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HOW ACOUSTIC REFURBISHMENT OF A CLASSROOM AFFECTED PUPILS AND SOUND LEVELS – A NATURAL EXPERIMENT

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ABSTRACT

We determined how pupils perceive activity noise in classrooms A and B having different room acoustic qualities. Classroom A was traditional (reverberation time 0.54 s). Additional noise control was applied in classroom B (0.32 s). In both classrooms, teachers kept controlled lessons according to four activity types. During the controlled lessons, activity sound levels were measured. At the end of each controlled lesson, pupils' experiences were inquired using a questionnaire. In general, the most annoying sound source was other pupils' speech. More pupils were annoyed by it in classroom A (65%) than in classroom B (15%). Activity sound levels during controlled lessons were 2−13 dB lower in classroom B. Noise control might reduce pupils' noise annoyance and enable quieter activity especially during the loudest lesson types.

Keywords: *classroom acoustics, classroom noise, noise annoyance, noise effects, school acoustics*

1. INTRODUCTION

Finnish Building Code [1] involves the following target values for classrooms:

1. Environmental noise level ≤35 dB L_{Aeq};
2. Building service noise level ≤33 dB L_{Aeq};
3. Reverberation time 0.50–0.70 s (250–2000 Hz);
4. Speech Transmission Index, STI≥0.70.

Three first requirements have been applied since 2000. The fourth was introduced in 2018. Because these requirements are quite stringent and they are usually well obeyed in Finland, it would be easy to believe that there are little reasons to study classroom acoustics. However, the pedagogic methods have become more versatile: many teachers increasingly apply modern methods where group work and interaction are even more usual than previously. During group work, for example, the classroom can be used in a similar way as open-plan offices. In this situation, it is not useful that STI is kept high throughout the room. Therefore, it would be interesting to investigate, how noise control affects pupils and sound levels in a normal classroom. Since the sound level depends on activity type of the lesson, the activity type should be controlled.

The purpose of our study was to examine the experience of noise and sound levels in two classrooms differing in noise control. The full version of the study, including a broader literature review, is given in Ref. [2].

2. MATERIALS AND METHODS

This study compared the classroom activity noise and pupil's experience of it during different types of learning (lesson types) in two classrooms (classroom types). Classroom B was acoustically refurbished (improved noise control). Classroom A represented the situation before the refurbishment. Two permanent teachers teaching daily in these two classrooms agreed to arrange controlled lessons according to *lesson type* descriptions explained below:

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1. **Quiet**: e.g., reading a book quietly or an exam;
2. **Dialogue**: teacher or pupil is talking, one after the other;
3. **Group**: several people are speaking; and
4. **Activity-based**: Several people speaking and moving.

Participants were 10–11 years old pupils, who studied in classrooms A and B. The classroom A had 21 pupils and the classroom B had 18.
The classrooms had the same room size (60 m^2). Ceilings were covered with 20 mm wool suspended by 200 mm in both classrooms. The classroom A had 2.9 m^2 of sound-absorbing panels (50 mm wool) glued to the wall. The floor was hard (Linoleum). Desks and chairs had metal legs and wooden surfaces producing noise during use. The classroom B had 13 m^2 of sound-absorbing panels (50 mm wool) glued against the wall, soft flooring (textile carpet), sound-absorbing curtains, some sound absorbing (soft) furniture with four beanbag chairs, five stool cubes, four teepee space dividers, and quietly closing drawers. The reverberation time, STI, and speech SPL at different distances from the speaker were examined according to ISO 3382–2 and ISO 3382–3.
Activity sound level is the A-weighted equivalent SPL during the 30-min controlled lesson, $L_{\mathrm{Aeq,30min}}$. The sound level meters (2 in both classrooms) were hidden from the sight of the pupils on top of the closets (height 2.1 m) so that the values were comparable between the classrooms.
Pupils filled two types of questionnaires: general questionnaire (once) and shorter questionnaires after four controlled lessons. *General annoyance* was asked by: "How much noise annoys you in this classroom in general?" *Annoyance* after each lesson was asked by: "How much noise annoyed you during this lesson?" *Annoyance caused by different sound sources* was asked by: "How much you are annoyed by the following sounds in this classroom during this lesson?" It was followed by 8 items listed in Sec. 3.
Differences between groups on general annoyance were tested with Student's t-test for independent samples. Annoyance during controlled lessons was analyzed with Mann–Whitney U test. The response categories 1 and 2 of annoying noise sources were coded as "not annoying" and categories 3 and 4 were coded as "annoying". If less than five pupils considered the sound source annoying, the conclusion was that the sound source was not annoying and no further tests we performed. For variables with more than four annoyance ratings, the differences between the classroom types were analyzed using Fischer's exact test.

3. RESULTS

The measured room acoustic conditions are shown in Table 1. The activity sound levels are reported in Table 2.
The general annoyance was lower in the classroom B than in A (p<0.05) (Figure 1). In addition, annoyance was lower in the classroom B than in classroom A during lesson types Dialogue (p<0.05) and Activity-based (p<0.05) (Figure 2). The most annoying sound source was other pupils' speech (Figure 3). More pupils reported being annoyed by other pupils' speech in classroom A (65%) than in classroom B (15%) (p<0.05).

Table 1. Room acoustic conditions in classrooms A and B. $L_{\mathrm{Aeq,B}}$ is the mean A-weighted SPL of background noise in unoccupied room (ventilation). T_{20} is the mean reverberation time within 125–8000 Hz. STI is the mean in pupil's area. $L_{\mathrm{A,S}}$ [dB] is the mean A-weighted SPL of a standard effort speech in pupils' area.

	A	B
$L_{\mathrm{Aeq,B}}$ [dB]	29	29
T_{20} [s]	0.54	0.32
STI	0.76	0.80
$L_{\mathrm{A,S}}$ [dB]	54.7	52.3

Table 2. Equivalent A-weighted SPL in classrooms A and B during four 30-min controlled lessons, $L_{\mathrm{Aeq,30min}}$ [dB].

Lesson type	A	B
Quiet	53	44
Dialogue	53	51
Group	59	55
Activity-based	72	59

4. DISCUSSION

Classroom B had fainter activity sound levels, and fever pupils reporting noise annoyance in general, and fever pupils reporting annoyance from other pupils' speech than classroom A. The sound levels during lesson type "Dialogue" were almost the same in both classrooms, but during other lesson types, the sound level in classroom B was fainter. The difference was the largest (13 dB) for lesson type "Activity-based".

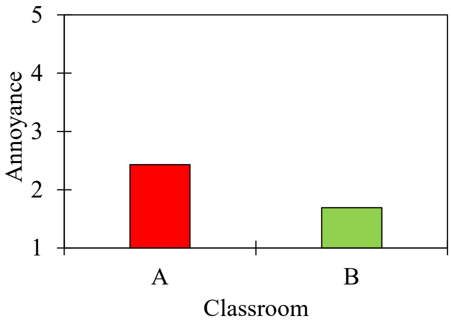

Figure 1. The average general annoyance reported by the pupils in classrooms A and B. Scale: 1 Not at all, 5 Extremely. The difference is significant ($p<0.05$).

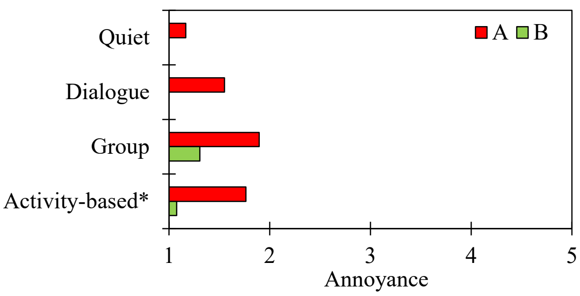

Figure 2. The average annoyance during the four test lessons presented for the classroom types (*$p<0.05$).

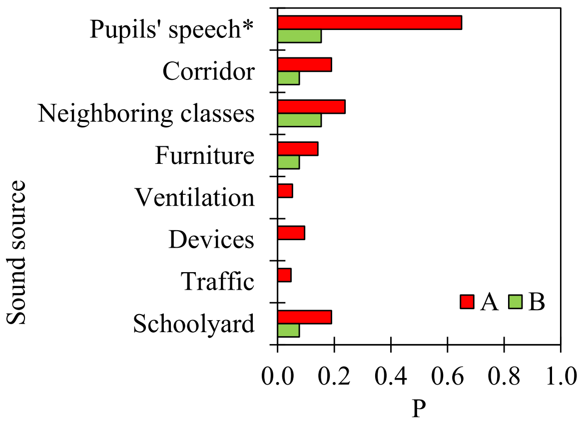

Figure 3. The proportion of pupils (P) annoyed by sound sources in classrooms A and B (*$p<0.05$).

The larger room absorption of classroom B cannot alone explain the differences in activity sound levels: the calculated effect of additional absorption in classroom B in diffuse field is under 3 dB. We believe that textile carpet and quiet furniture in classroom B reduced the noise emission caused by walking, item dropping, chair moving, and furniture door closing. Lower level of movement sounds probably fostered the use of lower voice effort.

The most annoying sound type was other pupils' speech. Other pupils' speech was more annoying in the classroom A. This suggests that noise control made in classroom B diminished the annoyance toward other pupil's speech.

The main limitation of our study is that both the teachers and pupils in classrooms A and B were different. Activity SPLs can be initially different due to different pupil material, teaching methods, and teacher's voice level. This probably influenced the results at least to some extent but we cannot know the direction. Further limitation is that the data in both classrooms is based on only one controlled lesson per lesson type. Findings may be accidental. Future research should be more extensive (more classrooms, more controlled lessons).

5. CONCLUSIONS

Our study shows a novel approach into examining activity noise in schools. Our study indicates that noise control (added wall absorption, quiet furniture, soft flooring, soft furniture, curtains) might reduce noise annoyance among pupils and enable quieter activity especially during the loudest lesson types: the activity-based study periods. However, our study concentrated on one case and more research on the topic using similar methods is needed.

6. ACKNOWLEDGEMENTS

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