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## How do staff perceive the sound environment in operating theatres with the present standards and building regulations?

Maria Quinn

Saint-Gobain Ecophon (Hyllinge, SE), [maria.quinn@ecophon.se](mailto:maria.quinn@ecophon.se)

Standards and regulations regarding the sound environment in healthcare facilities are often focused on sound insulation to avoid overhearing and disturbances from adjacent rooms and the outdoors. The aspect of room acoustics is in many European countries regulated by only one parameter, Reverberation Time (RT). The Swedish Standard has set the maximum to  $RT < 0.6$  seconds in operating rooms. The objective of this survey was to assess if this level creates a comfortable sound environment where staff are confident to interpret oral instructions and alarm signals from the technical surveillance?

We conducted a survey of a total of 154 nurses working in operation rooms. The results showed that the sound environment has importance for the nurse's possibility to conduct their work in a good manner. Also the results show that staff often found it difficult to interpret the direction of the sound. The ability to concentrate was affected and poor sound environment was sometimes the cause of misunderstanding oral instructions. Perception of wellbeing due to the sound environment decreased when there was numerous staff in the room and the workload was stressful.

### Introduction

Healthcare facilities are complex buildings with many high demands on functionality, technical equipment and hygiene aspects. Its purpose is not only to be a workplace but a place of recovery, a place to welcome babies into the world and sometimes the place for someone to end their life. One needs to consider many more factors when designing a hospital than the average office workplace.

Noise is a recurring problem that has been researched in many hospitals. We have standards to regulate the impact of traffic noise as well as disturbing noise from one room to another. Sound insulation seems to be working well but there is a lack of good solutions to solve room acoustics [1, 2]. Meaning what happens with the noise generated within a specific room? In the Swedish Standard 25268 "Acoustics – Sound classification of spaces in buildings.." [1] the maximum reverberation time (T20) for an Operating Room is set to  $< 0.6$  seconds. This is to pass the minimum requirement by reaching the level Sound Class C. For improved acoustics one can also aim for Sound Class A which would include a T20 of  $< 0.5$  seconds. Verification that these requirements have been met can be achieved in one of two ways. Either an acoustical measurement according to SS 3382-2:2008 [3, 4] or a calculation of the estimated T20.

In the following it is our assumption that the operating rooms our respondents work in have met these demands.

With the building materials used and the shape of most room types we find that sound waves are being reflected back and forward with very little sound absorption and decrease of the sound energy. Hard, reflective materials affect sound in a non-desirable way and sound pressure level is far exceeding the World Health Organization limit of  $L_{eq}$  35dB(A) [5]. As the technological development continues to move forward in a rapid pace each new machine adds more and more sound into the room. Due to the nature of the work conducted, alarm signals are the traditionally most frequently used queue to signal for the staff attention. Lack of space in combination with a lot of staff and high flow of various support functions add on to the total amount of noise. The heightened sound levels are affecting both staff and patients in a negative way [6].

Operating theatres are one of the most technically advanced spaces in the hospital and they are especially exposed to high noise levels. It is often difficult to hear clearly what all the other staff in the room are saying and there is a risk of information being misunderstood or overseen [7]. Noise can cause several kinds of psychosocial effects or symptoms furthermore cause physical responses with the patient in form of heightened blood pressure, increased heart rate and respiration amongst other things [8]. Noise has a negative distracting effect on humans' performance at work as too much noise can lead to stressed and easily distracted staff. The impact of a poor sound environment can also become a security risk for the patients in terms of medical errors [9].

## Method

The surveys were handed out to randomly selected groups of nurses when the author conducted an educational presentation on sound and its impact on healthcare while visiting hospitals. One group of respondents was addressed during a two day training in medical devices in the operating theatres field; this group had participants from all over the country (Sweden). The survey was conducted during late 2013-2016. Questions were written in Swedish and consisted of multiple-choice answers as well as possibility to add comments for example; which sounds are desirable? Which sounds are not desirable? Saturation in the responses is believed to have occurred as the answers diversity eased off hence no more respondents were invited to take the survey.

The questionnaire has not been validated. Answers were coded and survey responses were entered in Excel worksheet. An analysis of the data was conducted in Excel.

## Result

The first two questions assured us that the sound environment was indeed an issue of importance for both staff well-being and for patients' well-being as estimated by the staff. The perceived sound environment in general terms were rated as poor, with a mean of 2.04 in the scale 1-4 (4-very good, 3-good, 2-poor, 1-very poor). This indicates that there seems to be much that can be improved. Breaking this down into the possible clues regarding sound parameters leads us to question 3b; Is it easy to interpret human speech in the room? On a scale of 1-3 were 3-agree fully, 2-agree partially, 1-do not agree, the group in total scored 1.9. When comparing the group of staff working in an operating room with staff only working in treatment rooms there is a difference in the replies. OR-staff rated this question to 1.6 whilst other staff rated it 2.1. Interpreting human speech seems to be a bigger challenge in the operating room.

Can we penetrate this more? Next step would be to see if interpreting the direction of the sound was affected. Question 3d; It is easy to hear where the sound is coming from? OR-staff scored 1.8 (compared to other staff 2.0) in the same scaling as above. Question 3f; The sound environment sometime causes misunderstandings in our interaction? The group as a whole scored 2.4 and the OR-staff 2.5 with the rating 3-agree fully, 2-agree partially, 1-do not agree (as to Figure 1).

Our next question relates to what happens when the workload increases and there is many staff present in the room? The answers on question 3g concludes that this is even more so affecting the sound environment (as to Figure 1).

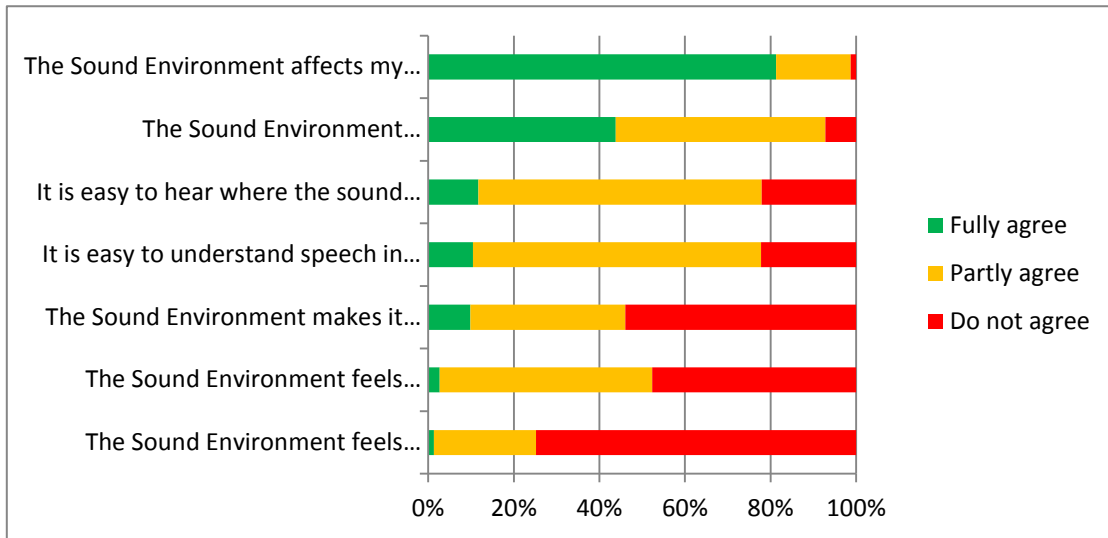


Figure 1: Answer to questions 3a-3g (n=154)

Comparing the following questions were respondents could indicate preferred, likeable sounds and unwanted, disturbing sounds shows two different palettes of sounds. On one side we have soft comfortable sounds such as low human speech, correct alarm signals that needs to be heard and addressed and music. On the other side respondents list disturbing sounds such as unnecessary machine sounds, unnecessary alarm signals, human speech, sudden loud noises and ventilation. Many respondents chose to describe the quality of the sounds such as (desirable) soft, dampened, melodious, non-sharp and friendly. And at the other end (unwanted) they were described as high pitched, hissing, sudden, monotonous, hard, and sharp. Significantly more answers were added into the unwanted sounds than desirable ones (as to Table 1).

Table 1: Summary from question 4 and 5 “Free Comment” (n=154)

Question 4: Desirable sounds (number of answers)	Question 5: Unwanted sounds (number of answers)
soft sounds (36)	machine noise (54)
silence (14)	alarms (42)
important alarms (13)	loud human speech (32)
human speech (13)	loud noise (31)
music (11)	ventilation (18)

## Discussion

Healthcare facilities are complex buildings with numerous different types of rooms that range from technically more uncomplicated areas such as administrative office spaces to high-tech hybrid operating theatres. The demand and strain on both staff and patients differ depending on the nature of the illness and examination and treatment options. Highly specialized localities often have complex medical technical equipment and ventilation systems that generally add to the sound pressure level but also cause disturbances in ability to interpret speech and alarm signals due to unwanted reflections of the sound waves [7]. In an operating theatre there is the aspect of sterile zones to consider as well and how they might or might not influence perception of sound. Staffs have their ears and mouth covered both supposedly influencing ability to determine direction and distance of sound as well as supporting the interpretation of the sound wave with lip reading [10]. In addition to this the inner circle of the sterile zone will by default have their backs toward most other staff in the room.

Interpretation of sound is individual and the perception of what is considered noise can vary as it is dependent on more factors than sheer combination of sound pressure level and frequency. Noise affects our cognitive response and influences our ability to concentrate, our short term memory, level of fatigue and motivation to “go the extra mile”. These effects of sound are not always taken into consideration when designing the operating room. However, research shows that staff can suffer from alarm-fatigue [11] and that misunderstanding in oral instructions is common [8]. Misunderstandings might not be of life threatening sort but seem to delay procedures such as the wrong size of requested material is collected from outside the operating room [11].

In our survey we find that a large amount of unwanted sounds come from alarms from the technical equipment. This part of the problem needs to be addressed by the manufacturers of the devices and proper acoustic demand set in tenders so that the purchase of each device is put in context with the rest of the sound producing devices. Ventilation is also mentioned frequently as a disturbance and this also need to be addressed by the suppliers and manufacturers in addition and facility managers should make sure acoustic requirements are actually met after installation. Human behaviour also contributes to which sound or noise level will be dominant in a situation as we have a tendency to raise our voices to reach above the general noise level with 10-15dB to be heard [12]. The next consideration would be room acoustic design in order to create the most optimal circumstances using layout and building materials to optimize room acoustic parameters [13].

## Conclusion

Have we been able to set the optimal requirement for room acoustic demands with current descriptors only using reverberation time? Can we do better in designing and treating these challenging rooms in order to better support staff ability to hear and interpret oral instructions, interpret alarm signals and suffer from less fatigue due to a demanding sound environment? When analysing the responses in this survey the inclination is that having met the minimum reverberation time does not guarantee a good work environment with optimal speech intelligibility and minimised risk of medical errors due to noise. It is our conclusion that we can still improve the acoustics in these rooms which would benefit all staff and that there is still more to gain by continue to search for ways of acoustic improvement. These may come from standards and regulations, room design, surface material used, or all combined. Hygienic aspects are often mentioned as a hinder to use sound absorbing materials in specialised area within hospitals but the market offers both cleanable and disinfectable products that enables usage (local rules may apply).

### Limitations of study

Survey was done anonymous, individual operating rooms cannot be identified and has not undergone measurement or calculation to establish that they fulfill the acoustical building regulations. Number of participants is too low to draw any general conclusions.

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