

The effect of acoustical treatment on primary school children's performance, sound perception, and influence assessment

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Abstract. A previous field study showed that more than 85% of Dutch children reported they were bothered by noise in the classroom. To investigate the impact of acoustical treatment on children's phoneme identification, 335 school children (9 to 13 years old) from the previously studied schools were invited to take part in a series of tests in the acoustical chamber of the SenseLab. All the children performed two series of listening tests and evaluations in chamber A (untreated) and chamber B (acoustically treated) respectively, while at the same time one of seven background sounds (45dB or 60dB traffic noise, 45dB or 60dB children talking, 45dB or 60dB music, or no sound) were randomly played in the chambers. T-tests were conducted to compare the results of children's phonological process tasks, sound perceptions, and influence assessments in these two chambers. Results showed a statistically significant difference in children's sound perceptions ($p=0.01$). Children reported the untreated chamber A to be noisier.

1 Introduction

Over the past decades, the acoustical condition of classrooms has arisen much attention because of its important role in school children's comfort and performance. Several previous studies indicated that children are much more impaired than adults by noise and exposure to noise may impair children's performance [1]. Results of a previous field study conducted by Bluysen et al. [2] showed that noise was the main annoyance for children in classrooms in the Netherlands. 98% of children could hear noise in their classroom and 87% of children reported to be bothered by the noise. Such an unfavourable learning environment might have a negative impact on children's comfort, performance and health [3, 4]. Therefore, improvement of the acoustics in classrooms is an important topic to consider for research.

Reverberation time (RT), as one of the major parameters to measure the acoustics, is often used in guidelines, such as the Requirement of Fresh Schools in the Netherlands and the Building Bulletin 93 in the UK. Many studies have found that a longer RT could impair children's performance [3] [5], especially for children who have a hearing problem [6] and who are not native speakers [7].

Several ways to improve the RT in classrooms have been studied before, for example using acoustical ceiling tiles [8] or fleecy floor coverings (carpets) [9]. All of them have been proved to be effective to reduce the potential noise perception in a classroom. However, only few studies investigated children's response to these or other forms of acoustical treatment.

Therefore, to examine the effect of acoustical treatment of a room on children, this study was carried out. 335 primary school children were invited to participate in two series of experiments in the acoustical chamber of the SenseLab, which was divided into an acoustically treated and an untreated part [10]. In these two chambers, children were asked to perform two series of tasks and evaluations, while one of seven background sounds (45 dB(A) or 60 dB(A) children talk, 45 dB(A) or 60 dB(A) traffic, 45 dB(A) or 60 dB(A) music, or no sound (≈ 30 dB(A))) was randomly playing. This current paper shows the result of the comparison of children's performance, sound perceptions, and the influence assessment between these two chambers. The effect of sound type and sound pressure level on children will be reported elsewhere.

2 Methodology

2.1 Study design

This study was part of a series of tests performed in the SenseLab [9], with 335 children from seven primary schools that took place on 10 different days between February 13 and April 5, 2018 [10].

2.2 Facilities

The study reported here was conducted in the acoustical chamber of the SenseLab (width 2.4m, length 2.6m, height 2.1m). The chamber was equally divided into two parts (or two chambers) by a thick curtain. One of them did not have any acoustical treatment, so it was called

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the untreated chamber A, while in the other one acoustical absorption panels were attached to the three walls and ceiling by magnets, and was named the acoustically treated chamber B. The estimated RTs of these two chambers were 0.33 and 0.07 seconds, respectively (average from 250 to 2000 Hz). In each chamber, there was a speaker placed in a corner and two chairs placed on the opposite side (see Fig. 1). Both of the speakers in these chambers were controlled through a laptop and played the same sound files at the same time.



Fig. 1. The set-up in one of the chambers.

2.3 Performance task

To test performance, a phonological processing task, aimed to evaluate children's hearing ability, was used. In each of the questions, three consonant-vowel-consonant Dutch words, including two with similar pronunciation and one with different pronunciation (e.g. cop, cup, fos), were played together with the background sounds via the speakers. Children were asked to select the (odd) one with the different pronunciation and to mark the corresponding answer on the questionnaire (see Fig. 2). Before the test, all the words were spoken by a 38 years old Dutch male and recorded by a sound analyser (type Norsonic Nor 140), were merged with seven different background sounds respectively, using Adobe Audition software, and were calibrated in the chamber to get the correct sound pressure levels.

2.4 Procedure

On the day of the study, all the children first filled in a one-page personal information questionnaire, and then were divided into groups with maximum 16 children. On each experimental day, two or three groups participated. During the series of tests in the test chambers, the participating group was further divided into four subgroups and started each in one of the four test chambers of the SenseLab (the thermal, air, light and acoustics test chamber). After 7-8 minutes, the groups moved on to the next test chamber, until they had visited all of the test chambers. Before the children entered the acoustics chamber, an instructor carefully explained the procedure of the acoustic test to them, and demonstrated how to answer the questions with an example task, and then handed them a one-page questionnaire (see Fig. 2).

The acoustic test consisted of two parts, of which each comprised of four phonological processing

questions, one sound perception evaluation with a five-point scale and one influence assessment with a three-point scale (see Fig. 2). Children in both parts of the chamber (A and B), started the test at the same time. After the first part, they changed positions to the other part of the chamber and repeated the test. Each had a duration of three minutes. After the second time, children were asked to answer one more question: "Which chamber do you like better? And why?"

Acoustics

School name: _____		Group: _____	
Person ID: _____		Date: _____	

Chamber ☐

1- Listen to the pronunciation of three words; two of them have the same sound, one is different. Please mark the different one.

1	<input type="checkbox"/> A	<input type="checkbox"/> B	<input type="checkbox"/> C
2	<input type="checkbox"/> A	<input type="checkbox"/> B	<input type="checkbox"/> C
3	<input type="checkbox"/> A	<input type="checkbox"/> B	<input type="checkbox"/> C
4	<input type="checkbox"/> A	<input type="checkbox"/> B	<input type="checkbox"/> C

2- What do you think of the background noise?

☐ very quiet ☐ quiet ☐ neutral ☐ noisy ☐ very noisy

3- What do you think of the influence of the background noise on your preference?

☐ good influence ☐ no influence ☐ bad influence

Extra question

1- Which chamber do you like better? And why?

☐ Chamber A ☐ Chamber B Because: _____

Fig. 2. Excerpt from acoustical chamber questionnaire for the listening task.

2.5 Data management and analysis

All the data were manually typed in and stored in IBM SPSS Statistics 24.0. For the performance tasks, one point was given for each correct answer. The total scores of each child for both tests (in Chamber A and B) were calculated. For the sound perception, the five-point scale (very noisy-noisy-neutral-quiet-very quiet) was coded into a score from 1 to 5 correspondingly. Similarly, for the influence assessment, the three-point scale (bad influence-no influence-good influence) was coded into a score from 1 to 3.

Descriptive analysis was used to show children's personal information (e.g. age, gender etc.), and the general result of children's performance tasks, sound perceptions, and their influence assessments. In all of the analyses, except for their personal information, every child was regarded as two subjects, each one corresponding to one part of the test.

In addition, comparative analysis was also conducted to evaluate the effect of the acoustical treatment, by means of the independent-samples t-test. Results of children's performance tasks, sound perceptions, and their influence assessments were all compared between these two chambers A and B.

2.6 Ethical aspects

The parents of the children that participated, received and signed a consent form before the experimental day. All the forms were collected on the experimental day. Only the children whose parents agreed on their

participation took part in the series of tests. The ethics committee of the TU Delft gave approval for the study.

3 Results

3.1 Participants

In all, 335 children including 167 girls and 168 boys participated. Among them, 14 children reported having hearing problems, 27 children of the first day used the wrong version of the questionnaire, and four children of the sixth day skipped one part because of speaker failure. All of them were excluded from the analysis. After the filtering, 290 children, including 145 girls and 145 boys, with an average age of 10.6 years (SD of 1.1 years), were left.

3.2 Descriptives

3.2.1 Performance test

According to the result of the t-tests, there was no statistically significant difference of children's test scores between Chambers A and B ($p=0.29$). The mean value was 3.0 in chamber A and 2.9 in chamber B (see Table 1). As shown in Fig. 3, the percentage of children who got the full score were higher in the chamber A than

in chamber B, while for the other scores, the percentage of children for those scores were almost same for the two chambers.

3.2.2 Sound perception

According to the result of the t-tests, there was a statistically significant difference of children's sound perceptions between the two chambers ($p<0.05$). Children evaluated chamber A to be noisier (mean=2.7) than chamber B (mean=3.0) (see Table 1). As shown in Fig. 4, the percentages of children that selected 'very noisy' and 'noisy' were higher in chamber A than in chamber B, while for the 'neutral', 'quiet' and 'very quiet', the percentage of children was higher in chamber B than in chamber A.

3.2.3 Influence assessment

With respect to the assessment of influence, there was no statistically significant difference of children's answers between the two chambers ($p=0.78$). The mean value of children's influence assessment in these chambers were almost identical: 1.87 for chamber A and 1.89 for chamber B (see Table 1). The distributions of children's answers (Fig. 5), were also almost identical.

Table 1. Comparison of children's test scores and evaluation scores between Chamber A and B.

	Chamber A	Chamber B	t^a	P-values ^b
Test scores	3.03 (1.11)	2.93 (1.10)	$t_{568} = 1.065$	0.287
Sound perception	2.70 (1.07)	3.01 (1.15)	$t_{551} = -3.282$	0.001
Assessment of the influence of sounds	1.87 (0.75)	1.89 (0.76)	$t_{541} = -0.278$	0.781

Notes:

- a. The t-value obtained from t-tests, measured the size of the difference relative to the variation in the sample data. The greater the t-value (either positive or negative), the greater the evidence that there is a significant difference.
b. P-values obtained from t-tests. P-values in bold mean statistically significant at the 5% level.

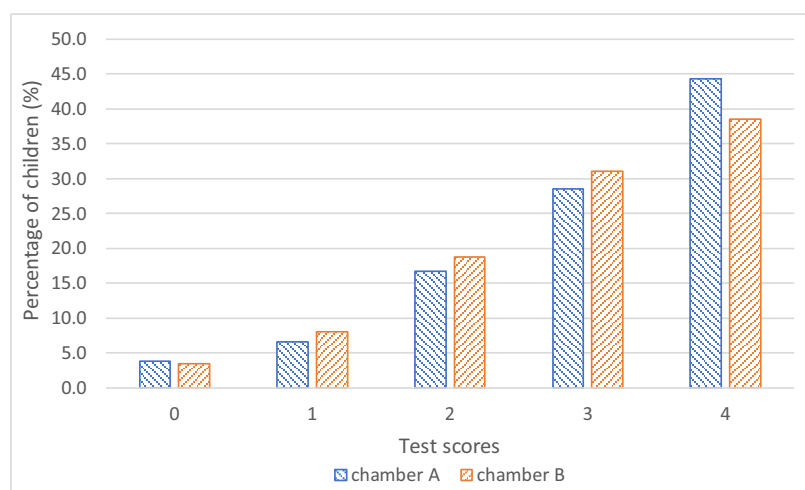


Fig. 3. The distribution of children's test scores.

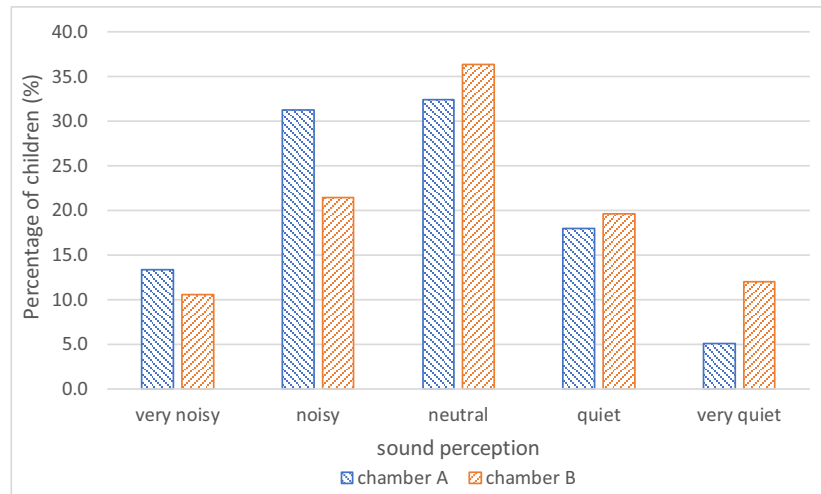


Fig. 4. The distribution of children's sound perceptions.

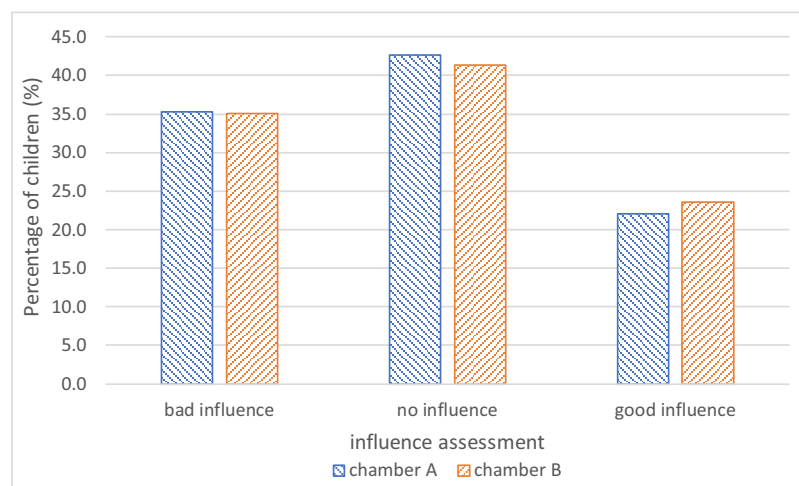


Fig. 5. The distribution of children's influence assessment.

3.3 Comparison in different background sound conditions

To further clarify the effect of the acoustical treatment of a room on children, all the data were separated into seven files based on the seven background sounds, and then the comparison between these two chambers was conducted again in each of these conditions. The results were shown in Table 2.

3.3.1 Performance test

The differences of children's test scores were not significant in almost all the sound conditions, except for one: the '60 dB(A) children's talk' ($p=0.001$). Under this condition, as shown in Fig. 6, children performed significantly better in chamber A (mean=3.1) than in chamber B (mean=2.5). Besides, this tendency can also be seen under the '45 dB(A) children's talk' and '45 dB(A) traffic' sound conditions, although the differences

were not significant. On the contrary, when the background sound was '60 dB(A) music' or 'no sound', children performed slightly better in chamber B.

3.3.2 Sound perception

Among the seven sound conditions, the statistically significant differences of children's sound perceptions between these chambers can be found in the '60 dB(A) music' ($p=0.035$) and the 'no sound' ($p=0.028$) conditions. Under these two conditions, as shown in Fig.7, children evaluated chamber A to be noisier than chamber B. The same tendency can be seen in most of the other conditions, except for the '45 dB(A) music'. Under this condition, children's sound perceptions were almost the same for the two chambers.

3.3.3 Influence assessment

With respect to the differences of children's influence assessment between these chambers, none of them was

statistically significant under these background sound conditions. The fluctuation of children's assessment for these background sounds was quite small, the differences between the highest and the lowest assessment scores were only around 0.6 for both chambers. Children rated either no influence or bad influence for all the background sounds in both chambers.

Concerning the last question about the preference of chambers, results showed that more children (58%) preferred chamber B over chamber A. After the separation of data based on the seven background conditions, the same preference was seen in most conditions except for the 'no sound' condition, in which there were slightly more children (53%) preferring chamber A.

3.4 Children's preference of these chambers

Table 2. Comparison between chamber A and chamber B for the different conditions

	Test scores		Sound perception		Influence assessment	
	t ^a	p ^b	t	p	t	p
45 dB(A) children's talk	$t_{93} = 1.563$	0.121	$t_{90} = -0.872$	0.386	$t_{89} = 1.086$	0.280
60 dB(A) children's talk	$t_{60} = 3.469$	0.001	$t_{59} = -1.926$	0.059	$t_{56} = -0.562$	0.576
45 dB(A) traffic	$t_{73} = 1.847$	0.069	$t_{70} = -1.864$	0.066	$t_{69} = -1.588$	0.117
60 dB(A) traffic	$t_{109} = -0.420$	0.675	$t_{108} = -1.977$	0.051	$t_{106} = -0.793$	0.430
45 dB(A) music	$t_{67} = 0.251$	0.803	$t_{62} = 0.347$	0.730	$t_{62} = -0.569$	0.572
60 dB(A) music	$t_{90} = -1.704$	0.092	$t_{91} = -2.139$	0.035	$t_{90} = 0.278$	0.781
No sound	$t_{62,2} = -1.038$	0.303	$t_{59} = -2.253$	0.028	$t_{57} = 0.368$	0.380

Notes: a. The t-value that obtained from the t-tests measured the size of the difference relative to the variation in the sample data; The greater the t-value (either positive or negative), the greater the evidence that there is a significant difference.
b. P-values obtained from the t-tests; P-values in bold mean statistically significant at the 5% level.

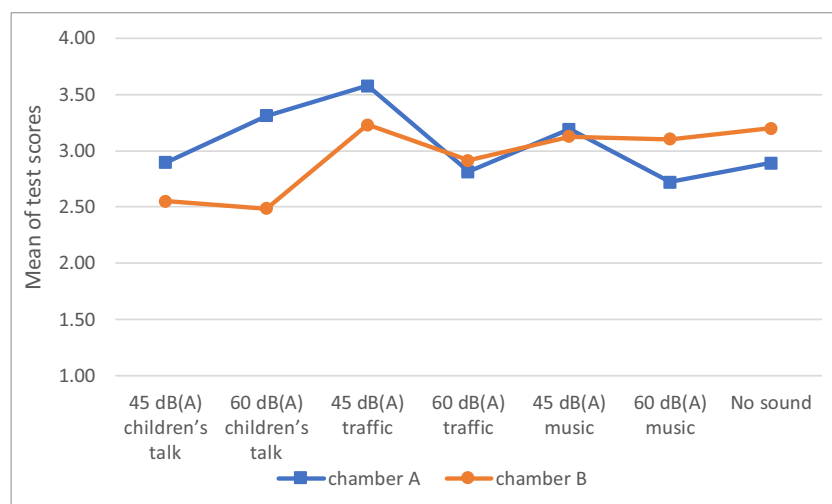


Fig. 6. Difference of children's test scores between Chamber A and B.

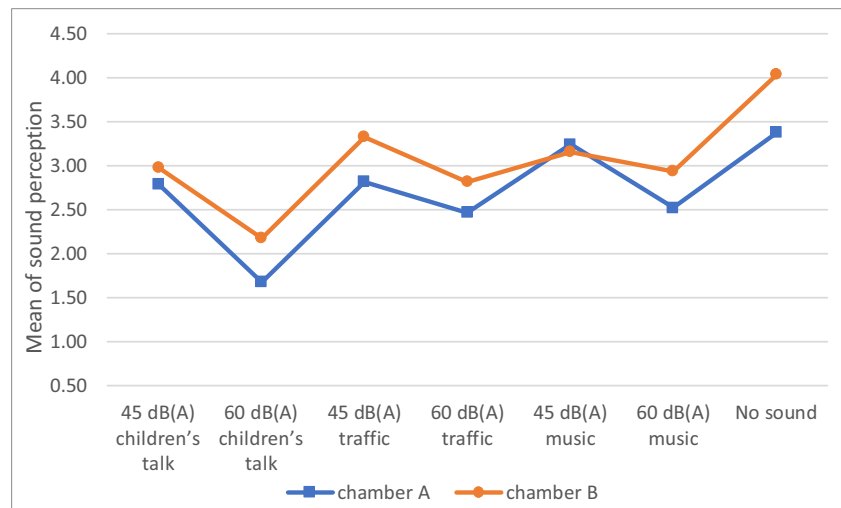


Fig. 7. Difference of children's sound perceptions between Chamber A and B.

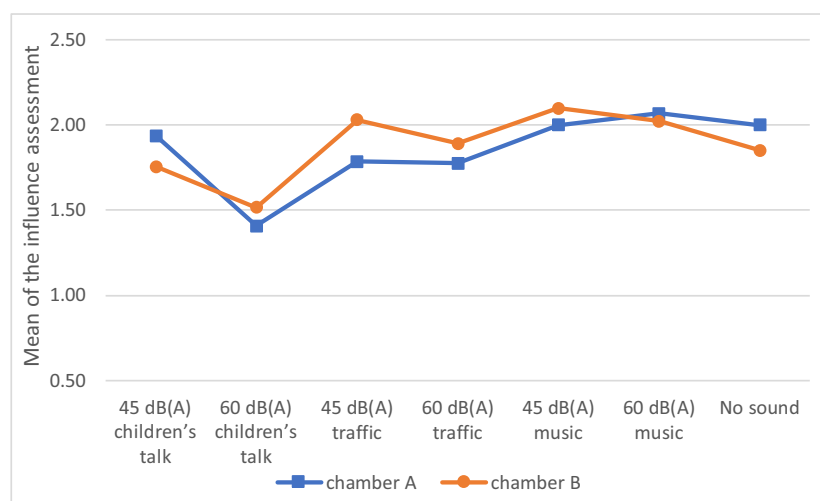


Fig. 8. Difference of children's influence assessment between Chamber A and B.

4 Discussion

Children's talk is the most common noise in classrooms. How to minimize its adverse effect on children's performance and comfort is one of the most important research topics. This study found that under this type of noise, children performed better in the untreated chamber ($RT=0.33s$) than the acoustically treated chamber ($RT=0.07s$). This raised the question about the RT as applied in our guidelines for classrooms. It seems that a lower RT is not always better. At this point, Nijs and Rychtáriková [11] suggested that 0.3s may be the appropriate RT for a quiet classroom with high signal-to-noise ratio; If the RT is too low then overdamping may occur and the loudness of the signal may get too low, then the speech intelligibility might be high but the audibility low. Therefore, the reason why children, in general, performed worse in the treated chamber under noisy conditions might be because of this overdamping and the corresponding low audibility. They performed

better in the treated under the 'music' or 'no sound' conditions might be because of the high speech intelligibility. In other words, if there is no noise in the treated chamber, the high speech intelligibility could compensate for the low audibility, while under noisy conditions, an appropriate RT is much more important. Both the speech intelligibility and the audibility should be kept at its optimum value.

Nevertheless, although the acoustical treatment was not always beneficial to children's performance, it seemed to work well for children's sound perceptions, no matter which type of background sounds. The results attained from this study indicate that the acoustical treatment does have the potential to reduce noise perception, and this is also confirmed by earlier findings on the impact of acoustical covering on noise perception [9].

In addition, this study found that from children's point of view all the background sounds, no matter whether it was noise or music and no matter with or without acoustical treatment, might have an adverse

effect on their performance. This verified the conclusion of Shield and Dockrell [12] that noise has a detrimental effect on children's performance, and the conclusion of Hargreaves and Noth [13] that listening to music might impair children's performance since it occupies their cognitive capacity (e.g. identify the instrument, the musical components), and this impact will be more obvious when listening to high arousing music.

5 Conclusions

The current study was part of a series of tests performed in the SenseLab [10]. It investigated the effect of acoustical treatment of a room on children's phonological processing performance, sound perception and influence assessment by conducting a series of tests in a laboratory environment.

A statistically significant difference of children's sound perceptions between the acoustically treated chamber and the untreated chamber was found, which demonstrated the positive effect of the acoustic treatment. However, the treatment is not the more the better. It should be done moderately since over-treatment could have adverse effects on children's performance, especially with the 'children's talk' as the background sound.

Based on children's preference of these two chambers, one more conclusion might be attained: as long as there is a background sound, the acoustically treated environment was more welcomed by the children.

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