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Activity noise in acoustically different classrooms – sound levels and pupils' experience

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ABSTRACT

Our purpose was to determine how pupils perceive activity noise during different activity types in two classrooms having different room acoustic qualities. One was a traditional classroom (reference classroom, reverberation time 0.54 s, 21 pupils), while the other was a refurbished classroom (demo classroom, 0.32 s, 18 pupils). In both classrooms, teachers kept test lessons according to four different activity types: quiet work, one person speaking, group work, and activity-based work. The pupils were10—11-year-old. During the test lessons, activity sound pressure levels were measured, and at the end of each test lesson, pupils' experience was inquired with a questionnaire. In addition, pupils filled a general questionnaire concerning school noise. In general, the most annoying sound source was other pupils' speech. More pupils were annoyed by it in the reference classroom (65%) than in the demo classroom (15%). Activity sound pressure levels during test lessons were lower in the demo classroom than in the reference classroom. The smallest difference between the classrooms was during one person speaking (2 dB L_{Aeq}) and largest during activity-based work (13 dB L_{Aeq}). The difference could not be explained by larger room absorption on reference classroom. Most probably the softer environment fostered also calmer behavior. The study presents a new approach using test lessons for studying activity sounds in schools in acoustically different environments.

Keywords: Schools, Activity noise, Classroom acoustics, Pupils' experience, Noise annoyance

INTRODUCTION

Noise is unwanted or unpleasant sound that in schools can influence children's cognitive behavior and learning (1,2). External noise has a clear influence on children (3) and it has been extensively studied. However, in the schools that reside in areas without a special

external noise burden, the external sound level influenced classrooms' internal sound levels only during the quietest activity (4). Therefore, the influence of activity noise on students should be more examined.

The classrooms' acoustic design influences how the activity sound is replicated. The acoustic design should make the space suitable for its functions. However, classrooms have multiple functions as teaching nowadays requires multiple learning methods. When examining the SPL of occupied classrooms, Shield and Dockrell (4) classified classroom activity into six categories with different sound pressure levels: [1] children sitting at tables doing silent reading or tests; [2] children sitting at tables or on the floor, with one person (teacher or child) is speaking at any one time; [3] children sitting at tables working individually, with some talking; [4] children working individually, moving around the classroom, with some talking; [5] children working in groups, sitting at tables, with some talking; and [6] children working in groups, moving around the classroom, with some talking. The sound pressure level during the quietest activity [1] was 56 dB L_{Aeq}, while it was 77 dB L_{Aeq} for the loudest activity [6] (4).

Activity-based learning methods that include the collaborative and active ways of learning are now emphasized in the new Finnish national core curriculum for basic education (5). These activities probably produce the loudest classroom noise. At the same time, learning environments should enable the teachers' speech to be heard clearly.

One of the most examined room acoustic measures in classrooms is reverberation time (RT), which tells how long time it takes for a sound to decay by 60 dB. Children studying in classrooms with long RTs performed worse in a phonological processing task, reported a higher burden of indoor noise, and rated the relation to their teachers and peers as well as their achievement motivation less positively than the children studying in classrooms with short RTs (6). Long RT makes the speech less intelligible because the fastest modulations, i.e., level variations, of speech are blurred. During noise, long RT impairs speech perception compared to short RT (7,8), and children are more affected than adults (9,10). However, some studies have shown that a decrease in RTs might decrease performance and require an increased mental effort, especially when a pupil is sitting further from the teacher (11).

In our study, we examined the experience and SPLs of different learning activities in two classrooms with different acoustic solutions. The main difference of these two classrooms was in RT. The activities were created by teachers keeping four test lessons with different activity types. The first aim of the study was to examine whether this approach is suitable for examining schools' activity noise during different school activities. The second aim was to explore the experience and activity SPLs in acoustically different classrooms. The full study has been published (12) and this article gives a summary of it.

MATERIALS AND METHODS

Study Design

This study compared the classroom activity noise and its experience during different types of learning (lesson types) in two classrooms (classroom types). One classroom was refurbished paying special attention to room acoustic conditions and quiet furniture (the demo classroom). The other classroom was a classroom representing the stage before the refurbishment, but at the same time, it represented a normal classroom in that school (the reference classroom). Two permanent teachers teaching daily in these classrooms agreed to design test lessons according to lesson type descriptions (Table 1). These lesson types were condensed from the classification from Shield and Dockrell (4). During the test lessons, classrooms' activity SPL was measured as well as the pupils' experience with a questionnaire at the end of the lesson.

In addition, the pupils also filled a general questionnaire on school's sound environment.

Table 1. The names and description of the lesson types

Lesson type	Description
L1 Quiet work	E.g., reading a book quietly or an exam.
L2 One person talking	Teacher-led teaching/teaching discussion/making tasks independently. One person speaking at a time.
L3 Group work	Pair or group work or an activity that produces similar SPL, where several people are speaking at the same time.
L4 Activity-based work	Several people speaking and moving in the classroom at the same time.

Participants

Participants were 10–11 years old pupils, who studies in the two classrooms. The Reference classroom had 21 pupils and the Demo classroom had 18. In the Demo classroom, five pupils received special support for their learning and their results are not included in the questionnaire analysis. The parents and pupils gave their written consent to participate the study and the study went through an ethical review at the University of Turku.

Classroom types

The Demo and the Reference classrooms both had 60 m^2 (9.0 x 6.7 x 2.9 m and 7.7 x 7.8 x 2.9 m, respectively). They both had 20 mm mineral wool ceiling suspended by 200 mm. The Reference classroom had 2.9 m^2 of sound-absorbing panels (50 mm mineral wool, Class A) glued against the wall, the floor was hard and non-absorbing (Linoleum). Desks and chairs had metal legs and wooden surfaces.

The Demo classroom had 13 m^2 of sound-absorbing panels (50 mm mineral wool, Class A) glued against the wall, and the floor wall-to-wall textile carpet. Tables and most of the seating had hard surfaces. In addition, the Demo classroom had sound-absorbing curtains, some sound absorbing (soft) furniture with four beanbag chairs, five stool cubes and four teepee space dividers. The pupils' drawers were also closing quietly.

Room acoustic conditions

The classrooms' reverberation time, speech transmission index (STI) and speech SPL at different distances from the speaker were examined according to standardized methods (RT: ISO 3382–2 (13). Spatial decay of speech SPL and STI: ISO 3382–3 (14)). The measurement equipment included an omnidirectional loudspeaker (Nor276), a real-time analyzer (Sinus Soundbook MK2_4L,) and a condenser microphone (B&K 4165). Room acoustic conditions are summarized in Table 2.

Table 2. The summary of room acoustic measurements performed in an unoccupied space.

Measure	Demo	Reference	Description
$L_{Aeq,B}$ [dB]	29	29	the mean A-weighted SPL of background noise in unoccupied room
T_{20} [s]	0.32	0.54	the mean reverberation time within 125-8000 Hz.
STI	0.80	0.76	the mean Speech Transmission Index.
$L_{A,S}$ [dB]	52.3	54.7	the mean A-weighted SPL of a single speaker.

Activity sound monitoring

Activity sound level is the A-weighted equivalent SPL during the lesson. It was monitored with four similar sound level meters (Neutrik XL2) equipped with a Type 2 microphone (M2211). The measured quantity was $L_{Aeq,1min}$, which is the 1-min equivalent A-weighted SPL. The meters were hidden from the sight of the pupils on top of the closets (height 2.1 m) facing the wall toward the aisle. The meters were on their places for two weeks. The reported value is the equivalent A-weighted SPL during 30 min test lesson $L_{Aeq,30min}$.

Questionnaires

Pupils filled two questionnaires: the general questionnaire in the beginning of the study period and the test lesson questionnaires at the end of each test lesson. Table 3 describes the variables included in this examination. General questionnaire (GQ) had questions on general annoyance and annoying noise sources in general. The test lesson questionnaires (TLQ) had questions annoyance during test lesson and annoying noise sources during this lesson. The general annoyance question and annoyance during test lesson question were formulated according to ISO/TS 15666 (15). The annoyance of different sound sources was modified from the article (16).

Table 3. The variables from the questionnaires presented with the questions, questionnaires, and response scales. GQ denotes general questionnaire and TLQ denotes test lesson questionnaire.

Variable	Question (Questionnaire)	Response scale
General annoyance	How much noise annoys you in this classroom in general? (GQ)	1= Not at all, 2=Only a little, 3=To some extent, 4=A lot, 5=Extremely
Annoyance during test lesson	How much noise annoyed you during this lesson? (TLQ)	
Annoying sound source	How much you are annoyed by the following sounds in this classroom in general? (GQ)/during this lesson? (TLQ)	
Pupils' speech	Pupils' speech	1= Sound is not audible, 2 = sound is audible, but does not annoy me, 3 = Sound annoys a little, 4 = Sound annoys a lot
Corridor	Sounds from the corridor	
Neighboring classrooms	Sounds from the neighboring classrooms	
Furniture	Moving desks and chairs and other furniture	
Ventilation	Sounds from ventilation (hum)	
Devices	Sounds from teaching devices (e.g., projector)	
Traffic	Sounds from cars outside	
School yard	Sounds from pupils in the school yard	

Statistical analysis

The questionnaire data was analyzed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, NY). Differences between groups on general annoyance was tested with Student's t-test for independent samples. Annoyance during test lessons was analyzed with Mann–Whitney U test, as the estimations were non-normally distributed. As the response scale regarding annoying sound sources (Table 3) was discontinuous, these variables were dichotomized. The response categories 1 and 2 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.

RESULTS

Activity sounds' monitoring

The activity sound levels and number of people in the classrooms during the test lessons are reported in Table 4. The activity SPLs were the most similar during L1 one person speaking and they differed the most during L4 activity-based work.

Table 4. The activity SPLs, $L_{A,eq,30min,}$ and the number of people in the classrooms presented for each test lesson.

	N		$L_{A,eq,30min}$ [dB]	
Lesson type	Demo	Reference	Demo	Reference
L1 Quiet work	16	19	44.1	52.7
L2 One person speaking	17	22	50.6	52.5
L3 Pair/group work	18	20	55.5	58.8
L4 Activity-based work	19	22	58.7	71.6

Experience

The general annoyance was lower in the Demo classroom (mean = 1.7) than in the Reference classroom (mean = 2.4) ($t(32)= –2.3$, $p = 0.027$) (Figure 1). In addition, annoyance was lower in the Demo classroom than in the Reference classroom during L2 One person speaking (U = 72, p = 0.029) and L4 Activity-based work (U = 87, p = 0.027), but not during L1 Quiet work (U = 96, p = 0.240) or L3 Group work (U = 82, p = 0.077) (Figure 2).

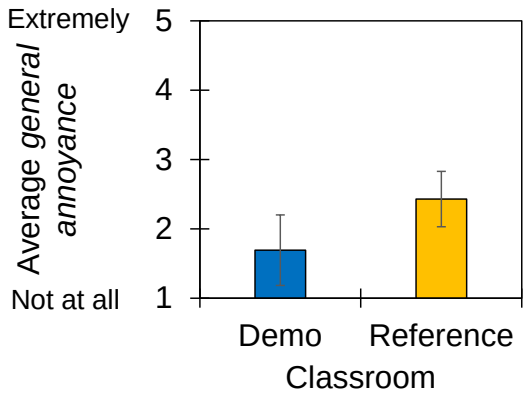

Figure 1. The average general annoyance presented for the classroom types. The error bars denote the 95% confidence interval of the mean.

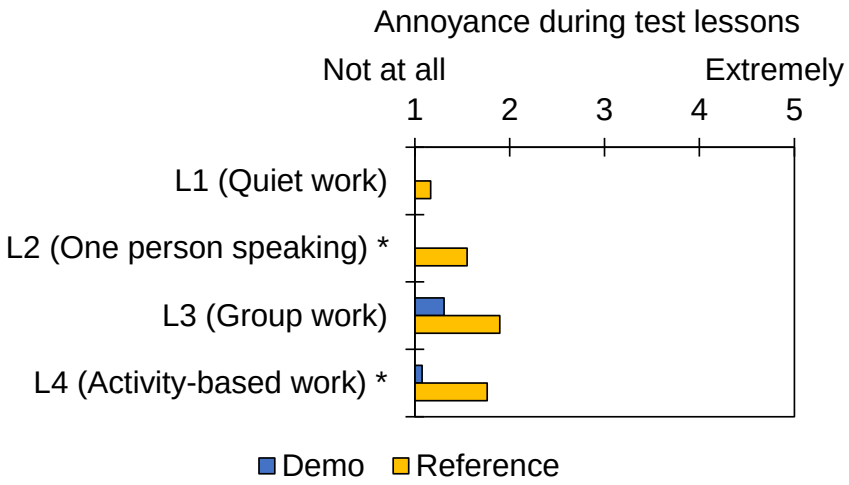

Figure 2. The average annoyance during test lessons presented for the classroom types. Asterisk * denotes a statistically significant difference between the classroom types (p<0.05).

The most annoying sound source was other pupils' speech (Figure 3). More pupils reported being annoyed by other pupils' speech in the Reference classroom (65%; 13/20) than in the Demo classroom (15%; 2/13) (p = 0.011). The pupils in these classrooms did not differ in annoyance of other sound sources. Less than five pupils reported being annoyed by sounds from furniture, ventilation, devices, or traffic.

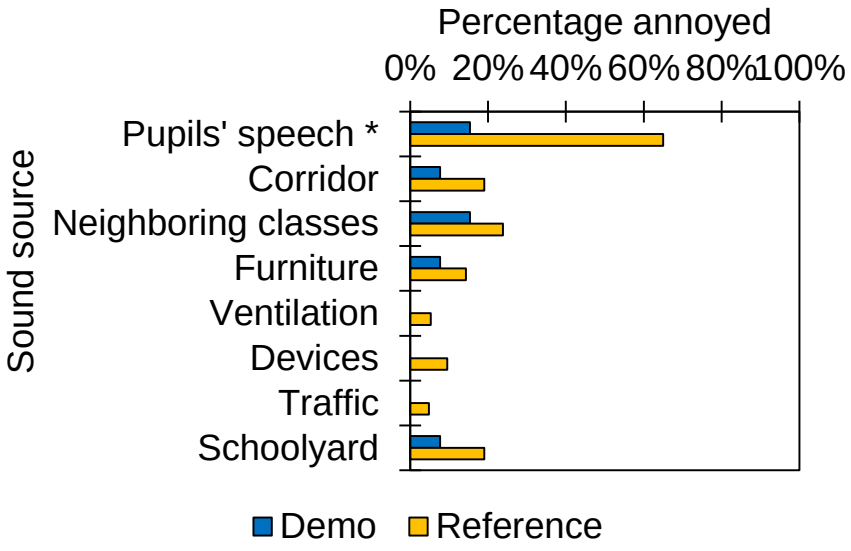

Figure 3. The percentage of pupils reporting sound sources as annoying presented for the classroom types. Asterisk * denotes statistically significant differences between the classroom types (p<0.05).

DISCUSSION

The Demo classroom that had a considerably short reverberation time was related to quieter activity sound levels, and fever pupils reporting noise annoyance in general and related to other pupils' speech than the Reference classroom. The sound levels during one person speaking were almost the same in these two classrooms, but during other lesson types, the activity in Demo classroom was quieter. The difference was the largest (13 dB) for L4 Activity-base work. The acoustic environment alone cannot explain the reduction of activity sound

levels in these classrooms. However, we think that textile carpet and quiet furniture in the Demo classroom further reduced the noise emission caused by walking, item dropping, chair moving, and furniture door closing. We expect that they guided to a quieter behavior.

The reverberation time in the Reference classroom was relatively short (0.54 s), as for example the RTs of 21 German classrooms ranged from 0.49 to 1.11 (6). The RT of the Demo classroom was even shorter (0.32 s), which is actually not fulfilling the Finnish regulations requiring RT = 0.5–0.7 s within 250–2,000 Hz (Ministry of the Environment, 2018).

The most annoying sounds were pupils' speech, sounds from neighboring classes, corridor, and schoolyard. Similarly, chatter, noises from the corridor and scraping sounds from chairs and tables were the most disturbing sound sources in Swedish schools (16). All these sound sources are related to school activity. Other pupils' speech was clearly more annoying in the Reference classroom than in the Demo classroom. This suggests that the acoustic refurbishment diminished the annoyance toward other pupil's speech. Young pupils benefit from short RT during noise more than adults (9,10) reducing RT even below the regulated level might bring benefits for pupils in this age group. However, this needs more research.

The study has several limitations. The main limitations are that we studied only two classrooms, where both the teachers and pupils 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 estimate the direction. Further limitation is that the data in both classrooms is based on one test lesson per lesson type. Our study shows that a similar approach could be used, but more research on larger number of classrooms and test lessons are needed.

CONCLUSION

Our study shows a novel approach into examining activity noise in schools. The test lessons designed by the teachers showed different activity sound levels and pupils rated noise annoyance during test lessons differently. The refurbishment in the Demo classroom was planned with the focus on acoustics and possibility to use activity-based learning methods. Our study indicates that the room acoustic material solutions together with quiet furniture might reduce pupils' noise annoyance and enable quieter activity especially during activity-based learning methods. However, our study concentrated on one case and more research on the topic using similar methods are needed.

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