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Teachers' and Children's Experiences after an Acoustic Intervention and a Noise Controlling Workshop in two Elementary Classrooms

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Abstract

Introduction: Treating sources of noise is a novel aspect of voice ergonomics intended to enhance the preconditions for good voice production and easy listening. **Objective:** To improve experiences of listening and voice ergonomics in classrooms. **Methods:** Participants were two female elementary school teachers with voice symptoms and their pupils (N=50). Two interventions were performed: the Acoustic Intervention and then the Workshop Intervention where the teachers and pupils were active. Teachers' voice symptoms and pupils' and teachers' experiences of the interventions were elicited by questionnaire. **Results:** The teacher with many voice symptoms experienced more annoyance from sounds and benefitted more from the interventions. After the interventions both teachers suffered fewer voice breaks and voice symptoms such as lump and mucus in the throat. The pupils reported improvement in the teachers' voice clarity and audibility ($p = 0.001$). Pupils aged 12-13 years were more annoyed by sounds than those aged 8-9 years ($p = 0.003$). The older pupils experienced less sound annoyance after both interventions and the younger ones after the Workshop Intervention. **Conclusions:** The importance of good acoustics and individuals' ability to improve voice ergonomics and listening conditions was demonstrated.

Introduction

Noise during lessons consists mainly of teachers' and children's speech and activities and also of noise from devices such as those used in teaching [1][2]. Recently such noise has been referred to as activity noise and has been investigated separately from background noise, which is continuous and typically consists of noise due to ventilation, heating and lighting [1][2]. Noise levels during lessons may vary from 58 to 73 dB depending on the activities [3][4][5][6][7]. Because the activity noise tends to cover the teacher's voice to a considerable extent, the teaching process is rendered more

difficult and this is also detrimental to listening conditions in the classroom [6][8][9][10][11]. Both teachers and children have reported activity noise such as speaking and sounds from furniture being moved as the loudest and most annoying sounds in the classroom [5][12][13][14].

An unconscious reaction to speaking in a noisy environment is to increase the vocal effort by changing e.g. voice loudness and pitch (the Lombard effect) [15][10][16]. Elementary school teachers face this phenomenon daily because activity noise levels in classrooms have been shown to be high [1][6][17][18][19][20]. Poor classroom acoustics affects noise levels, teachers' voice usage and children's learning outcomes and also the wellbeing of teachers and children [5][21][22][23]. It is known that music and sports lessons include intermittent loud sounds [6][18] [19]. In addition to this, Pirilä et al. [20] found that activity noise level during lessons in core subjects (mathematics, science, etc.) was also high and had a loading impact on female teachers' voices. They concluded that improving the condition of teachers' voices necessitates decreasing activity noise levels during lessons.

Observing and addressing sources of noise are an integral part of what is known as voice ergonomics recently developed with a view to improving the precondition for good voice and speech production and also for easy listening [24]. According to earlier research, teachers and pupils do not know enough about the harmful effects of noise and how to reduce noise through their own actions [25][26]. It has also been found that the level of activity noise is actually higher for children than for adults since the children are closer to the floor [27]. A few studies based on school and daycare settings have reported potential activities to raise awareness of activity noise and to implement measures to reduce it (e.g. lectures on noise, developing games about noise in order to increase awareness of the harmful effects of noise, using toys causing less noise and having firmer pedagogical control) [28][29][30]. Even though children's ability to recognize situations where the

noise is too loud is weaker than that of adults [31], children are able to some extent to estimate the intensity and harmfulness of the surrounding noise levels [1][25][31][32][33][34][35][36]. In addition, research has shown that nearly all children and adolescents are able to name at least one action to decrease noise levels [25]. It has also been found that higher sensitivity to noise annoyance is related to higher cognitive load in the tasks of older pupils [36].

The purpose of the present study was to assess whether it is possible to enhance voice ergonomics and listening conditions during lessons and to decrease teachers' and pupils' experiences of sound annoyance by means of a two-phase intervention: first, an Acoustic Intervention and second a Workshop Intervention, being attempts to increase the pupils' and teachers' awareness of noise in the school environment and to guide them to carry out noise reducing actions. In addition, an attempt was made to identify the variables most characteristic of children's experiences of listening and learning conditions and furthermore, to ascertain the role of age.

The research questions were as follows: (1) Do the teachers' voice symptoms change after the interventions? (2) Do the teachers' and pupils' experiences of annoyance at the sounds during lessons change after the interventions? (3) Do the pupils' experiences of the clarity and audibility of their teacher's voice change after the interventions? (4) Do the pupils´ experiences of the listening conditions change after the interventions? (5) What variables best characterized pupils' experiences of listening and learning conditions? (6) Do the children's ages affect the degree of annoyance at sounds during lessons?

Material and methods

2.1 Participants

The participants were two female teachers with voice symptoms (Teachers A and B) and their pupils (Groups A and B) from elementary schools (Table 1). The teachers were recruited from a larger ongoing voice ergonomic and rehabilitation study. Five teachers reported having inadequate acoustics in their classrooms. Of these teachers one with younger pupils (aged 8-9 years) and one with older ones (aged 11-12 years) were selected. The teachers had no hearing loss or neurological disorders, they were non-smokers and their mother tongue was Finnish. The teachers, children and their parents were informed as follows: acoustic panels will be installed in the classroom, during the workshop meetings information will be given about noise and children will be guided to identify sources of noise during lessons and to evince ideas about how these noise problems could be solved. Participation was voluntary. All the pupils were willing to be involved.

Table 1. Background information on teachers, pupils and classrooms.* SFS EN ISO 3382-2 [37]

Teachers	A 40-year-old female with working history of twelve years.	B 38-year-old female with working history of eight years.
Pupils	Group A N=15 2nd and 3rd grade, children aged between 8 and 9 years	Group B N=35 6th grade, children aged between 12 and 13 years
Classrooms	Median background noise level measured in empty classroom was 35 dB (L_{Aeq}). Median activity noise level during lessons was 60 dB. Reverberation time met the standards at frequencies of 1000 – 4000 Hz, but exceeded the standards* 0,1 s at frequencies of 125 – 500 Hz.	Median background noise level measured in empty classroom was 35 dB (L_{Aeq}) Median activity noise level during lessons was 58 dB. Reverberation time met the standards* at all frequencies measured (125 – 4000 Hz).

2.2 Interventions and Timetable for Measurements

Acoustic Intervention (Acoust Int)

The phases and the timetable of the study are presented in Figure 1. At the initial stage, the ceilings of the classrooms were partly covered by sound absorbing materials and the other surfaces were

acoustically sound reflective hard materials. In both classrooms the Acoustic Intervention was carried out by adding acoustic panels to the ceiling and to the rear wall. The acoustic design and measurements were performed by the author JJ (acoustics planning manager) and by the company A-Insinöörit Ltd, Oulu, Finland. More detailed information on the Acoustic Intervention and the acoustic measurements has been published elsewhere [38].

Workshop Intervention (WS Int)

The WS Int consisted of three weekly 45-minute meetings. For practical reasons the first workshop meeting was held six weeks after the Acoustic Intervention. During the meetings information was given about noise and its effects on voice production and listening in everyday life and in the classroom context (more detail in Appendix I). Children were additionally given so-called *noise passports* and were instructed to write or draw their observations of sources of noise during lessons and ideas about how noise problems could be solved. Based on the summaries of the noise passports the children planned and implemented noise controlling solutions with the help of the teachers and researchers (authors SP, JJ, ENH, LR and speech pathology students HL and VL) during the second and third meetings.

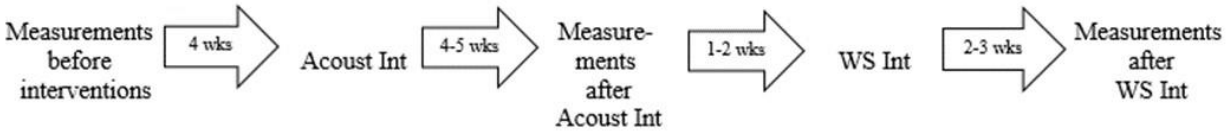

Figure 1. Study design.

2.3. Teachers' Voice Symptoms

Teachers' voice symptoms were evaluated with a modified version of the voice screening method by Simberg et al. [39]. Teachers were asked if their voices felt tired, hoarse or dry, if their voices did not penetrate the noise, if they had voice breaks or aphonia and if they had a feeling of a lump,

irritating mucus or pain in their throats. For the analyses the score from the voice questionnaire was summarized (0 = less than once a year, or never, 1 = a couple of times a year or occasionally, 2 = about once a month or quite often, 3 = almost every week or very often). The minimum total score was 0 and the maximum 27. Our self-report questionnaire reveals the number of voice symptoms and their frequency but it has no criterion for voice disorder. This was used because we wanted to elicit the daily dysfunctions caused by voice malfunctioning according to the framework of the ICF (the World Health Organization's International Classification of Functioning, Disability and Health) [40].

2.4. Teachers´ and Pupils' Experiences

Teachers' and pupils' experiences of the annoying sounds during lessons and pupils' experiences of the teacher's voice were elicited with a questionnaire (Table 2) developed for this study and based on the literature [14][35][36][41] and our own clinical experience. The responses were given once each measuring day (before the interventions, after the Acoustic Int and after the WS Int) by marking a 100 mm long visual analogue scale (VAS) [42]. The higher the score the greater the perceived disadvantage. The minimum score for each question was 0 and the maximum 100 (0 = perfect match with the assertion, 100 = no match at all with the assertion). Before completing the questionnaire the children practised using the VAS with the help of the researchers. By summarizing the score of the questionnaire items the parameters "Teachers' Experiences of the Annoyance of Sounds During Lessons" and "Pupils' Experiences of Annoyance from Sounds During Lessons" were formed.

Table 2. Items elicited in questionnaires (abbreviations in parentheses).

Teachers were asked if	Pupils were asked

• Extra talk of pupils was annoying (Extra talk of pupils). • Sounds of pupils' activities were annoying (Pupils' activities). • Sounds of furniture being moved were annoying (Furniture). • Noise from the corridor was annoying (Corridor). • Noise coming from outside was annoying (Noise coming from outside). • Noise from ventilation was annoying (Ventilation). • There was echo in the classroom (Echo).	• About the clarity of the teacher's voice (Clarity). • About the loudness of the teacher's voice (Loudness). • If the teacher needed to raise her voice (Need to raise). • If they needed to concentrate in order to hear the teacher's voice (Need to focus). • If extra talk of other pupils in the class was annoying (Gabble). • If the other pupils talked a lot during lessons (Amount of gabble). • If sounds from other pupils' disturbing activities were annoying (Rattle, chatter). • If the classroom was noisy or quiet during lessons (Peace during lesson). • If sounds from furniture were annoying (Furniture noise). • If sounds from the corridor were annoying (Corridor noise). • If noise from outside was annoying (Outside noise). • If sounds from the ventilation system were annoying (Ventilation noise).

2.6 Statistical Analyses

The statistical analyses were done using SPSS software (IBM SPSS Statistics v. 22, Armonk, NY). Means of the sum score were used when analysing the data from the questionnaires on the teachers´ and pupils' experiences of the annoying sounds during lessons and of the pupils' experiences of the clarity and audibility of the teacher's voice. Raw scores were used when reporting the results of the teachers' voice symptoms.

Exploratory factor analysis was used to identify the variables which best characterize children's experiences of listening and learning conditions and to find out if the children's ages affected this. The items of the questionnaires were analysed by principal component analyses with orthogonal rotation (Varimax). The factor structure of the questionnaire on the pupils' experiences was investigated using eigenvalues (values > 1.0 as a criterion) and accounted variances. Sum scores were calculated for each factor from the items at every measuring point.

Repeated measures of ANOVA was used to examine differences between the experiences of the pupils in Groups A and B at various time points (first with the total sum score and afterwards with

each of the factors).

3. Results

3.1 Teachers' Voice Symptoms

Before the interventions the teachers had reported several weekly and monthly occurring voice symptoms. After the interventions there were only minor changes in the voice symptoms of Teacher A, whose total score was 7 points before the interventions, 6 points after the Acoustic Int and 8 points after the WS Int. By contrast, there was a notable decrease in the voice symptoms of Teacher B after the interventions: her total score was initially 20 points, after the Acoustic Int it was 10 points and after the WS Int it was 3 points. After the Acoustic Int both teachers suffered less from the voice symptoms "I feel a lump in my throat" and "I feel irritating mucus in my throat" and after WS Int they suffered less often from the voice symptom "I have voice breaks when talking".

3.2 Teachers' Experiences of the Annoyance of the Sounds During Lessons

After the Acoustic Int both teachers reported less annoyance from the sounds during lessons (Fig. 2). After the WS Int the annoyance decline continued for Teacher B but not for Teacher A. Before the interventions, Teacher B had experienced more annoyance from the sounds than had Teacher A and Teacher B benefitted more from both interventions. Both teachers experienced less annoyance from the pupils' extra talk and activities and also from the corridor noise after the Acoustic Int (Fig. 3), but their experiences varied in the case of the noise of moving furniture, of the noise coming from outside the school building, of ventilation noise and of echo in the classroom. After the WS Int both teachers found the furniture noise less annoying, but otherwise their results varied. Teacher A reported less annoyance from echo in the classroom and more annoyance from pupils' activities and from corridor noise. Annoyance from the extra talk of pupils and from noise coming from outside

did not change. Teacher B was less annoyed by pupils' activities and noise from the corridor and ventilation. She reported more annoyance from the extra talk of pupils and from noise coming from outside and she found there was more echo in the classroom.

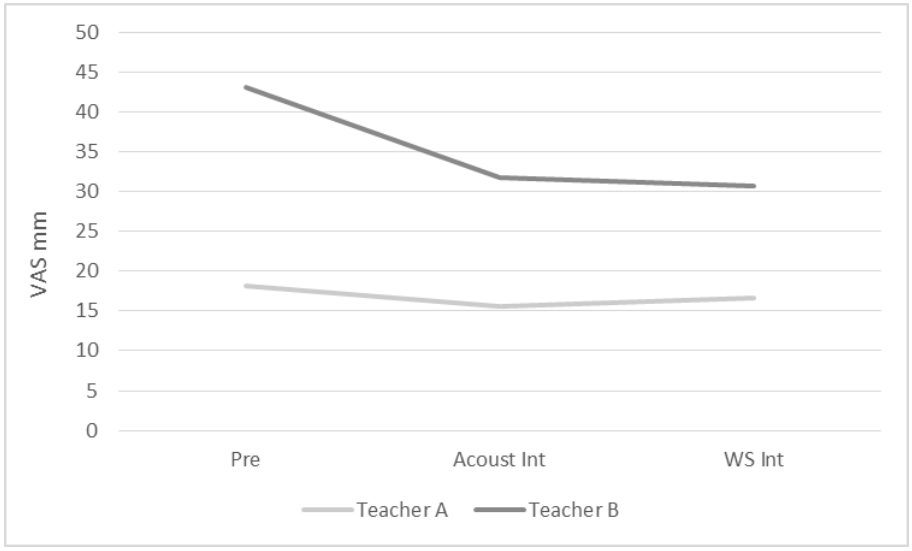

Figure 2. Mean values of teachers' experiences of annoyance from sounds during lessons. The higher the score the greater the perceived annoyance (VAS 0–100 mm). Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.

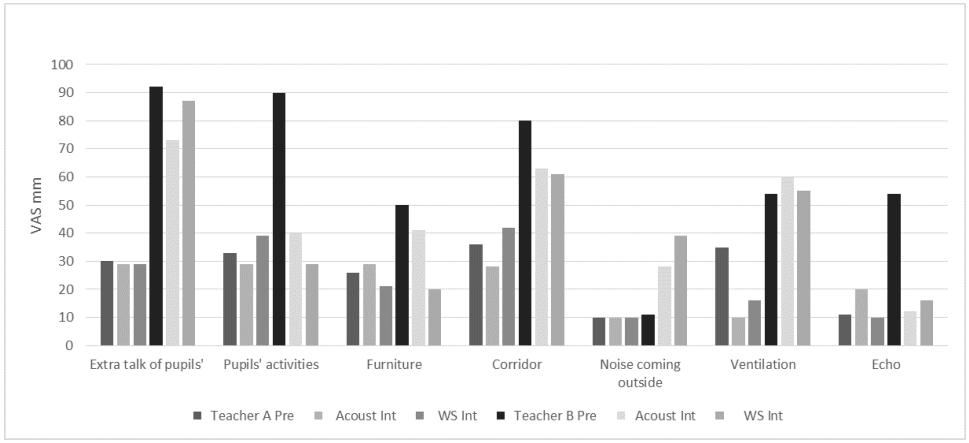

Figure 3. Reported experiences of Teachers A and B of annoyance from sounds and changes therein after the interventions. The higher the score the greater the perceived annoyance (VAS 0–100 mm).

Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.

3.3 Pupils' Experiences of Sounds During Lessons and the Effect of Age

Experiences of the sound environment improved after the WS Int for Group A and after both interventions for Group B (Fig. 4). The older pupils (Group B) suffered significantly more from activity noise than did the younger ones (Group A), $F(1, 48) = 799{,}906$, $p = 0.003$. The results showed that the experiences of pupils in Groups A and B changed statistically significantly, $F(2, 96) = 5{,}718$, $p = 0\ .005$ over time.

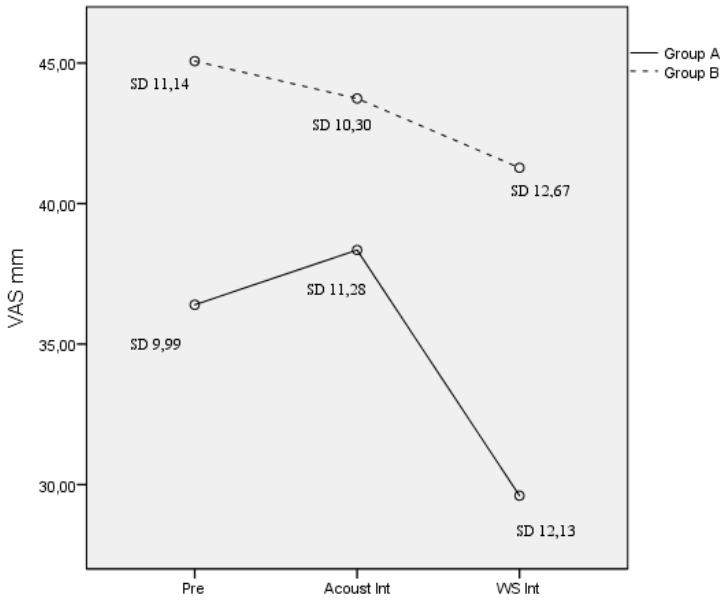

Figure 4. Mean values of pupils' reported experiences of annoyance from sounds during lessons. Group A (n=15), Group B (n=35). The higher the score the greater the perceived annoyance (VAS 0–100 mm). Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.

Underlying Factors for Pupils' Experiences

The Exploratory Factor Analysis showed that four distinct factors underlay pupils' responses to the questionnaire about the annoying sounds during lessons. These factors were labelled according to the highest communalities of the variables (more detailed in Appendix II).

Factor 1: Clarity and Audibility of Teacher's Voice.

For both groups there was a statistically significant improvement in the perceived clarity and audibility of the teacher's voice after the interventions ($p = 0.001$). Post hoc tests with Bonferroni correction showed that pupils in Group B heard the teacher's voice significantly better after WS Int (mean = 1.480; SD 1.4479; $p = 0.005$) than in the initial phase (mean = 2.374; SD 1.7621). The tests also showed that in Group B the pupils need to concentrate in order to hear the teacher's voice was significantly reduced after WS Int (mean = 1.680; SD 1.37879; $p = 0.016$) compared to the initial phase (mean = 2.374; SD 1.7621). The experiences of Group A did not change statistically significantly.

Factor 2: Creating and Maintaining a Peaceful Learning Atmosphere During Lessons

After the interventions the groups reported no improvement in peacefulness during lessons ($p = 0.676$).

Factor 3: Annoyance of Irritating Noise from Ventilation, Corridor and Furniture

For both groups there was a statistically significant decrease in the experience of annoyance from irritating noise from ventilation, corridor and furniture ($p = 0.015$). The groups' reported experiences of annoyance differed significantly ($p = 0.0019$) on the items "Sounds from furniture" and "Sounds from the corridor". Post hoc tests with Bonferroni correction showed that in Group A the annoyance from the irritating noise from furniture (mean 2.1933; SD 2.07243; $p = 0.009$) and

corridor (mean = 3.040; SD 2.15963; p = 0.014) diminished significantly after the WS Int compared to the phase after the Acoustic Intervention (mean = 4.280; SD 1.7072 and mean = 5.167; SD 2.2815 respectively). The experiences of Group B did not change statistically significantly.

Factor 4: Annoyance from Other Pupils' Extra Disturbing Activities and Speech.

After the interventions the pupils' reported experiences of the disturbing activities and extra talk of their classmates did not diminish in either group (p = 0.199). Post hoc tests with Bonferroni correction showed that the groups' experiences differed significantly (p = 0.001) on the item "There is usually a lot of extra talk by other pupils during lessons". Children in Group B reported experiencing significantly less extra talk by other pupils after WS Int (mean = 6.457; SD 1.3178; p = .005) compared to the initial phase (mean = 7.066; SD 1.2714). The experiences of Group A did not change statistically significantly.

Discussion

In this study we wanted to assess whether it is possible to alleviate experiences of sound annoyance and to improve listening conditions and voice ergonomics in classrooms by means of a two-phase intervention: first, an Acoustic Intervention and second, a noise controlling Workshop Intervention. The target was specifically that teachers and their pupils would commit to the noise controlling workshop process. Both teachers and pupils participated actively and innovatively in the Workshop Intervention and they found that the listening conditions in the classrooms improved and sound annoyance decreased. Voice ergonomic conditions were also better after the interventions; the Workshop Intervention in particular seemed to improve them. After this intervention the teachers reported fewer voice breaks during lessons. Both older (aged 12-13 years) and younger (aged 8-9

years) pupils reported experiencing their classroom sound environment in much the same way as their teachers. The older pupils were more sensitive to noise annoyance during lessons than were the younger ones. After the interventions the older pupils reported hearing their teacher's voice significantly better and they were less annoyed by the extra talk of their classmates. The younger pupils benefitted greatly from the functional approach in the Workshop Intervention and they reported less annoyance from furniture and corridor noise. Both teachers and pupils commented spontaneously on their experiences of the interventions during our research, especially in the course of the workshops. We report some of these comments in this discussion section.

Teachers' Voice Symptoms after the Interventions

The results show that the teacher with many voice symptoms in particular benefitted from the interventions. The other teacher, who had fewer voice symptoms, reported a slight increase in symptoms after the interventions. This increase may be attributable to heightened awareness of voice usage. We could also speculate if the end of the spring term entailed vocally demanding tasks (e.g. lots of discussions with parents, school celebrations). Both teachers commented spontaneously that it was easier and softer to speak after the acoustic intervention. Kristiansen et al. [43] in their study on 102 teachers found no statistically significant effect of the acoustic refurbishment on teachers´ voice hoarseness and fatigue after work. It is possible that the differences between the findings of these studies are attributable to the small number of teachers in our case study and the different method of assessing the voice symptoms after work. In addition, there may have been factors that could have affected the teachers' voice production in the present study but that were not assessed, such as indoor air quality and reflux. These ought to be assessed in further studies.

Annoyance from Noise after the Interventions

As a whole, the results were largely as expected: after the Acoustic Intervention both teachers reported that the classroom sound environment was better, which concurs with the earlier studies by Sjödin et al. [29] and Kristiansen et al. [43]. There was also less echo in the classrooms, as shown previously in studies on acoustic refurbishment [5]. The findings of the present study are interesting because the reverberation times and background noise levels in the classrooms almost met the standards [37] even before the interventions. Might it therefore be that acoustic recommendations for speaking conditions are not yet adequate?

After the acoustic intervention both teachers found noise from corridors less annoying. This result differed from the findings of Sala and Rantala [5], who reported an increase in annoyance from corridor noise after the acoustic treatment since corridor noise is more audible in an attenuated classroom with lowered noise levels [44]. However, our result seems to suggest that improved attenuation may actually help to dampen noise coming from outside. The teachers' experiences differed regarding annoyance from ventilation noise and noise coming from outside the school building. The teacher who had fewer voice symptoms and who taught the younger children found the ventilation noise less annoying and reported no changes in her annoyance at ventilation noise. The other teacher, who had many voice symptoms and who taught the older children, found the ventilation noise and the noise coming from outside more annoying after the acoustic intervention. Sala and Rantala [5] reported that after acoustic treatment there was an increase in annoyance from ventilation noise but no change in annoyance due to noise coming from outside. The difference could possibly be explained by the small number of participants in our study and their individual reactions to the annoyance due to noise.

After the workshops both teachers found the noise from moving furniture less annoying, but otherwise the teachers' experiences were different. The teachers spontaneously reported of the workshops that they were useful and functional and that after them the pupils paid more attention to the annoying extra talk and activities in the classroom.

The older pupils (aged 12-13 years) reported experiencing less sound annoyance after both interventions and the younger ones (aged 8-9 years) after the WS Int. Pupils reported spontaneously during the workshops that it was important that they could improve their own learning environments and have an opportunity to create and implement actions themselves. These findings indicate that the workshop activities imparted to the children a sense of being able to influence their comfort in the classroom [25] and demonstrates that children and adolescents are to some extent able to estimate the surrounding noise level [3][12][14][29][34][35] and to invent noise abatement measures [14][25]. According to the results the younger pupils in particular benefitted from the functional approach and concrete operating instructions in the WS Int.

Because the initial reverberation time and background noise level in the classrooms were quite the same, it seemed that the age of the pupils affected how they evaluated and experienced the sound environment. The pupils aged 12-13 years seemed to be more sensitive to noise annoyance during lessons. It is possible that such higher sensitivity to noise annoyance is related to the higher cognitive load in the tasks of older pupils [36].

Pupils' experiences of learning conditons after the interventions

The factor analysis of the pupils' questionnaire revealed four underlying factors explaining the learning conditions in the classroom. To some extent these resembled the factors found in the study by Brännström et al. [12]. The pupils found that the *clarity and audibility of the teacher's voice*

improved significantly after the acoustic treatment, which corroborates the findings of Sala and Rantala [5]. Pupils also reported that the *annoyance of irritating noise from ventilation, corridor and furniture* decreased significantly after the interventions, which may have reduced the children's need to concentrate hard in order to hear what the teacher was saying. Just like the previous factor clarity and audibility of the teacher's voice, the listening conditions improved after the acoustic interventions and further still after the workshops. These results are noteworthy; it is essential for learning that the pupils can hear what the teacher is saying without excessive disturbances. *Annoyance due to other pupils' extra disturbing activities and talk* decreased significantly in the pupils aged 12-13 years after the WS Int. It seemed that these older children were able to control their behaviour better than were the younger pupils. Sala and Rantala [5] have also reported that after the acoustic treatment pupils were less annoyed by the extra talk of other pupils.
Neither of the interventions improved the factor *Creating and maintaining a peaceful learning atmosphere during lessons.* It is possible that the children's perceptions of peace to work during lessons were very individual. These might have been better elicited through more items on this in the questionnaire.

Methodological Considerations

The results of this case study are indicative, and more data should be provided for better reliability and significance.

Conclusions

The results showed that the Acoustic Intervention together with the Workshop Intervention decreased participants' experiences of sound annoyance and enhanced listening conditions and voice ergonomics in the classrooms. The Workshop Intervention was easy to carry out and

motivated the children and teachers to pay attention to their own actions in order to reduce the activity noise during lessons. Noise management should not merely be a part of the physical environment; it should also include active and inclusive collaboration between specialists in voice and acoustics and teachers and pupils.

Ethical Consideration

The study was approved by the Regional Ethics Committee of the Northern Ostrobothnia Hospital District and by the Education and Culture Authority of the City of Oulu. The study is registered in ClinicalTrials.gov.

Disclosure Statement

SP, ENH, AY, LR: The authors have no conflicts of interest to declare.

JJ: Working as Planning Manager of Acoustics at A-Insinöörit Ltd, Oulu, Finland.

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Author Contributions

SP conceived the original idea, designed and directed the study, performed the interventions and the analyses and took the lead in writing the manuscript. JJ, ENH and LR contributed to the design and implementation of the study and performed the interventions, the analyses and participated in the writing of the manuscript. AY assisted with the study design, the analyses and in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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Figure 1. Study design.

Figure 2. Mean values of teachers' experiences of annoyance from sounds during lessons. The higher the score the greater the perceived annoyance (VAS 0–100 mm). Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.
Figure 3. Reported experiences of Teachers A and B of annoyance from sounds and changes therein after the interventions. The higher the score the greater the perceived annoyance (VAS 0–100 mm). Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.

Figure 4. Mean values of pupils' reported experiences of annoyance from sounds during lessons. Group A (n=15), Group B (n=35). The higher the score the greater the perceived annoyance (VAS 0–100 mm). Pre=before the interventions, Acoust Int=after the Acoustic Intervention, WS Int=after the Workshop Intervention.

Appendix I. Content of the Workshop Intervention (*WS Int*).

First meeting
Noise orientation: Lectures about noise and its effects. Examples of different kinds of sounds and noise sources. Noise sources in the classroom. Is it possible to reduce noise? Children measured levels in the classroom with a noise level meter by the help of the researchers.
Noise demonstration: Children were divided into three groups with different tasks. The first group recited words at the front of the classroom, the second group listened to them at the back of the classroom and at the same time the third group made irritating sounds in the middle of the classroom. By turns the groups exchanged their locations in order to do all three tasks. How did it feel to speak and listen in a noisy environment?
Noise passports and noise measurement with a smartphone noise meter application: Children were asked to write down in their noise passports their observations of the annoying noise sources in the classroom and their ideas for reducing the noise levels they noticed. Children were guided to measure the noise levels with their smartphone noise meter applications. Children having no smartphones of their own could measure with a classmate, a researcher or teacher. After 2-3 days the noise passports were gathered and analysed by the researchers.
Second and third meetings
Analysing the noise passports. According to children the main annoying noise sources in the classroom during lessons were extra talk of the children themselves, sounds from chairs, sounds from searching for pencils and pencil cases from backpacks during lessons. Goals and methods were set on the basis of the summary of the children's noise passports
Goal 1: *To reduce the extra talk of the children themselves. Method:* All the children wrote two similar sentences or drew two similar pictures on a piece of a soft baize that served as a reminder to themselves to reduce extra talk. One of the sentences/drawings was stitched or glued to a big board that was placed on the

classroom wall as a common reminder. The other sentence/drawing was placed on the child's desk as a reminder (Fig. 5).
Goal 2: *To reduce the noise from chairs. Method:* Noise reducing socks for the chairs were made with a piece of a soft felt fastened to the legs of the chairs by the children with the help of the teachers and the researchers (Fig. 5).
Goal 3: *To reduce the annoying sounds that come from searching for pencils and pencil cases from backpacks during lessons. Method:* In Classroom A the children sat around a round table (five children per table). A round underlay made of a soft felt was placed in the middle of the table. At the beginning of the lesson children put their pencils, rubbers and pencil cases on the underlay in order to avoid searching for them in their backpacks during the lesson. In addition, children in Group A painted their sensations of noise during an art lesson. (Fig. 5).

Noise reducing socks for the chairs made by the children, examples of children's ideas and reminders to reduce noise (photo S.Pirilä).

A painting of one child's view of pleasant and unpleasant sounds (photo S.Pirilä).

Appendix II. Items of the pupils' questionnaire and the results of the Exploratory Factor Analysis.

Items in the pupils' questionnaire	Loadings	Factors	Cronbach's alpha
Clarity of teacher's voice.	0.877	Factor 1	
Loudness of teacher's voice.	0.738		
I need to concentrate carefully in order to hear the teacher's voice.	0.522	Clarity and audibility of teacher's voice	0.630
The extra talk of other pupils in the class is annoying.	0.480		
During lessons our class is noisy or quiet.	0.834	Factor 2	
The teacher needs to raise her voice.	0.710	Peaceful learning atmosphere and maintaining it during lessons	0.581
Sounds from the ventilation system are annoying.	0.742	Factor 3	
Sounds from the corridor are annoying.	0.679		
Sounds from moving furniture are annoying.	0.640	Annoyance due to irritating noise from ventilation, corridor and furniture	0.577
Sounds from other pupils' disturbing activities are annoying.	0.784	Factor 4	
There is usually a lot of extra talk by other pupils during lessons.	0.667	Annoyance due to other pupils' extra disturbing activities and talk	0.619
Noise from outside is annoying.	0.534		