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An investigation of room functions and acoustic demands in selected departments in three Danish Hospitals

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ABSTRACT

Hospitals contain many different room types, each having its own contribution to the main function of treating patients. Different room types with different functions demand different acoustics. Currently only a few recommendations in terms of room acoustics are mentioned in the Danish Building Code, BR18. Recommendations, only to a limited degree, fulfill the demand for a sufficient acoustic environment for staff and patients. In this study different room types were investigated from selected departments in Bispebjerg, Frederiksberg and Hvidovre hospitals. Four room types were investigated; examination/treatment rooms, control rooms, nurse stations and lunch rooms. From interviews with staff and questionnaires, information about functions and acoustic demands was collected for all four room types. Furthermore, acoustic parameters, T_{20}, EDT, C_{50} and STI were measured in the rooms. Recommendations in BR18 were found to be insufficient to meet the acoustic demands in several of the rooms. Future recommendations should be formulated to ensure a satisfactory acoustic environment, which meet the function demands in the rooms. A systematic investigation of room functions and use of facilities in hospitals in regards to noise is needed to be able to make such recommendations.

Keywords: Room acoustics, hospital, staff

1. INTRODUCTION

Noise in hospitals is a well-known problem first mentioned in 1859 by Florence Nightingale in "Notes on nursing" (Nightingale, 1859). Since then and documented for the past 50 years, noise levels have been excessive in hospitals (Busch-Vishniac, Barnhill, Hunter, Orellana, & Chivukula, 2005). Increased noise levels influence patients and staff. Studies show that noise has negative influence on the recovery and sleep quality of patients (Elbaz, et al., 2017), and therefore patients' recovery time is increased with exposure to noise (Fife & Rappaport, 1976). Reverberation has an impact on patients sleep (Berg, 2001). Noise also has a negative effect on staff in hospitals. It has been found that noise induces stress in nurses (Topf & Dillon, 1988), also influence hospital staff's quality of work (Mahmood, Chaudhury, & Valente, 2011), has an effect on communication in hospital staff (Woloshynowych, Davis, Brown , & Vincent, 2007). As noise is somewhat affected by the acoustic environment, regulations and recommendations regarding the acoustic environment exist. The Danish building code suggests a reverberation time of $T \leq 0.8$ s. in patient rooms (this recommendation has, since this study was performed, been changed to $T \leq 0.6$ s.) and $T \leq 0.6$ s. in examination rooms. However, the building code does not mention any other room types in hospitals such as control rooms,

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surgery rooms, lunchrooms, nurse stations among other room types. This study investigates four different room types, where only examination rooms are mentioned in the Danish building code, by measuring room acoustics and interview and hand out questionnaires to staff. The objectives of the study are:

How does noise influence staff in three Danish hospitals?

How can we solve challenging acoustic/noise conditions in hospitals?

2. METHODS

Rooms in three different hospitals were investigated in 2017: two of the hospitals were built in the beginning of the 20th century, Bispebjerg hospital in 1914 and Frederiksberg hospital in 1903 and the youngest one, Hvidovre hospital was built in 1976. Bispebjerg was furthermore listed.

In two of the hospitals, departments were contacted to report back whether the staff had reported issues about noise and if they wished to participate in the project. Six departments reported back and participated in the project and made rooms, they found problematic, available for acoustic measurements and filled out questionnaires. Later on the project another hospital, Hvidovre hospital, participated with one department, because of lack of time and development in the project, the department only participated by being group interviewed. List of departments and room types are shown below:

Table 1 – Abbreviations for departments and room types

Abbreviation	Department	Abbreviation	Room type
E	Emergency department	Ex	Examination room
D	Dermatological department	CR	Control room
P	Palliative Department	LR	Lunch room
R	Rehabilitation department	NS	Nurse station
W	Work and occupational medical department	TR	Treatment room
X	X-ray department		
M	MR-department		

2.1 Questionnaires

Questionnaires were handed out to staff in departments in Bispebjerg and Frederiksberg hospitals. The questionnaires included four major questions with five possible answers, the questions said:
Q1: "*When you think back over the past six Months, how disturbed have you been by noise while you have been at work?*"
Q2: "*When you think back over the past six Months, how often have you experienced that you could not hear or understand what a colleague and/or a patient said because of noise?*"
Q3: "*When thinking about the past six Months, how often have you experienced that you could not speak confidentially with a patient without other patients hearing you?*"
Q4: "*When thinking back over the past six Months, how often have you experienced that a patient said that he/she could not hear or understand important information you were giving?*"
For the four questions the participants were asked to answer in what rooms the issue occurred. The questionnaire also contained a fifth question about noise sources, saying:
Q5: "*When thinking back over the past six Months, cross out up to five noise sources you found disturbing at you work place.*"
Finally the participants were asked about gender, age, hearing impairment and if they considered themselves as sensitive to noise.

2.2 Interviews

All representatives from the different departments were informally interviewed. A planned interview was performed with the staff at the MR-department at Hvidovre hospital about the

nurse/control room. The interview was performed right after the noise measurements were performed. The interview was performed informal, as a group interview, unstructured, and as a receptive interview. To the purpose an interview guide was produced in correspondence with (Kvale & Brinkmann, 2015), see table 2:

Table 2 – Research questions and corresponding interview questions

Research question	Interview questions
1. What influence does noise have on hospital staff?	1-1. What causes noise in the room? 1-2. In your own words how does noise influence you and your work at the hospital?
2. How can the working environment be improved with design of rooms?	2-1. How do you think the noisy environment can be improved?

2.3 Measuring room acoustic parameters

The room acoustic parameters, early decay time (EDT), reverberation time (T20), clarity (C50) and speech transmission index (STI) were measured with an omnidirectional speaker and B&K DIRAC software with e-sweeps after (DS/EN-3382-2, 2009) using the engineering method.

3. RESULTS

3.1 Issues in measured room types and room functions of each room type (based on interviews)

The interviews with staff revealed the following issues and functions of the measured rooms in the hospitals that were linked to noise and the acoustic environment. In general the work environment was described as busy and noisy.

Examination/treatment rooms

The staff experienced that the acoustics environment in the examination rooms challenged them when communicating with patients. In some of the examination rooms staff had solved the problem by having patients wearing headphones and talk into a microphone.

One of the major functions of the examination rooms and treatment rooms is that important information is passed from the patient to the staff and from the staff to the patient often in a challenging vocabulary. Many of the patients in the hospital are elderly people, who have a higher chance of hearing impairment. Poor room acoustics challenge especially hearing impaired.

Examination rooms/treatment rooms are often small and have a high demand of cleaning.

Control rooms

The control rooms were perceived noisy and hectic by the staff. They explained how many different people would come and go through the space furthermore the control rooms have a constant loud background noise from equipment (x-ray equipment and MR-scanners).

The investigated control rooms were in x-ray departments and MR-department. The communication in the control rooms are mostly between staff individually and only short messages are given to the patients. A lot of noise from equipment influences the control rooms and the staff told that they easily can get filled up with noise and feeling tired and have headaches during/after work.

Nurse stations

The nurses described the nurse stations as noisy and sometimes also hectic because of constant run

of nurses coming in shortly to write on medical journals and leaving again and sometimes talking about work.

The nurse stations hold some of the same functions as the control rooms regarding communication between staff, however without high background noise from equipment and normally no communication with patients. The nurses often need quietness to concentrate about writing in patient's medical journals. It was observed that the nurse stations tested in this project often were crowded.

Lunch rooms

The staff found the lunch rooms included in this paper as noisy and that noise would build up from voices making it a challenge to have conversation with their colleagues.

The functions of the lunchrooms are that it is a space where staff can have conversations with each other and relax while taking a break. In general the impression was that the staff found the lunchrooms noisy which may be a consequence of them missing a space where they can take a quiet break.

Overall this sorted the four room types into three types of acoustic issues: reverberant environment, noisy/hectic environment and voices/noise building up. These issues were used later on to try and run statistics to see if there was a tendency that staff were more unsatisfied with rooms with some issues than others.

3.2 Room acoustics in room types

The room acoustic parameters EDT, T20, C50 and STI were measured to evaluate the acoustic environment for the four different room types.

Reverberation time T_{20}

The reverberation time shows that special attention has been given to ensure a sufficient acoustic environment in the control rooms and in two out of the three nurse stations. The lunchrooms showed long reverberation time for the low frequencies which may be why staff is complaining about noise from voices building up in these rooms. The acoustic environment in all the examination rooms in Bispebjerg and Frederiksberg hospital are not satisfying showed in (D) by too long reverberation time.

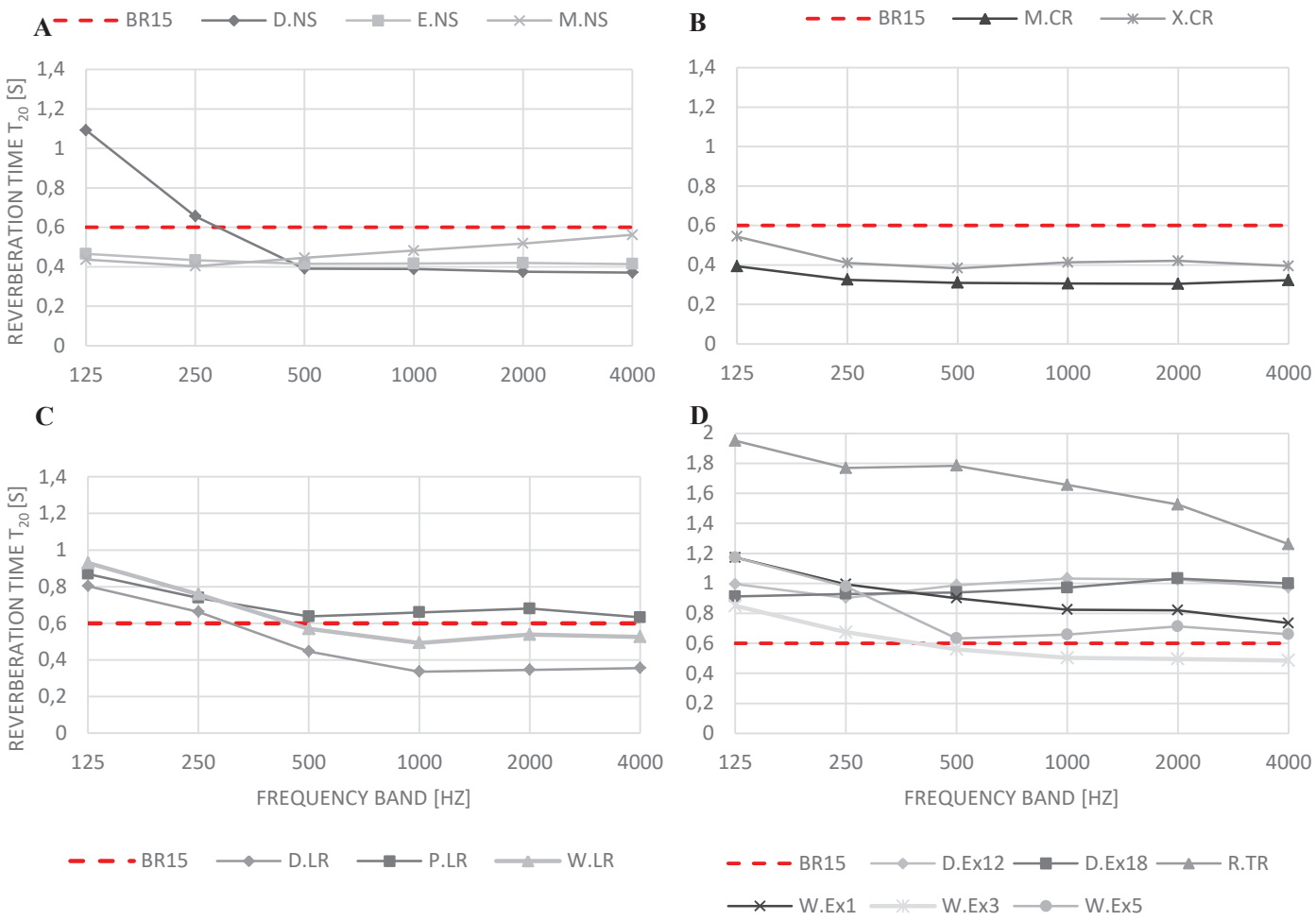

Figure 1- Reverberation time T_{20} (A) nurse stations, (B) control rooms, (C) lunch rooms, (D) examination rooms.

Speech transmission index

STI is calculated from noise-free impulse responses, and it shows a similar trend to T_{20}. STI is generally excellent in nurse stations, control rooms and lunchrooms, meaning that for a normal hearing person the acoustic environment is proper for communication. Depending on the background noise, STI in realistic occupied conditions could differ from these values.

STI values are generally lower in the examination rooms, where only two rooms have an excellent STI, the resisting five have either a good or fair STI, which may lead to low speech intelligibility especially for hearing impaired patients and patients who communicate in a foreign language.

Table 2 – Speech transmission index (STI)

Room	Nurse station		Room	Control rooms		Room	Lunch room		Room	Examination rooms	
E.NS	0,79	Excellent	M.CR	0,83	Excellent	D.LR	0,81	Excellent	D.Ex12	0,62	Good
D.NS	0,82	Excellent	X.CR	0,80	Excellent	P.LR	0,72	Good	D.Ex18	0,61	Good
M.NS	0,8	Excellent				W.LR	0,74	Good	R.TR	0,53	Fair
									W.Ex1	0,64	Good
									W.Ex3	0,76	Excellent
									W.Ex5	0,68	Good

3.3 Staff perception of acoustics in room types (interview and questionnaires)

The answers to the questionnaires from staff show a normal distribution for Q1 and Q2 around "moderately/sometimes", and a normal distribution for Q4 around "slightly". For Q3 most participants answered "considerably". For Q5 regarding noise sources, the three different cases with *talking* scored highest. It is also noticeable that only 3% answered "*Not at all*" to Q1.

A one-way ANOVA was run between the questions and the issues to try and see if the staff experienced one of the four questions more often than others for one of the three different issues. This test revealed that for Q2 there was a weak effect of issue with a significance level of 0.05 ($F(2.62)=3.723$, $p<0.0298$), the significant difference was between Noisy/hectic environment and Noise/voices building up.

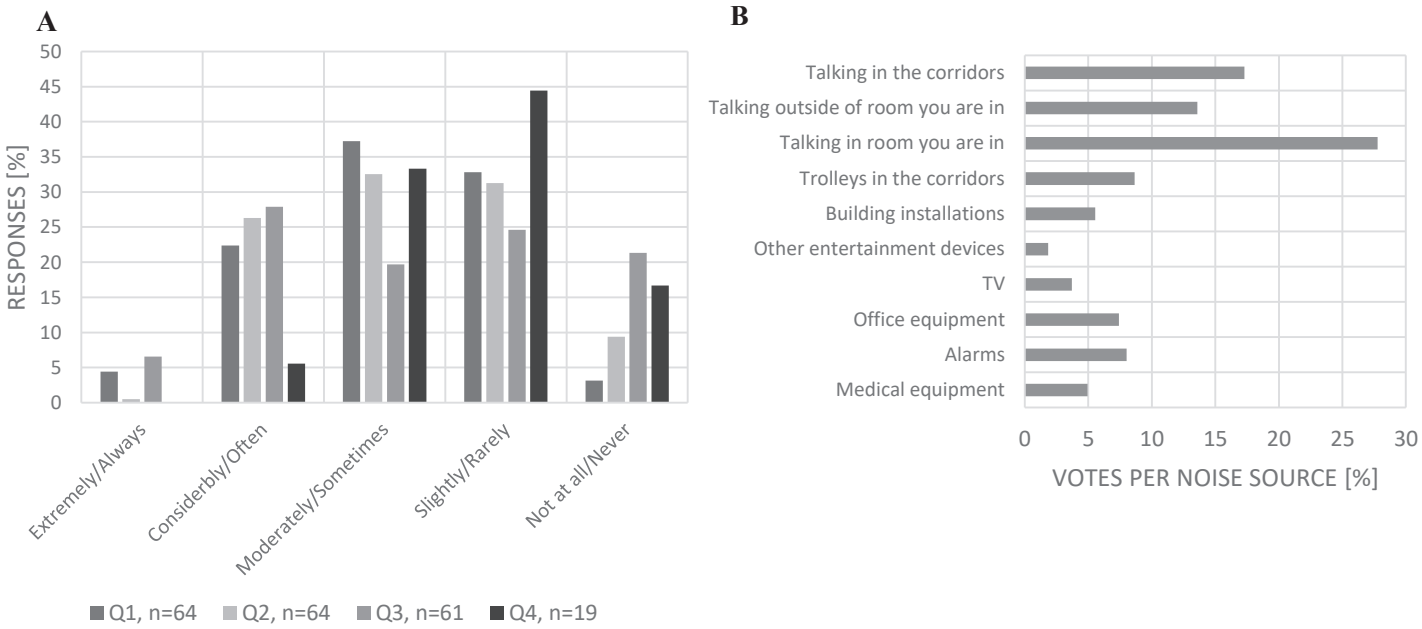

Figure 2 - Results from questionnaires. (A) Answers to Q1-4 in percent, (B) answers to Q5 in percent.

4. DISCUSSION

The interviews and questionnaires revealed that noise is a problem in the three tested hospitals according to staff. Only three percent answered "*not at all*" to Q1, about how disturbed the staff had been by noise the past six Months, meaning that the remaining 97% have been disturbed by noise to some degree. This result agrees with the findings in the group interview were the participants said that they were bothered by noise and that it coursed tiredness and sometimes headaches. Q3, regarding talking confidentially with patients was experienced "*often*" by most participants; this indicates that especially confidential conversations with patients is a challenge.

Of the sound sources, the participants found most disturbing, talking got the most votes. This tells that when designing hospitals architects, designers, engineers and acousticians should pay special attention to designing hospitals to minimize disturbance from voices. This finding corresponds to the findings of Buxton et. al, who found that the noise sources that had the greatest arousal effect on patients' sleep was alarms and voices, especially upset voices (Buxton, et al., 2015). A design to attenuate voices has been tested by Luertz et. al, who made a study where noise levels were compared before and after a refurbishment of a hospital wing where focus was to bring down voices, leading to a significant reduction in noise levels (Luetz, et al., 2016).

The different rooms measured showed particular high reverberation time and low STI in examination/treatment rooms in Bispebjerg and Frederiksberg hospital. This finding may be a consequence of the two hospitals not being renovated to fulfill the functions of a modern hospital, perhaps due to that Bispebjerg hospital is listed. It may also be a consequence of patients not being able to speak out or not listened to when talking about the discomfort the acoustic environment is causing. Long reverberation time and poor STI may especially be a challenge for hearing impaired

patients, since a larger number of patients are elderly, and hearing impairment is increasing with age. This may potentially cause loss of information for patients (Harris & Swenson, 1990) even for patients wearing a hearing aid (Reinhart, Souza, Srinivasan, & Gallun, 2015). Reverberation may even be a problem for normal hearing patients as reverberation impairs listener's ability to distinguish between competing voices (Culling, Hodder, & Toh, 2003).

The acoustic environment in the nurse stations, control rooms and lunchrooms were found to be good with the exception of some of the lunchrooms having high reverberation time for the low frequencies, which may cause voices to build up. Generally this means that for a normal hearing person the acoustic environment is good for communication in these types of rooms. Therefore the source to discomfort may be a consequence of too many noise sources and it should rather be looked into the capacity of people in these types of rooms (Rindel, 2012) and (Svensson, Jeong, & Brunskog, 2015).

The many complaints about lunchrooms may be an indication of staff needing a quiet place to retreat from the noisy working environment they experience, and they expect the room where they have their breaks to be quiet, which is not the case. In the group interview the staff explained how they had an office to withdraw to but with a window, so patients would tap on the window to ask questions. They also told how often they are disturbed during their breaks to attend to a patient.

The control rooms were found to be very noisy although they were acoustically regulated, indicating that acoustic regulation cannot solve the noise problem in hospitals alone. Control rooms and similar noisy rooms should be designed in such a way that staff feel less disturbed by noise, when working.

4.1 Future perspectives

This study is just one of the first steps in investigating noise and acoustic environment in hospitals. More projects should be performed to investigate how the acoustic environment in each room type influences their users staff as well as patients. Such studies will draw more attention to the acoustic environment in hospitals and perhaps lead to more sufficient guidelines to regulate acoustics in hospitals.

5. CONCLUSION

Staff is found to be very influenced by noise and experienced all four phenomenon asked in Q1-4 equally. Of noise sources they found voices most disturbing. The group interview revealed that some of the consequences were tiredness and sometimes headaches due to noise.

Room acoustic measurements showed especially poor room acoustics in examination/treatment rooms, indicating that attention has especially been given to the working environment for staff than in favor of patients. Areas with a lot of noise, e.g., control rooms, were found to be well acoustically regulated, indicating that we cannot minimize the disturbance in staff by acoustic regulation alone. Lunchrooms and one nurse station showed poor acoustics for only the low frequencies which may still be bothering staff as they in interviews especially pointed their lunchrooms out as rooms with especially a lot of noise and uncomfortable acoustic environment. Which indicates that staff need a quieter place to retreat doing their breaks perhaps due to a general hectic and noisy working environment.

More research is needed to come up with precise recommendations to design hospitals to minimize noise and improve the sound environment both for patients and staff. The acoustics in the three measured hospitals were found to be not sufficient, though some of the room types did fulfill the recommendations in the Danish building code. This finding indicates that the recommendations in the Danish building code are not sufficient, but may also mean that the issue cannot be solved alone by recommendations/requirements. Noise in hospitals must be reduced by considering the different room functions carefully with the possibility of being flexible towards changes and new equipment and treatment possibilities. Noise in hospitals is a large problem and it should be considered also from authorities, that when changing the function of a room and when refurbishing, the room acoustics must be considered. A change of a room could impact on noise levels adversely, causing the staff to be less satisfied at work, and patients to a slow recovery.

Acousticians should be included in the early design stages of hospitals to ensure good acoustic conditions and sound environment in hospitals. Furthermore the acoustician has an important job in understanding and knowing what functions the acoustics should support.

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