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Indoor environment and acoustic conditions in two Finnish hospital wards

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The aim of this study was to determine the acoustic conditions of two typical Finnish wards. The methods included various acoustical measurements and questionnaires for patients (N=58) and nurses (N=27). The average sound pressure levels were within 49 and 58 dBA in the corridors, office and patient rooms. Personal noise exposure levels among nurses were below 70 dBA. The noise was mainly caused by people. Building acoustic measurements showed reasonable agreement with national directions. Indoor environment was not a problem for most patients. Some disturbance from thermal conditions, dry air and noise was experienced. Other patients' snore and groans bothered some patients. Night-time sleep was disturbed most by anxiety, pain, noise, thermal conditions and an uncomfortable bed. Number of occupants in the room was associated with environmental complaints. Nurses were more bothered by environmental factors than patients, giving highest annoyance ratings to thermal conditions, air quality and noise. Nurses experienced stress and difficulties in concentration due to noise. Sounds of phones ringing were experienced as particularly detrimental. Acoustic design guidelines developed for open plan offices could be considered in ward offices. Lack of privacy was the most obvious problem in both staff and patient evaluations.

1 Introduction

E.g. indoor air problems, logistic inefficiency and major renovations of hospitals have been in public discussion in Finland. The conventional design principles of hospital buildings are under serious reconsideration. This requires development of new guidelines for indoor environment. There is no published data available about acoustic conditions in Finnish hospitals.

The aim of this study was to determine the acoustic conditions of two typical Finnish hospital wards. The study was a pilot study which aimed to the development of acoustic and subjective measurement methods which describe the acoustic conditions in wards. Both nurses' and patients' opinions were considered.

2 Materials and methods

2.1 Wards

The study was carried out in Turku University Hospital (TYKS). The first ward was located in A-hospital constructed in 1937. The ward had been renovated in 1995-1997. The second ward was located in T-hospital where construction finished in 2003. Both wards were specialized in internal diseases. The ward in A-hospital accommodated more acute patients than the other ward. In T-hospital, most patients shared a room with one other person, whereas in A-hospital, rooms mostly accommodated 2 to 5 patients. Some beds were temporarily placed along corridors. Both wards had 24 beds.

2.2 Subjects

A total of 58 patients took part in the survey, 41 from A-hospital and 17 from T-hospital. 76 percent of subjects were male. The median age group of respondents was 66-70 years in A-hospital, and 61-65 years in T-hospital. 35 percent of respondents were over 70 years old. The number of respondents in different room sizes is presented in Table 1. Patients had stayed in the ward for 4 days in average when completing the questionnaire. The staff version was completed by 17 nurses from A-hospital and 10 from T-hospital, all female. The median age group in A-hospital was 31-35 years and 36-40 in T-hospital. The respondents had worked in the ward for 9 years in average in A-hospital and 2 years in T-hospital.

	Room type (number of occupants)					
	1	2	3	4	5	corridor
A-hospital	1	5	9	5	14	5
T-hospital	2	14	1			
Total	3	19	10	5	14	5

Table 1. Number of respondents in the patient sample.

2.3 Questionnaire method

Separate hospital environment questionnaires were developed for nurses and patients. An office acoustics questionnaire tool developed by the research team [1] was used as a starting point and modified on the basis of a literature review on previous studies on hospital acoustics.

The aim of the questionnaire was to find out whether noise is a problem and how the problem relates to other, major or minor, problems in the hospital ward environment.

Both patient and staff version covered disturbance from indoor environment, disturbance from specific noise sources, and privacy. Patients were asked about factors influencing sleep quality. The version for nurses covered noise-related stress, psychosocial stress factors and general stress symptoms. General stress symptoms included tiredness and exhaustion, irritation, difficulties in concentration and difficulties in sleeping. In most questions, the answer was given on a 5-point Likert scale. Both versions included two open-ended questions about indoor environment problems and possible solutions.

The questionnaire was handed out to patients by staff and filled in while staying in the ward. Questionnaires were only given to patients who were well enough to answer them without help. Nurses who had been working in the ward for at least 2 months completed the questionnaire via internet. Data was gathered during two weeks before Christmas in December 2007 and in one extra week in January 2008.

2.4 Statistical analyses

The results from two wards were compared using Mann-Whitney U-test. The analyses were done separately for patients and nurses. Spearman's correlation coefficients were calculated to assess connections between room size and environmental complaints in the patient data. Subjects who were in private rooms were left out from these analyses because there were only 3 respondents in this

group and they seemed to differ from rest of the sample, possibly due to worse physical condition. Corridors were considered as the room type with largest number of occupants. For nurses, sum variables for psychosocial stress and general stress symptoms were calculated for assessing correlations between stress and noise complaints. The SPSS 16.0 software was used for the statistical processing. In figures, significant results are indicated with asterisks, * p <.05, and ** p <.01.

2.5 Noise and building acoustic measurements

Noise measurements included personal noise exposure measurements of nurses, $L_{EX,8h}$, (ISO 1999), 24-h sound level recordings in different fixed locations and individual noise observations during basic activities.

The acoustic measurements were carried out in corridors, patient rooms, staff offices, and quest rooms. Acoustic measurements included sound insulation between spaces, R'_w (ISO 140-4), reverberation time, RT (ISO 3382-2) and Speech Transmission Index, STI (IEC 268-16, ISO/CD 3382-3) inside the room or between adjacent rooms. STI was determined using normal speech effort and the background noise level of ventilation noise.

3 Results

3.1 Staff survey

Indoor environment. Nurses were much more disturbed by indoor environment than patients. Highest annoyance ratings were given to thermal conditions, dry air and air quality (Fig. 1). Noise caused in average moderate disturbance. There were no significant differences between the two buildings, except for thermal conditions which were better in the older building (A-hospital).

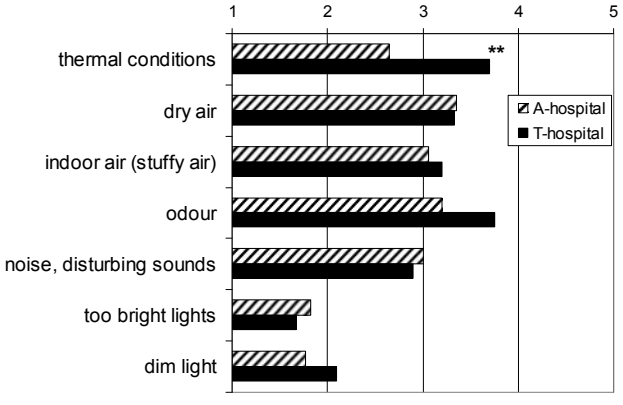


Fig. 1 "How much have you been disturbed by the following environmental factors while working in this ward during the past month?" (1= not at all, 5= very much)

Noise sources. Sounds of phones ringing disturbed work most (Fig. 2). In most cases, the disturbance of specific sound sources was worse in A-hospital although the differences were mostly not statistically significant.

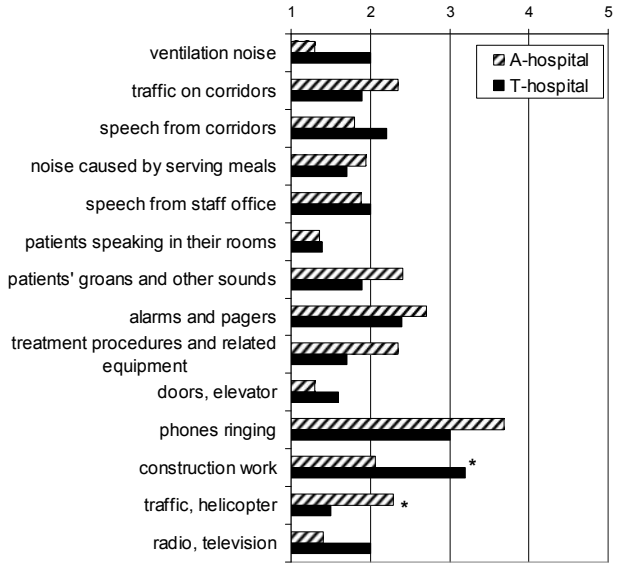


Fig. 2. "How much have the following sounds disturbed your work performance in this ward during the past month?" (1=not at all, 5= very much)

Privacy. Maintaining patients' privacy was experienced as most difficult in patient rooms and corridors (Fig. 3). In A-hospital, more than 80 percent of nurses felt that patient privacy was poor in patient rooms. However, speech privacy was rated less favourably in the modern hospital when considering the staff office which includes a patient service desk. This results most likely from the modern design used in some T-hospital offices in which two sides of the office are left without walls or glasses to form an open and accessible service desk.

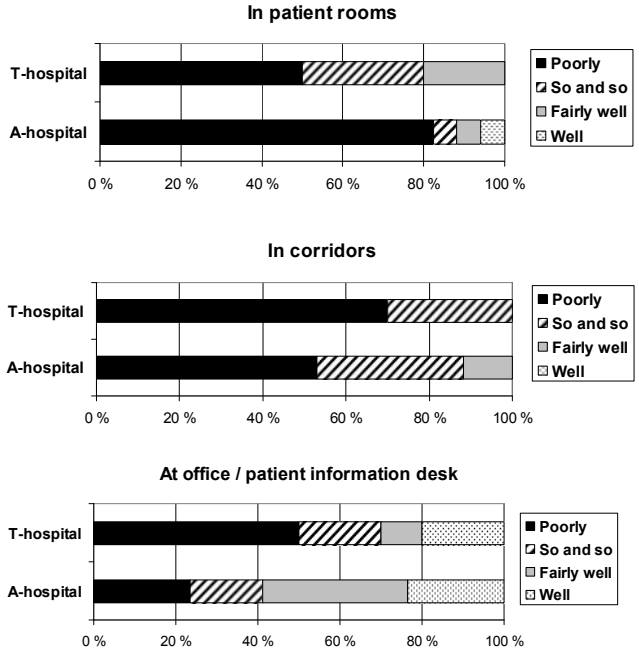


Fig. 3 "How well can you have conversations with patients and other staff members so that the private and intimate issues of patients are not heard by other patients or outsiders?

Stress. More noise-related stress was found among nurses in A-hospital (Fig. 4). In the total sample, 33 percent expressed moderate or strong irritation caused by noise, 41

percent reported moderate or strong noise-related tiredness and 44 percent expressed that noise caused moderate or plenty of difficulties in concentration.

The psychosocial work environment was more stressful in A-hospital in terms of greater need to hurry at work ($p<.05$), lower job satisfaction ($p<.05$) and fewer possibilities to influence issues related to one's work ($p<.05$).

In the total sample, overall psychosocial stress was associated with the degree of disturbance from different noise sources, e.g. phones ringing ($r=.701$, $p<.01$), patients' groans ($r=.483$, $p<.05$) and alarms and paging ($r=.433$, $p<.05$). Psychosocial stress was also associated with noise-related tiredness ($r=552$, $p<.01$), noise-related difficulties in concentration ($r=518$, $p<.01$) and noise-related irritation ($r=.517$, $p<.01$). Similar connections were found between general stress symptoms and noise complaints but with slightly smaller correlations.

Open-ended questions. The open-ended questions shed more light to specific problem areas. In both wards, the offices with patient service desks formed the biggest problem. In A-hospital, the office was a closed room where many people worked simultaneously answering phone calls, writing reports, preparing medication lists and monitoring alarms. Crowdedness and the resulting noise were experienced to hamper concentration to important tasks and cause stress. It seems that ratings in other questionnaire items reflected to large degree these office conditions. In T-hospital, some offices were open, as described above. Concentration to work was experienced to suffer from distractions caused by the lack of walls. The main problem, however, was the difficulty to maintain privacy when taking phone calls and talking to patients at the desk. Nurses also felt that the open area invited patients to "hang around" unnecessarily which made it more difficult for nurses to get their work done.

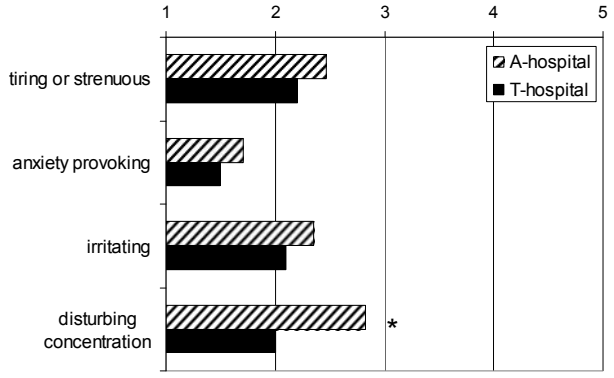


Fig. 4 "During the past month, have you found the acoustic environment of this ward..." (1= not at all, 5= very much)

3.2 Patient survey

Indoor environment. Patients were very little disturbed by environmental factors. Therefore, results are not reported in detail. Thermal conditions disturbed patients more than other environmental factors during day. Day-time noise disturbed patients more in A-hospital ($p<.01$) but the mean disturbance in A-hospital was still only 1.9 on the scale from 1 'not at all' to 5 'very much'. The most disturbing sound source in both wards was snore or groans of other patients but the degree of disturbance was in average low.

Sleep. Night-time sleep was disturbed most by psychological factors and issues related to physical well-being, such as anxiety and worry, pain and sleeping in a strange place. Other patients' snore and groans disturbed sleep in average to the same degree as pain although there was much more variation in the effect of pain on sleep. Other sounds disturbed less. Ventilation hum, movement in the room and traffic noise disturbed patients least.

Privacy. Privacy was the most obvious problem in the patient results (Fig. 5). In A-hospital, where rooms generally had a higher number of occupants, more than 40 percent of patients felt that outsiders could overhear them talking about personal issues to staff or guests. In T-hospital, speech privacy in patient rooms was good. In both wards, more than one third experienced lack of privacy when speaking to staff in corridors or at the service desk.

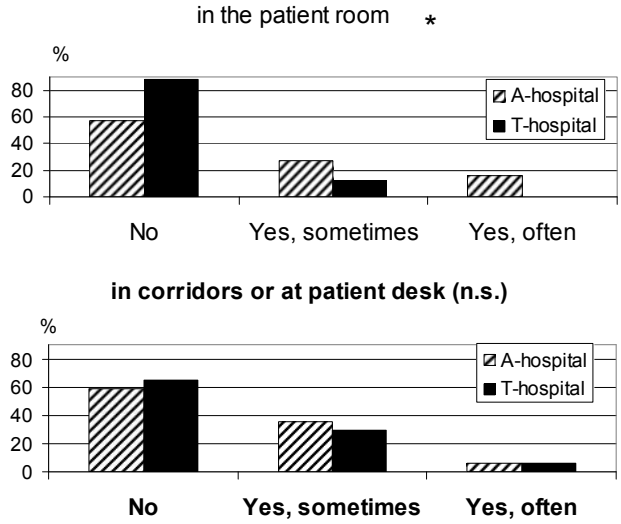


Fig. 5 "Do you feel that other patients or outsiders hear your personal matters when you are speaking to nurses, doctors or your guests?"

Occupancy of room. When data from both wards was combined, number of occupants in a room was correlated with noise complaints ($r=.568$, $p< .01$) and weakly correlated with complaints about odour ($r=.346$, $p<.05$) and too bright lights ($r=.35$, $p < .05$). Number of room occupants had a weak correlation with sleep disturbance caused by speech ($r=.397$, $p<.01$), noises caused by equipment in the room ($r=.373$, $p<.01$), lights ($r=.347$, $p<.05$), and ventilation noise ($r=.341$, $p <.05$). Other factors disturbing sleep were not correlated with number of occupants in the room. Day-time noise disturbance and sleep disturbance caused by noise were greatest for those placed along corridors.

3.3 Noise

Sound level recordings were made in corridors, patient's rooms and nurse's offices. Results are presented in Fig. 6. Noise levels during day-time were between 49 and 58 dB. The night-time noise levels were 36 - 52 dB. The noise was mostly caused by speech and human activities. Ventilation noise levels were very low.

Noise exposure of 19 nurses was determined. The results are presented in Table 2. The noise exposure levels were low and caused mainly by normal speech during work. The noise exposure levels are higher than the levels in Fig. 6 because of subject's own speech and motions.

Fig. 6 Results of the 24-h sound level recordings in fixed locations. Top: A-hospital. Bottom: T-hospital. The average sound pressure level during daytime and night-time are $L_{A,eq,7\text{-}22}$ and $L_{A,eq,22\text{-}7}$, respectively. Daytime $L_{AF,min}$ represents the ventilation noise level.

	A-hospital		T-hospital	
Shift	N	$L_{EX,8h}$ [dB]	N	$L_{EX,8h}$ [dB]
morning	5	62 to 68	3	61 to 69
evening	3	61 to 69	3	61 to 70
night	3	59 to 66	2	56 and 58

Table 2 Noise exposure levels of nurses $L_{EX,8h}$ during different shifts. N=number of nurses investigated.

3.4 Building acoustics

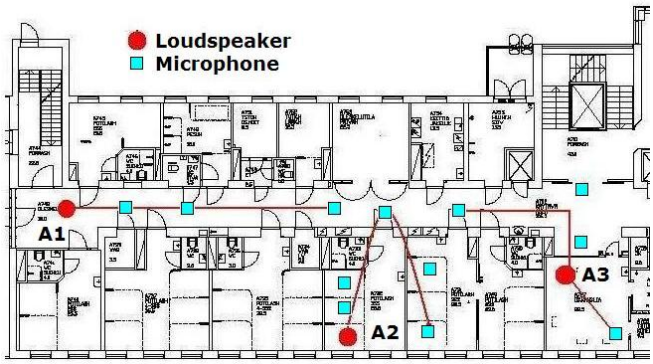
Weighted sound reduction index R'_w between patient rooms was 45 dB or higher (48 dB). The value of R'_w was 25 to 32 between patient room and corridor (35 dB). These results agree fairly well with current national directions. The sound insulation of doors is critical because the noise levels in wards are typically so low that sounds cannot be typically heard through walls when R_w>40 to 45 dB.

Average reverberation times are presented in Table 3. They are also in agreement with current national directions, which is 0.80 seconds.

Speech Transmission Index was determined in locations where private conversations occur and where these private conversations should not be heard. Therefore, STI measurements were made at different distances from the speaker's position. The results are presented in Figures 7. The results show clearly that speech intelligibility is high along corridors.

	Reverberation time [s]	
	A-hospital	T-hospital
Patient's room	0.65	0.45
Corridor	0.45	0.65

Table 3 Average reverberation time T_{20} of octave bands 250-4000 Hz.



A1	A2	A3
	From patient room	
Along corridor	to another	Office to corridor
0.75	0.74	0.75
0.71	0.69	0.62
0.62	0.15	0.41
	0.03	0.32
	0.03	

Fig. 7 STI versus distance in A-hospital. Similar results were obtained in T-hospital.

4 Discussion

The results showed that nurses were bothered by noise and other environmental factors. Noise was experienced to hamper work performance and cause stress. Conditions were better in the new, modern hospital but both wards had problems with providing adequate speech privacy for patients.

In the staff survey, psychosocial stress and stress symptoms were associated with noise complaints and noise-related stress. However, this connection does not necessarily imply a causal relation. Noise can be viewed as a stressor but it is also possible that workplace noise becomes harder to tolerate if one is already stressed for other reasons, e.g. psychosocial issues at work. The role of hospital acoustics in worker well-being should be further investigated.

The patient survey did not reveal major acoustical problems. The number of occupants in a room was, however, associated with indoor environmental complaints during day and noise-related sleep disturbance. The situation was worst for those located on corridor.

It seems likely that the acoustic environment has different effects on patients and staff. Nurses need to be able to concentrate on their work without extra distractions or stress factors. For many patients, however, some degree of sounds may be welcome to take their mind of their illness and prevent feelings of isolation, at least in day-time.

But it is also possible that the results from the patient survey underestimate the problem. The data has to be viewed with caution for two reasons. First of all, the Finnish healthcare system was in turmoil at the time of the study because 12 000 nurses had pledged themselves to resign if their demands for 25 % higher wages were not met. The situation raised much attention in the Finnish society and formed a threat to healthcare and patient safety. The crisis was resolved only two weeks before the present survey started. It was no longer possible to postpone our study. The patients' willingness to critically evaluate issues related to their care may have been hampered by this episode as there were still many expressions of support and encouragement to nurses' battle in the open-ended questions. We do not expect the staff survey to have distorted similarly because the resolution was very positive from their point of view.

The second shortcoming concerned the high age of the patient population which had not been taken into account in the planning of the questionnaire. Some questions were clearly too detailed and difficult for many patients. The staff questionnaire proved to be a more reliable tool. In the future, the patient questionnaire should be shortened and simplified. Interviews might be a more suitable method for gathering reliable data from patients. The staff questionnaire can be applied in future surveys with only minor modifications.

Acoustic measurements were extremely difficult to carry out because of continuous traffic in corridors and permanent occupation in most rooms. Simplified measurement methods need to be developed if measurements are carried out in an active ward. The slavish application of building acoustic standards, like ISO 140-4 and ISO 3382 was impossible.

It is suggested that reverberation time is not the best possible descriptor of room acoustics. Reverberation time does not correlate with e.g. speech privacy and distraction. Speech privacy could be evaluated by determining STI as a function of distance applying the method developed for open offices [3]. This method was applied also in this study.

In the future, recommendations for STI should be given between spaces or between separate audience areas if better acoustic privacy is desired. Recommendations for RT, R'_w and $L_{A,eq}$ are not sufficient to improve speech privacy in, e.g. reception area of nurses' office or to reduce distraction inside the staff's office.

This study gave suggestive evidence that the ward with lower number of patients per room was ranked better. However, there were other differences between the wards that may confuse this finding. The ward with smaller rooms was also more modern and had better overall conditions.

The Finnish acoustic recommendations should be revised [2]. They should consider the challenges of new hospitals better, e.g. privacy in different areas. E.g. visual openness of the ward could be solved without reducing acoustic privacy. Most of the technical methods to improve acoustic privacy and attenuation of speech propagation are already well-known in open office environments [3], e.g. absorption, masking and screening. Future work is needed to distribute existing knowledge to health care sector.

Our future project aims to repeat the survey in 10 wards by using an improved questionnaire and more effective and disclosing acoustic measurement methods. In addition, before-after experiment is necessary for proving the positive effects of acoustic refurbishments on staff and patients.

5 Conclusions

This pilot study gives evidence that noise is not the most serious indoor environmental problem in wards when building acoustic design has been paid attention to. However, the results of this study shall not be generalized because only two wards were surveyed.

Both nurses and patients experienced problems with speech privacy. Future acoustic recommendations should include requirements for speech privacy in the most sensitive areas.

Nurses were distracted by noise in the staff's office. Guidelines for open offices could be considered also in hospital offices [3].

Acknowledgments

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