ACOUSTICS IN ROOMS FOR REHABILITATION OF LARYNGECTOMEES

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Abstract:
Laryngectomy is a medical operation, resulting in the loss of "normal" speech. Laryngectomees can learn to speak using their oesophagus; this takes intensive training, often in groups of about 5-10 patients and a trainer. It has become clear that in hospitals the requirements for rooms, meant for this type of rehabilitation are often not met.

The aim of this research is to improve the acoustic functionality of the rooms for rehabilitation of laryngectomees. To this end, the acoustic parameters of such rooms have been measured: reverberation times, background levels, sound insulation of surrounding partitions.

Comparison with the requirements from earlier empirical knowledge shows the elements that have to be improved. The proposed measures include addition of sound absorbing finishing in specific positions, and better sound insulating doors.

Keywords: hospital acoustics, laryngectomees rehabilitation rooms

1. INTRODUCTION

Laryngectomy is the medical operation of removing the larynx, resulting in the loss of "normal" speech. Patients (laryngectomees) can learn to speak using their oesophagus. This takes intensive training, often in groups of about 5-10 patients and a trainer. It has become clear that in hospitals the quality of rooms, used for this type of rehabilitation is often not optimal. The aim of this research is to improve the acoustic functionality of the rooms for rehabilitation of laryngectomees. As a matter of fact, there are no standards for the acoustical quality of these rooms, and the criteria for optimal acoustical values still have to be established. It may seem that the training is a single function, it consists of two elements:

- training of each patient, which requires good optimal speech intelligibility,
- training of the patients in a normal daily life situation.

These functions all benefit from a low background noise level, but the required room acoustics is different. First a set of provisional requirements has been defined, based on experience in logopedics training, and room acoustics with a focus on speech intelligibility.

Next, the acoustic parameters of such rooms have been measured: reverberation times (RT), background levels, sound insulation of surrounding partitions.

Comparison with the requirements from earlier empirical knowledge shows the elements that have to be improved. The proposed measures include better sound insulating doors and addition of sound absorbing finishing in specific positions. Variable sound absorbing elements can be needed to adapt the room to its momentary functions, but is certainly indispensable for the future research into the optimal room acoustics for these training rooms.

2. REQUIREMENTS A PRIORI

The initial training starts as soon as is medically possible, in a 1-1-setting: the patient and the speech therapist in a hospital room. The training of laryngectomees does not imply special requirements here. After a few weeks patients take part in group training in a larger room. The distances between patients and therapist will be larger, so for training the speech intelligibility requires more attention. Getting used to conversation in daily life rooms, means rooms where the conditions for speech intelligibility are worse, usually caused by longer reverberation times of 1 s or more.

The social aspect of the meetings also is expressed in singing songs together. For this activity also a longer reverberation time is favorable.

So three different sets of conditions can be distinguished, for:

- one-to-one training room
- group training room
- daily life, social and singing room.

3. ROOM ACOUSTICS

The German standard DIN 18041 [1] gives requirements as well as possible solutions for the room acoustical design of this type of rooms. In general for training a reverberation time of 0.5 s and a background level of 35 dB(A) are a good starting point. The requirements of the sound insulation of partitions depends on the lay-out of the department; usually however a good quality door -with perimeter sealing- is necessary.

If we assume the sound absorption in the room located in the (suspended) ceiling only, Sabine's formula (T=V/6A) can be transformed into a relationship between the height of the room h and the sound absorption coefficient of the ceiling: $\alpha = h/3$.

A strongly sound absorbing ceiling (α= 80% or more) is thus necessary, and the room height should be less than 3 m.

To avoid specific resonances in the room, the addition of sound absorption -a strip at head level- to one or two walls is an easier solution than the alternative of avoiding parallel walls.

For a group training room a more sophisticated approach is desired. Certain sound reflections should be sustained to increase speech intelligibility; others should be suppressed. Depending on the shape and dimensions of the room, a partially sound reflecting ceiling and partial sound absorbing finishing of one or two walls is the solution. The examples in Fig.1 are taken from DIN 18041.The sound absorbing parts are cross-hatched.

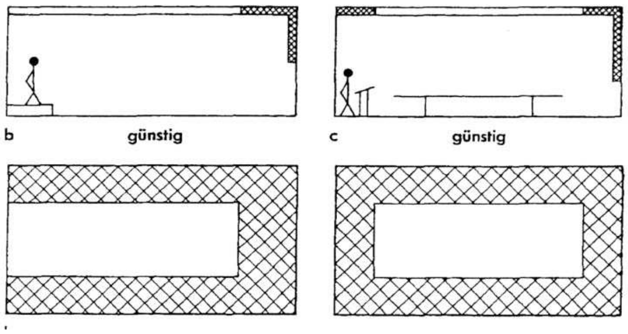

Fig. 1: Positions of sound absorbing surfaces, favourable for speech transmission

For the third room type (daily life, singing) a longer reverberation of 1s seems a reasonable choice. The necessary sound absorption can easily be found in a partial sound absorbing ceiling.

4. BACKGROUND NOISE

The background level is important for its influence on speech intelligibility, but also for its distracting effect; in training sessions decrease of concentration should be avoided. Therefore not only the equivalent sound level should be limited -at 35 dB(A)- but also sound peaks; there a limit of 40-45 dB(A) could be set.

The background noise can originate in several sources, each with its own character, for instance:

- installations for ventilation (HVAC): constant
- external traffic noise: fluctuating
- corridor next to training room: fluctuating, peaks
- adjoining rooms (depends on activities in these rooms)
- fellow patients (coughing): peaks

Controlling all these noise sources requires direct limits (ventilation); sound insulation values qualities of facades and internal partitions, including doors; and room acoustics.

The foregoing applies to training rooms -small and large; preferably they should also be applied to the daily life, social room. If desired to simulate noisy rooms, it would be easy to increase the sound level by means of artificial noise of any kind.

5. SOUND INSULATION OF FAÇADES, PARTITIONS AND DOORS [REQUIREMENTS]

For the façades the requirements can calculated from the incident traffic noise level and the sound limits in the training room; for each partition the requirements must be derived from the sound level in the adjoining room or corridor, and the sound limits in the training room. In many cases, like the corridor, an exact prediction of the sound level is not possible; then an estimate can be used, which could be based on measurements in a similar situation.

The first consequence of increased demands on the sound insulation of a façade, is the need to in a different way than through open windows. Instead special sound insulating ventilation devices can be placed in the façade, or -better, quiet- mechanical ventilation installed.

6. EXPERIENCES IN HOLY CROSS HOSPITAL KIELCE

Measurements were made on April 9th, 2013 with a Norsonic 140 sound level analyzer, and a Norsonic dodecahedron sound source, in the day-room that is used for training of patients.

The background level was measured in the empty room, with windows open and closed, because there is no other way of ventilation. The relevant values are presented in Table 1.

Table 1: Background levels in empty room.

	Windows closed	Window open
A-weighted sound level	33 dB(A)	37 dB
PSIL (500-2k Hz)	26 dB(A)	32 dB

In Fig.2 the 1/3-octave band levels are presented.

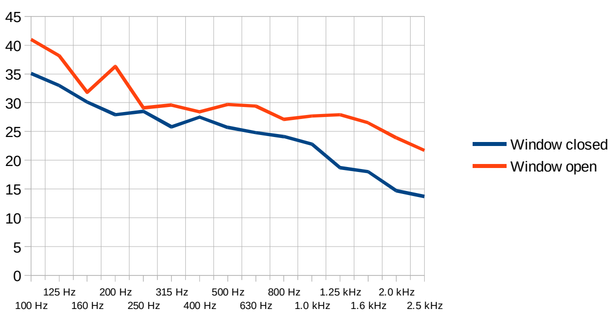

Fig.2: Background levels empty room

The reverberation time was measured in four configurations of source and microphone. The average values are given in Fig.3. The most relevant value for use in further calculations of speech intelligibility is T= 1.2 s.

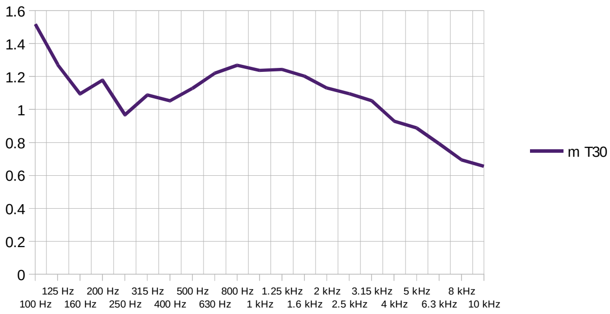

Fig.3: Reverberation time empty room

The corridor partition is largely a glazed construction, with a door. Conversation of groups of people in the corridor can be a source of noise to the training room. Therefore the sound reduction of this partition was measured, from corridor to room. The results in 1/3-octave bands are given in Fig.4.

The closing and opening of the door, in particular the lock, causes high sound levels; sound peaks far over PSIL= 50 dB were recorded.

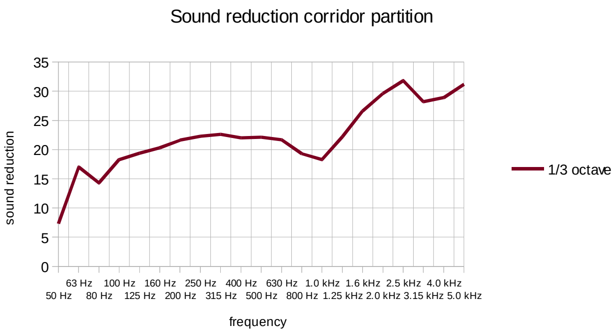

Fig.4: Sound reduction corridor partition (with door)

7. SPEECH INTELLIGIBILITY (AL_{CONS})

As might be the case in many other hospitals, there is only one room available for group training and social meeting, singing etc. training. This room does not differ from other day-rooms in the hospital. The quality of this room for use as a training room, can be judged based on speech intelligibility, expressed as Al_{cons} (Articulation Loss of Consonants) [2]. The value of Al_{cons} can be calculated from the now available data; it depends on the reverberation time and the background noise level. At distances less than a certain limit the value depends on the distance to the source as well; for simplicity only the Al_{cons} in the reverberant field will be regarded.

In table 1 the calculated values of Al_{cons} in the reverberant field are given for the measured reverberation time (1.2 s) and background level (30 dB), and for shorter reverberation times and higher background levels. The background level used here is the average value of the octave bands 500, 1000 and 2000 Hz (PSIL). The RT of 1.2 s applies to the empty room; if patients are present the RT can be estimated to reduce to about 1 s.

Table 2. AL_{cons} (%) for several values of reverberation time T and background level.

	background noise (PSIL)				
T	**30**	**35**	**40**	**45**	**50**
1.2	10.8	10.8	12.4	17.1	23.4
1.0	9.0	9.0	11.1	15.6	21.9
0.8	7.2	7.2	9.7	14.1	20.5
0.6	5.4	5.4	8.3	12.6	19.1
0.5	4.5	4.5	7.6	11.9	18.5

The meaning of these Al_{cons} -values for normal hearing listeners and normally articulating speakers can be illustrated as follows:

- < 3%: excellent
- 3-7%: good
- 7-15%: fair
- 15-33%: poor
- > 33%: unintelligible

For the training for laryngectomees no specific information is available, but the judgment shall be at least somewhat more stringent. If we draw the line at Al_{cons} = 5%, it becomes clear that only reverberation times below 0,6 s and below background noise PSIL=35 dB are satisfactory.

The normal background level is sufficiently low, but opening and closing of the door causes noise peaks of far over 50 dB PSIL, increasing Al_{cons} to unacceptable values, even if the RT would be much shorter.

Groups of people talking in the corridor area can easily produce sound levels of 70 dB(A), PSIL 65 dB. Taking into account the measured sound insulation of the corridor partition (figure 4), the resulting level in the room will be 50 dB(A), PSIL 42. Again, the Al_{cons} becomes too high, even if the RT would be much shorter.

8. DISCUSSION

The training room can be regarded as suitable for social group sessions and singing together. For training purposes a few items would have to be changed:

- RT should be reduced to 0.6 s, enhancing useful reflections as well
- sound insulation of the corridor partition should be increased by at least 10 dB
- the lock of the door should be changed in such a way, that closing and opening of the door is hardly audible

The circumstance that one room is available only for the purposes of training and social/singing remains a problem. A compromise is possible -RT 0.7 s- , but far from ideal.

A better solution is “variable acoustics”: regulation of the RT by means of removable sound absorption.

9. VARIABLE ACOUSTICS

Removable sound absorbing surfaces can be created by means of plushy curtains, that can be stored in a special closed cupboard. This conflicts however with the specific demands of a hospital room for training laryngectomees. A simple alternative consists of panels with a sound absorbing and a sound reflecting side, each pivoting on a vertical axis, mounted to the wall; see Fig.5.

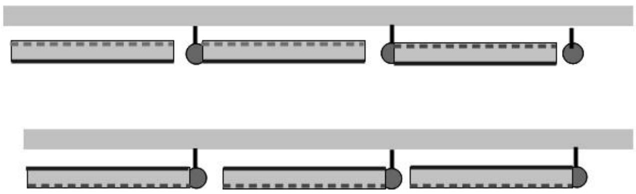

Fig.5: Vertical panels; sound reflecting vs. sound absorbing

The present furnishing of the room has only one wall available for this type of construction. So, in praxis the removable amount of sound absorption will be no more than 13 m2 (5,6 x 2,8 x 80%), assuming a highly sound absorbing material (absorption coefficient 80%). With the right amount of sound absorbing ceiling, the RT can then vary from 0.55 to 0.8 s. This range is smaller than our wish, but still usable.

10. FUTURE RESEARCH

A room for training and social meeting/singing with variable acoustics is not only a serious improvement if only one room is available, but also offers the possibility to investigate the optimal conditions for these distinguished purposes. For the users- patients and speech therapists- are the persons to judge.

Next, extension of this research to other hospitals in Poland and possibly other European countries is intended.

REFERENCES

[1] DIN 18041, “Acoustical quality in small to medium-sized rooms” (in German), Deutsches Institut für Normung, 2004.

[2] V.M.A. Peutz, “Articulation Loss of Consonants as a Criterion for Speech Transmission in a Room”, J. Audio Engineering Society, vol. 19, (1971).