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SUBJECTIVE EVALUATION OF SPEECH INTELLIGIBILITY

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1. INTRODUCTION

The aim of this work has been to investigate how different types of absorber treatment in classroom influence subjectively perceived speech intelligibility. A listening test has been carried out in order to classify different treatments in respect to achieved speech intelligibility.

The listening test has been performed by two groups of subjects. One group consist of normal hearing individuals. The other group consist of subjects that listened to the test with special earplugs attached to their ears. The earplugs have been used in order to simulate a minimal degree of hearing loss.

It is well recognised [1] that the acoustical conditions in a classroom are important in the educational management of hearing-impaired children. Further that a poor acoustical environment due to long reverberation times and/or high background noise levels affects these children, in a higher degree than normal hearing children. With minimal degrees of hearing loss is meant a pure tone threshold between 15 and 30 dB hearing loss. This type of hearing loss is often a secondary effect of a cold or an inflammation and usually of a temporary nature. As a result of these affections the eustachian tube becomes swollen and a low pressure appears behind the eardrum. As a consequence the eardrum becomes less movable and hearing loss between 15 and 30 dB appears. However, it is a difficult task to collect a group of subjects with this type of hearing loss since it is of temporary nature. Instead we have chosen, in consultation with a specialist for ear-diseases, to use normal-hearing persons and with means of special earplug simulate a minimal degree of hearing loss. The earplugs give a rather constant damping of 15 to 30 dB (rel. The threshold of hearing) through the frequency range 125 to 8000 Hz. Commonly used earplugs often damp higher frequencies much more effectively than lower frequencies. Listening through earplugs also reproduce a bit of the feeling of closeness that often appears in connection with hearing loss due to e.g. a cold.

2. METHOD

The recordings are made in a rectangular shaped classroom with a volume of 250 m^3. A loudspeaker in the classroom reproduced anechoic recorded male and female speech. Dummy-head recordings were made for 13 different absorber treatments of the classroom. Nine of these where selected for the listening test.

As a sound source, a small monitor loudspeaker was used. The directional distribution of this loudspeaker corresponds rather well with the directional distribution of speech around a human head. The loudspeaker was located at the teacher's desk during the recordings. As a listening position a place in the lower part of the classroom was chosen.

For each treatment case room acoustical parameters were measured. The following criteria was measured; reverberation time T(-5, -25 dB), early decay time EDT(0, -10 dB) and RASTI-values. The sound spectra for the speech at the listening position as well as background noise levels were also measured.

The sound pressure level at the listening position was determined in such a way that the sound power radiated by the loudspeaker was kept constant for all treatment cases. Before every measurement it was checked that the speech level at the listening position was good. The sound absorption due to pupils was simulated by absorbers designed for being equivalent to the absorption of a pupil. The numbers of occupied seats in the classroom were 15.

The dummy-head recordings were arranged so that paired comparison tests of the different treatment cases were possible. During the listening test the subjects listened to the treatment cases through earphones. For each comparison the task for the subject was to decide for which of the treatment cases the *speech intelligibility was greatest.*

A total of 25 listening tests with normal-hearing subjects have been carried out. For the group with simulated minimal degrees of hearing loss a total of 23 listening test were performed. For this group an audiogram was obtained with and without earplugs. This was done just before the test was performed. It was checked that the received damping was in region –15 to –30 dB and thereby corresponds to a minimal degree of hearing loss. The audiogram was only obtained for the subject's right ear. For three of the subjects the received damping deviate too much from what can be considered as a minimal degree of hearing loss.

3. TREATMENT CASES

The following absorber treatments of the classroom are included in the listening test.

1. Plaster board, perforated (12%) with sound absorbing felt
2. Plaster board, perforated (18%) with sound absorbing felt
3. Wood fibre (20 mm)
4. Wetfelt, fissured (15 mm)
5. Glasswool (15 mm), with an extra layer of paint
6. Glasswool (20 mm), with normal paint finish and additional spatter finish
7. Glasswool (40 mm), with normal paint finish + sound absorbing notice-board on the rear wall
8. Glasswool (20 mm), 75% with normal paint finish and 25% with extra paint layer + sound absorbing notice-board on the rear wall
9. Glasswool (20 mm), 75% with normal paint finish and 25% with extra paint layer

4. STATISTICAL ANALYSIS

The result from the listening test has been analysed using a modified Bradley-Terry model [2].
The modification, meaning that ties are permitted in the model, is developed by Rao and Kupper [3]. As a result of the model treatments ratings π are calculated such that t treatments have "true" treatment ratings $\pi_1, \pi_2, \ldots \pi_t$ such that $\pi_i \geq 0$ ($i=1, 2, \ldots t$) and $\sum_{i=1}^{t} \pi_i = 1$.
Estimation of π_i is obtained by the Maximum likelihood method. The number of paired comparisons has been reduced in order to reduce the time for the subjects to carry out the listening test. This has been done in such a way that we received an uncompleted but balanced schedule.

5. RESULT

Data from the listening test concerning normal hearing subjects has been analysed for the following cases:

1. Both male and female voice is included in the analysis. The number of subjects is 25, 13 of which have listened to a male voice and 12 to a female voice.
2. Only a male voice is included in the analysis. The number of subjects is 13.
3. Only a female voice is included in the analysis. The number of subjects is 12.

Data from the listening test concerning subjects with simulated minimal degrees of hearing loss has been analysed for the same cases as above but the number of subjects are for case 1; 20, case 2; 10, case 3; 10.

Estimation of the treatment ratings π has been calculated. The treatment with largest π has been judged as given the greatest speech intelligibility, the treatment case with the second largest π is judged as given the second greatest speech intelligibility and so on. A 95% confidence interval has also been calculated for π.

The preferences for normal hearing subjects and for subjects with minimal degrees of hearing loss regarding the different treatment cases are presented in figure 1 and figure 2 respectively.

In figure 3 and 4 the rating values π for normal hearing subjects and for the different treatment cases are presented as a function of reverberation times and RASTI-values respectively. The reverberation time constitutes the meanvalue for the octave bands 0.5, 1 and 2 kHz and is evaluated on the interval –5 to –25 dB of the reverberation curve.

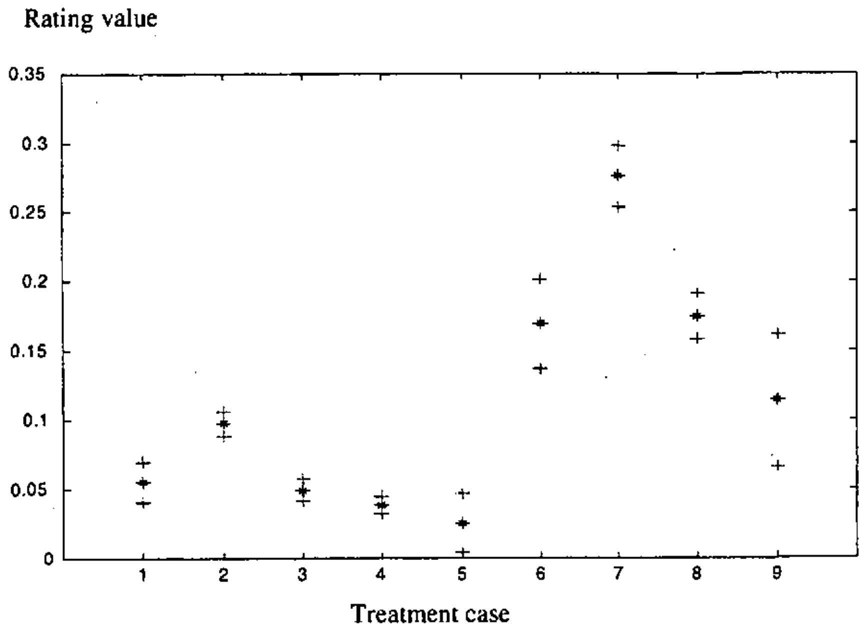

Fig. 1 Rating values for the different treatment cases according to paragraph 3. Both a male and a female voice are included in the analysis. Normal hearing subjects.

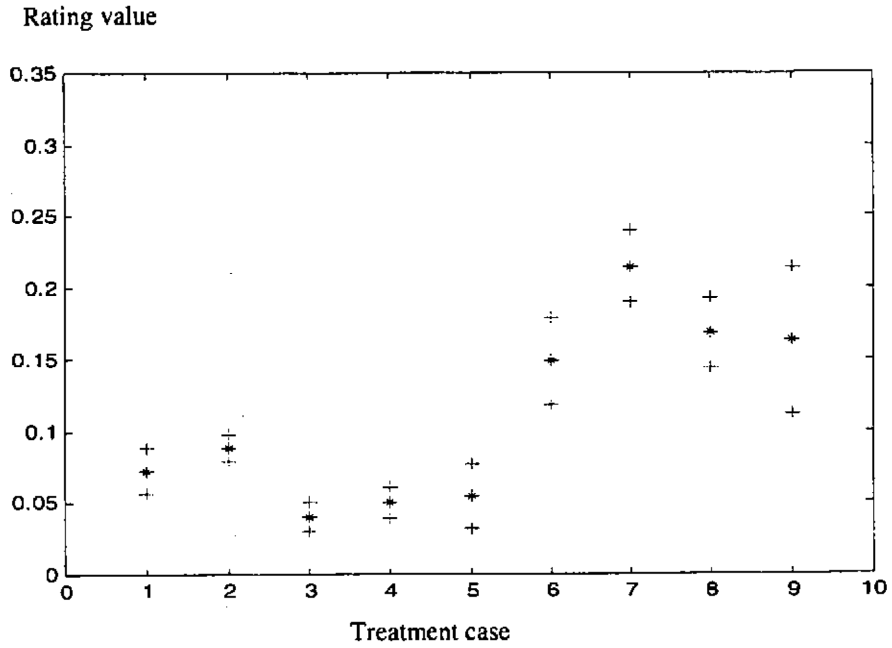

Fig. 2 Rating values for the different treatment cases according to paragraph 3. Both a male and a female voice are included in the analysis. Subjects with simulated minimal degrees of hearing loss.

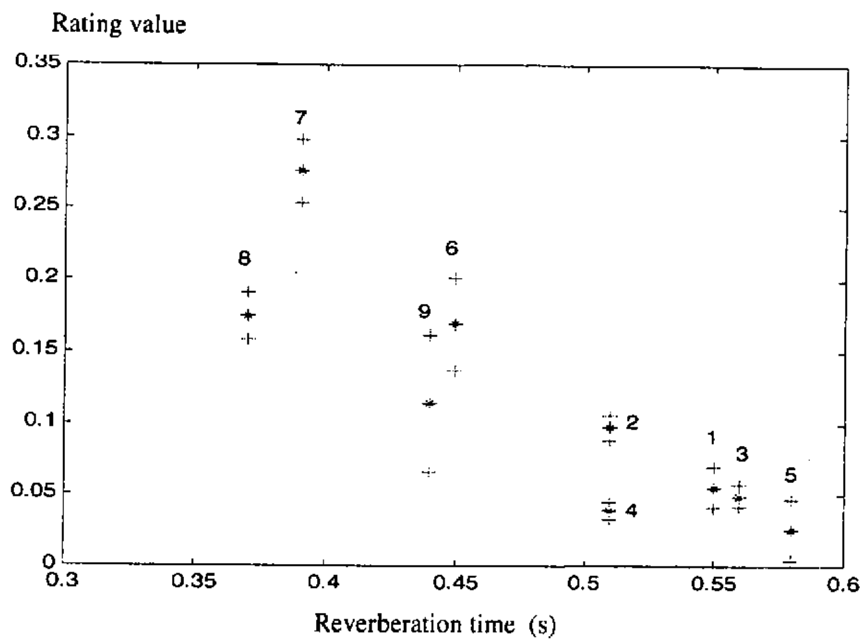

Fig. 3 Rating values as a function of reverberation time. The figures 1 to 9 in the diagram refer to the treatment cases according to paragraph 3.

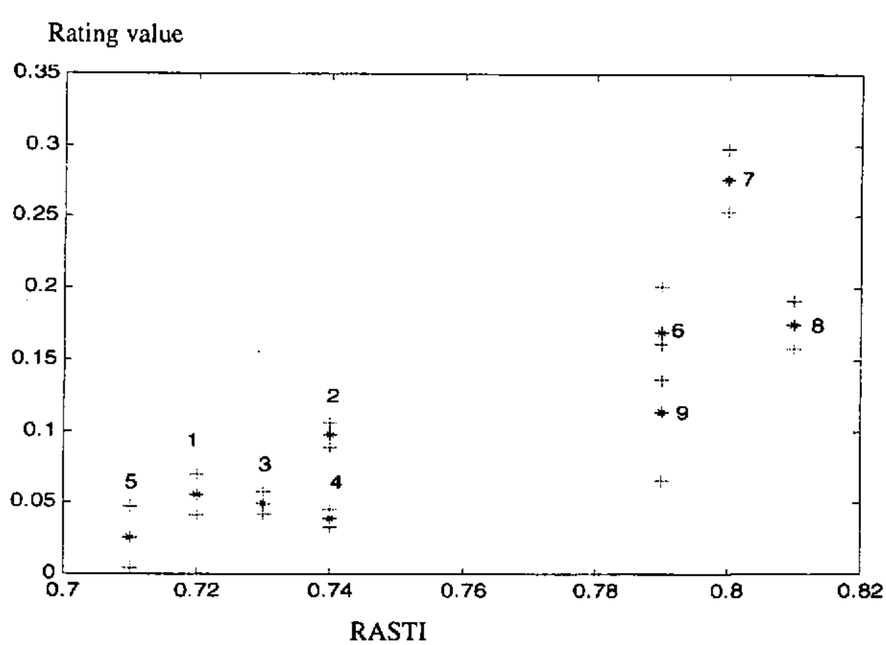

Fig. 4 Rating values as a function of RASTI-values. The figures 1 to 9 in the diagram refer to the treatment cases according to paragraph 3.

6. COMMENTS AND CONCLUSION

The comments and conclusion in this paragraph are based on the complete analysis presented in [4]. The results from the statistical analysis show that mainly two groups with significant differences in the preference can be outlined. In respect of the intelligibility the treatment cases 6, 7, and 8 are preferred before 1, 2, 3, 4 and 5. For male speech, the preferences for treatment case number 7 are significant much larger than for the rest. This is probably due to the fact that this case has the shortest reverberation time at low frequencies. Since the male voice often contains a relatively large amount of energy at low frequencies, short reverberation times at these frequencies are important for the speech intelligibility.

When the rating values are plotted as a function of reverberation times and RASTI-values we can in broad outline notice that for the regions in which the reverberation times and RASTI-values have been varied the preferences increase towards lower reverberation times and towards higher RASTI-values. The result shows that a significant improvement of subjectively perceived speech intelligibility is achieved if the reverberation time is changing from about 0.55 seconds to about 0.40 seconds. Concerning the RASTI-value the results show a significant improvement of subjectively achieved speech intelligibility if the RASTI-value changes from about 0.73 to about 0.80.

However, for almost equal RASTI-values and equal reverberation times there are discrepancies in the preferences. This indicate that there are other parameters besides reverberation time and RASTI-value that influence subjectively perceived speech intelligibility, e.g. the spectral distribution of sound energy in the speech.

The results above are valid for both normal hearing individuals and for persons with simulated minimal degrees of hearing loss.

7. REFERENCES

[1] Carl B. Crandell. Ear & Hearing Vol. 14 No. 3, 1993. Speech Recognition in Noise by Children with Minimal Degrees of Sensorineural Hearing Loss.

[2] R.A. Bradley. 1954. Biometries. Incomplete block rank analysis: On the appropriateness of the model for a method of paired comparisons.

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