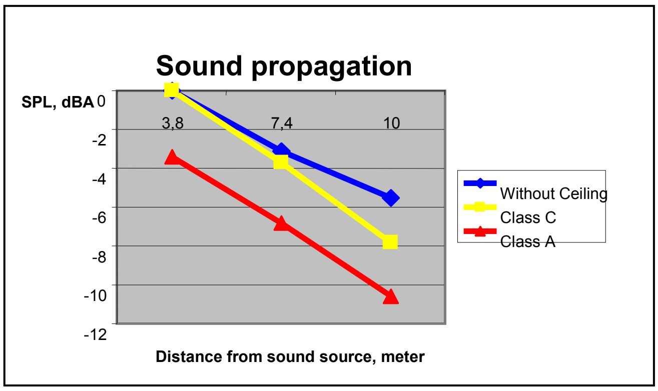

Diagram 3. Result of sound propagation measurement. The diagram illustrates the relative difference in sound level at the measurement points along the length of room. The sound level is thus 3-4 dB(A) lower at a distance of 3.8 metres as a result of the new acoustic ceiling.

Comments on the sound measurements

As shown by the presentation of the reverberation times measured, the results are not particularly affected in the frequencies given. Within the field of room acoustics, there is normally assumed to be a direct link between the added amount of absorption and the reverberation time of the room. In this case, the measurements do not support this assumption.

Current room acoustics theories (Sabine's formula and variations of the same) predict that the expected sound level reduction can be estimated on the basis of the difference in reverberation times. Calculations result in an expected sound level difference of 0.3 dB, which can be regarded as negligible. It is therefore motivated to evaluate whether the reverberation time is an appropriate parameter to use when trying to formulate a set of requirements for use in connection with future care premises of this character.

9 Interview 2: how is the change perceived?

The other set of interviews was carried out as far as possible with the same people as participated in the first set. It also turned out that half of the group in question had not worked on ward 5 since the alterations had been made and were therefore unable to describe fully how the situation had changed. Supplementary information was also acquired from the responsible head (head nurse), who had actively observed how the work on the ward was carried out prior to and after the ceiling alterations. The staff commented the alteration as follows:

"The noise feels more subdued."

"The noise from our equipment sounds softer."

"Less hard clang in the room."

"Certain colleagues say that they don't feel so tired after a day's work."

"I use a hearing aid and I notice a big difference. It used to feel chaotic when I was in the room. Now it is much better and much quieter."

"The staff thinks that it has felt calmer during this period. That could be one result of the improved environment."

"I have noticed that we talk more quietly. We used to talk louder. We don't raise our voices as much."

10 Conclusion

In relation to the problem that motivated the work on this case, it is possible to conclude that the noise situation on ward 5 has improved. It is difficult, however, to say unequivocally the degree to which the change will affect the staff's perception of the working environment in general. The total solution of the noise problem would probably involve moving to new premises.

It is clear that the "new sound environment" influenced the staff's behaviour as regards communication and their perception of the noise from equipment. It is interesting to note, too, that staff with hearing difficulties noticed a significant difference after the change in the sound environment. The second issue dealt with improved understanding for how sets of requirements for room acoustics should be drawn up for the future. At the same time as new premises are planned for functionality, sound environment requirements are often defined with regard to a certain reverberation time. This case demonstrates that this can involve risks since this parameter does not show any difference between the two situations involving different absorbents.

The reconstruction resulted in a noise level reduction (on the basis of a constant sound source) of about 3 dB(A) when more absorption was added to the room. A future set of requirements can be based on this and instead express the absorption performance of the ceiling surface (see classification standard SS-EN ISO 11654) as well as how much of the ceiling that is to be covered. Future field data will clarify the connection between the amount of absorption in the room and the sound level that can be achieved. Integrating the data in standards will be very helpful.