Healing soundscape: hospital acoustics 2.0

Evert de Ruiter
Peutz bv, Zoetermeer, The Netherlands
e.deRuiter@peutz.nl; ephjdeRuiter@gmail.com

Summary

In environmental noise control a more sophisticated approach has emerged in recent years: *soundscape* regards the complex sound environment, embracing positive sounds as well as annoyance. This approach is very well suited for use indoors too, for example in hospitals. Many sounds are annoying, disturbing, disquieting; literature abounds with alarming figures of high sound levels. But other sounds are pleasant, reassuring, relaxing, even necessary, like exchange of information between patients and staff. It is proposed not to focus too much on the physical -and psycho-acoustical- properties of the mix of audible sounds as such (spectrum, levels, time history, roughness, sharpness), but to take the information content of the composite sounds into consideration as well, and in particular their meaning to people, and their impact on them. This approach combines the properties of the building -sound production of HVAC, sound reduction of partitions, sound absorption of building elements- and the specific sound sources of the users, staff, visitors and patients. Many items of the total 'choir' of sound sources can be manipulated to some extent, thus enabling designers to enhance positive impacts and to reduce unwanted sounds. This will be illustrated for different types of hospital rooms.

1 Introduction

For the well being and cure of patients not only the medical care is important in hospitals, but the environment as well [1]. Lately the importance of the visual aspect has been recognized. Many papers and articles have been written about noise in hospitals [2], in wards [3], ICU [4][5] and Emergency departments [6], and many others.

For patients in bedrooms, hearing is a very important sense. A large part of patient life can be regarded as a "radio play": the daily activities are announced by their specific sounds. Footsteps of nurses, conversations of doctors and nurses, rattling trolleys, clanging of dust bins, etc. Other sounds accompany them: alarms, respirators, paging calls, ice machines, paper towel dispensers etc.

The notion of soundscape at first was only used to describe outdoor acoustical environments. For large or small rooms within buildings this approach also is useful.

For acoustical consultants the question "what *is* soundscape?" might be less interesting than "what is the *use* of soundscape?" In the discipline of environmental impact, only noise as a negative factor existed, just like toxic gases, fluids etc. And just like the chemical pollutants can be characterised by concentration values, noise exposure is expressed in dB(A).

Noise, regarded simply as a pollutant only, needs to be controlled. Therefore guidelines or laws are necessary, and they were developed and introduced in all European countries.

On the other hand, sound in urban environments can have a function in orientation, and other favourable effects. [7] Orientation and wayfinding within buildings, in particular in large complexes as hospitals often are, can also be supported by auditory "landmarks".

2 Noise Control

In noise control a simple model for the description of noise has been in use for a long time: the spectral aspect is basically expressed in A-weighting; the temporal aspect in the energy-equivalent value. For non-tonal, gently fluctuating noise no further correction is used.

The WHO-guidelines for community noise, section Hospitals (see Appendix) are an example of this approach. Next to the equivalent sound level, also limits are given for the maximum level. These guidelines are clearly meant for background noise only; however, this interpretation is not shared generally, although it is strongly supported by the fact that almost all articles in medical and nursing journals about noise surveys in hospitals show major exceedings of the WHO-criteria.

But... there is more. Sound influences people both consciously and unconsciously. A variety of non-acoustic variables play a role: character, recognisability of the source and relationship to the source, necessity, etc. It is not easy to take these factors into account.

3 Soundscape

The (short) history of soundscape research is described by Lercher and Schulte-Fortkamp [8], while Axelsson [9] reports on the progress of the international standard ISO 12913, containing this definition: *Soundscape: An environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society.*

Other meanings of soundscape, like certain special types of music or sound art, are not addressed here.

4 Functional soundscape

While human perception of sound is very complex, soundscape may offer a useful and practicable approach to noise control, both outdoors and indoors. From many investigations the general preferences outdoors are clear: sound of nature (birds, water) are regarded positive; traffic noise, construction noise and other mechanical sounds are annoying.

For indoor sounds there is a larger variety. But also here, the properties of the sources and the (individual) relationship of the observer to them are essential.

Every patient is exposed to many sounds from equipment, staff, other patients, visitors, traffic etc. [10]. Each of those can be associated with activities, with a character varying from pleasant, reassuring, promising, neutral to frightening.

5 Sound sources

5.1 Analysis- holistic

We can try to deduct the properties of the mix of sounds in a certain place from the sound signal as such: the psycho-acoustical approach. Because in this case the total soundscape is judged, this can be regarded as holistic. The intricacy of the human hearing system, however, is a major complication in the necessary analysis. This analysis is necessary to determine not only the quality of the soundscape as a whole, but also the positive and negative elements in it. From these constituting elements measures for improvement -if necessary- can be designed. This procedure is sketched in figure 1, comparable to a proposal by Brown and Muhar [11]

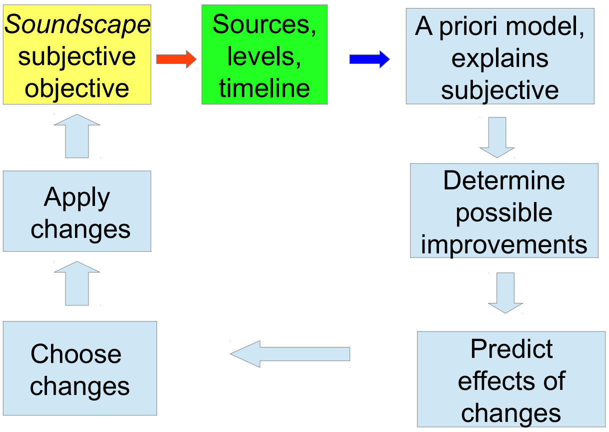

Fig. 1: Improving a soundscape

5.2 Synthesis- reductionist

Starting from an a priori inventory of the relevant sources, and their acoustical properties, the contributions to the physical sound field can be calculated. They can be judged separately, based on preferred values for each (type of) source. This can be regarded as a reductionist approach.

Practice has learned that it is not easy to extract an overall judgment from the contributions of the sources. We would have to consider different sensitivities, masking effects. For functional soundscape we can do without the overall judgment.

The difference in approaches is visualised in Figures 2 and 3.

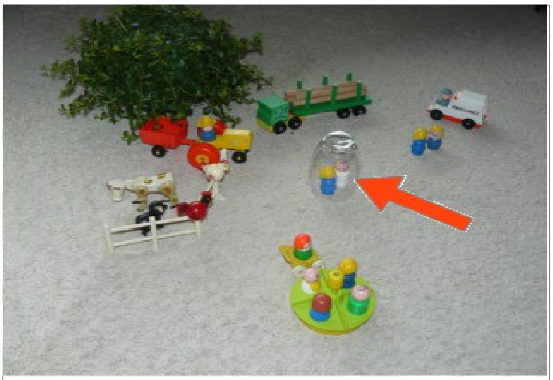

Fig. 2: Complex soundscape-holistic approach.

The "holistic" approach, starting from the complex soundscape requires analysis a posteriori of the sources and their contributions. The reductionist approach starts from the a priori knowledge of the sources, their strength and character.

Fig. 3: Contributions of sources- reductionist approach.

6 Effect tools

A complex sound can be objectively expressed in the usual acoustical variables (spectrum levels, time history), or psycho-acoustic notions like sharpness, roughness, etc. Psychological descriptions address the meaning of the sound source for the receiver: informative, pleasant, reassuring, alarming, matching visual ambiance, etcetera or their negations. The second type fits best in the chosen approach as a basis for criteria.

In general terms the options for soundscape design are limited: manipulation of sources, (elimination, adapting, adding), of transmission (screening and reflecting) and sometimes the immission (sound insulation of façades).

7 Floor plans

Organisation, routing and floor plans are strongly interconnected. Noise intruding in bed rooms from corridors (trolleys, conversations) can be reduced by application of sound absorbing ceilings, smooth floor covering, trolleys with big wheels, sound insulating doors. However, in the case of new hospitals routing and floor plan can be so arranged, that most of the bedrooms are situated off the main transport axes. Another example is the location of nursing stations in ICU or MCU. In case of an open connection between the nursing station and the patients room, disturbance is hardly avoidable.

Many of the papers in medical and nursing journals about noise in hospitals are just phenomenological. Issues of staff behaviour, too loud alarms and even sound absorption are addressed; but the influence of floor plans together with room acoustics is seldom mentioned. Konkani et al. [5] conclude that in an ICU "behavior modification programs are not effective in reducing noise levels."

8 Building acoustics

8.1 Hospital acoustics 1.0

As a first step basic noise control is required. Specific targets for sound absorption, admissible sound levels and sound reduction of partitions must be established in the design stage of the hospital. In almost all rooms and corridors a sound absorbing ceiling is a just starting point. In many cases it is still possible to add sound absorption in existing buildings. Control of noise from services like HVAC, toilets etc. also belongs to the primary requirements of the building.

Sounds intruding from adjacent rooms or corridors are controlled by means of the sound reduction of partitions; doors in partitions, being weak element in partitions, require special attention.

In Tables 1 and 2 examples of criteria are given.

8.2 Speech communication

Conversations of visitors and staff are multifaceted elements. At a very low level they can just be reassuring, confirming the presence of other people. At a level where the conversation is almost intelligible it can be annoying, and even dangerous if messages are misunderstood. Good intelligibility is required if the patient is addressed by staff, but not if not addressed. Sound absorbing finishings of the right quality in the right places are an important tool to control this. In rooms where speech intelligibility and speech privacy play a relevant part, a specific approach may be necessary. The general procedure in such cases can be as follows:

1. establish the total amount of sound absorption required in a room, for example from the target reverberation time
2. identify the surfaces that should be sound absorbing, to eliminate specific reflections
3. identify the surfaces that should be sound reflecting, to enhance specific (speech) transmission
4. allocate the sound absorption "ad 1 minus ad 2" to the neutral areas

9 Examples

Developing tools by experiment is troublesome in case of outdoor soundscape. Manipulating sources and transmission is often too expensive; almost identical sites where the effects of different measures could be compared are rare.

Indoor soundscapes are much easier. For instance identical hospital bed rooms exist in large numbers. They may already differ in orientation with respect to noisy roads; other differences can be applied, like adding or reducing sound absorption, more quiet equipment etc.

On the other hand, spaces with a more or less public character will be more similar to outdoor soundscape, as indicated by Dökmeci and Kang [12]

9.1 Hospital patient rooms

The number of potential sound sources in hospital bed rooms is very large. Joseph and Ulrich [13] give an extensive, but mostly qualitative survey of acoustical aspects of hospitals. In table 1 a possible inventory is given for the most common sound sources in a hospital bed room. Next to the direct noise level criteria and sound insulation demands, for a number of sources the architectural design is paramount.

Ice cube dispensers are widely used in USA, [14] but hardly in The Netherlands. The tinkling noise of ice cubes can be annoying, especially in the night period, and therefore would require a separate closet, which however not always is available, it seems.

9.2 Nurse stations

A similar table (Table 2) can be set up for nurse stations. There is no reason here to distinguish between night or day. The type of work remains the same, and sleep is not an issue here.

Speech privacy determines the requirements for the sound insulation of partitions and doors, depending on the functions of the adjacent rooms. In principle, all conversations in the nurse station should be regarded as confidential. Special care is necessary for open connections between a nurse station and corridors or other spaces accessible for patients. In some cases additional sound absorption can be sufficient to obtain reasonable speech privacy; otherwise the lay out should be reconsidered.

Source	**day**	**night**
Street traffic	L_{eq}= 35 dB(A)	L_{eq}= 25 dB(A)
General ventilation/AC	L_p= 35 dB(A)	L_p= 30 dB(A)
Corridor	Partition + door: R'_w= 25 dB	
Elevator	L_{max}= 40 dB(A)	
Medical equipment	L_{eq}= 35..40 dB(A)	L_{eq}= 30..40 dB(A)
Alarms, ringing	L_{max}= 60 dB(A)	silent
Sanitary installation noise (toilets)	L_{max}= 40 dB(A)	
Doors slamming	Architectural design *Lay out, organisation, room acoustics*	
Staff conversation		
Visitors conversation		
Roommates		
Neighbour room (mates)	Partitions: R'_w= 43 dB	
Ice cube dispenser	L_{max}= 50 dB(A)	?

Table 1: Sources and tentative noise criteria for a hospital patient room

Source	**Requirement**
Street traffic	L_{eq}= 40 dB(A)
General ventilation/AC	L_p= 40 dB(A)
Corridor	Partition + door: R'_w= 30 dB
Alarms, telephone ringing	L_{max}= 60 dB(A)
Sanitary installation noise (toilets)	L_{max}= 50 dB(A)
Neighbour rooms	Partitions: R'_w= 43..48 dB
Ice cube dispenser	L_{max}= 50 dB(A)

Table 2: Sources and tentative noise criteria for a nurse station.

10 Conclusion

This approach may differ from "normal" soundscape, as it stems from noise control - in buildings. But it is a more integrated approach than 1
usual, which is new in this field. On the other hand, application of the soundscape concept indoors offers chances for experimentation and field research that can be useful for the development of tools for both indoor and outdoor soundscape.

In the cases where acoustical measures are considered or designed, specifications are necessary, not globally, but for each source separately. So, despite the holistic character of the soundscape approach, in the end measures of a physical nature must be specified in a reductionist way, with noise impact values and target values for each source separately.

References

[1] Ulrich, Roger S. ,Effects of interior design on wellness: theory and scientific research, J. Healthcare interior design, 1991

[3] Siegmann, Silvester; Notbohm, Gert; Noise and sleep in hospitals, AIA-DAGA Merano, 2013

[2] Busch-Vishniac, Ilene J.; West, James E.; Kwon, Phillip; Dunn, Jeffrey; The challenges of noise control in hospitals, ICSV 14, 2007

[4] Maidl-Putz, Carolyn; McAndrew, Natalie S.; Leske, Jane S.; Noise in the ICU: sound levels can be harmful; Nursing Critical care, September 2014.

[5] Konkani, Avinash; Oakley, Barbara; Penprase, Barbara: Reducing hospital ICU noise: a behavior-based approach, J. Healthcare Engineering 5 no.2, 2014

[6] Ortega, Julienne; Kanapathipillai, Sangarapillai; Daly, Barbara; Hilbers, Julieanne; Varndell, Wayne, Short, Alison; The sound of urgency: understanding noise in the emergency department; Music and Medicine 5(1), 2013

[7] Ruiter, E. de: Soundscape, privacy, communication and orientation, International Congress 'Doing, thinking, feeling home: the mental geography of residential environments', October 2005, Delft, The Netherlands.

[8] Lercher, P., Schulte-Fortkamp, B.: The relevance of soundscape research to the assessment of noise annoyance at the community level, ICBEN 2003.

[9] Axelssön, Ö.: The ISO 12913 series on soundscape. Forum Acusticum 2011.

[10] Ryherd, E., Too noisy to heal, Healthcare Design, 2011

[11] Brown, A.L., Muhar A.: An approach to the acoustic design of outdoor space, Journal of Environmental planning and managemant, vol. 47, no. 6, November 2004.

[12] Dökmeci, P.N., Kang, J.: Classification of architectural spaces from the viewpoint of acoustical comfort, Inter Noise 2010.

[13] Anjali, J., Ulrich, R.: Sound control for improved outcomes in healthcare settings, Issue paper #4, January 2007, The Center for Health Design

[14] Hospital acoustics group on LinkedIn:

http://www.linkedin.com/groups/Hospital-Acoustics-2480179?trk=myg_ugrp_ovr

Appendix: Citation from WHO Guidelines

"4.3.3 Hospitals

For most spaces in hospitals, the critical effects of noise are on sleep disturbance, annoyance and communication interference, including interference with warning signals. The LAmax of sound events during the night should not exceed 40 dB indoors. For wardrooms in hospitals, the guideline values indoors are 30 dB LAeq, together with 40 dB LAmax during the night. During the day and evening the guideline value indoors is 30 dB LAeq. The maximum level should be measured with the instrument set at "*Fast*".

Since patients have less ability to cope with stress, the equivalent sound pressure level should not exceed 35 dB LAeq in most rooms in which patients are being treated or observed. Particular attention should be given to the sound pressure levels in intensive care units and operating theatres. Sound inside incubators may result in health problems, including sleep disturbance, and may lead to hearing impairment in neonates. Guideline values for sound pressure levels in incubators must await future research."