How Children Perceive the Acoustic Environment of Their School

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Abstract

Objective: Children’s own ratings and opinions on their schools sound environments add important information on noise sources. They can also provide information on how to further improve and optimize children’s learning situation in their classrooms. This study reports on the Swedish translation and application of an evidence-based questionnaire that measures how children perceive the acoustic environment of their school. Study Design: The Swedish version was made using a back-to-back translation. Responses on the questionnaire along with demographic data were collected for 149 children aged 9–13 years of age. Results: The Swedish translation of the questionnaire can be reduced from 93 to 27 items. The 27 items were distributed over five separate factors measuring different underlying constructs with high internal consistency and high inter-item correlations. The responses demonstrated that the dining hall/canteen and the corridors are the school spaces with the poorest listening conditions. The highest annoyance was reported for tests and reading; next, student-generated sounds occur more frequently within the classroom than any sudden unexpected sounds, and finally, road traffic noise and teachers in adjoining classrooms are the most frequently occurring sounds from outside the classroom. Several demographic characteristics could be used to predict the outcome on these factors. Conclusion: The findings suggest that crowded spaces are most challenging; the children themselves generate most of the noise inside the classroom, but it is also common to hear road traffic noise and teachers in adjoining classrooms. The extent of annoyance that noise causes depends on the task but seems most detrimental in tasks, wherein the demands of verbal processing are higher. Finally, children with special support seem to report that they are more susceptible to noise than the typical child.

Keywords: Children, education, gender, hearing impairment, noise

INTRODUCTION

The acoustic environment of educational institutions are of fundamental importance in that students are exposed to them as they receive oral instruction, perform exercises in the course of their studies, and socially interact with their teachers and peers. Previous studies indicate that poor listening environments affect speech understanding negatively, and children are more affected than adults.[1,2] Several studies have shown that normal-hearing children’s speech understanding becomes poorer in the presence of background noise.[2-5] In addition, unfavorable reverberation times (too long or too short) deteriorate speech understanding in children with normal hearing.[2,4,6-8] The present study investigates children’s own ratings and opinions on the sound environment of their school to add information on noise sources, and how to further improve and optimize children’s learning situation in their classrooms.

Along with the negative impact of adverse listening conditions on speech understanding, noise also affects the framework for learning. The theory postulates that listening to a degraded speech signal (e.g., presented in noise or with a non-typical voice quality) allocates more cognitive resources to auditory processing.[9] Thus, given that cognitive resources are limited, the degraded signal reduces the resources available for the task at hand. For example, Enmarker et al.[10] found that listening in noise could influence short-term memory and delayed recall in children. Shield and Dockrell[11] examined how 7- to 11-year-old children’s performance on standardized tests for arithmetic, science, reading, and writing were affected by noise in the classroom. They found that performance decreased with the increasing noise levels. The same findings were seen for noise

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In summary, a previous research indicated that background noise affects speech understanding, working memory performance, and delayed recall. Noise and reverberation measurements are important tools to describe and to improve the sound environment in classrooms. Children's own ratings and opinions on their schools' sound environments add important information on noise sources and how to further improve and optimize children's learning situation in their classrooms. On the basis of these previous findings, the aims of the present study were threefold: (1) to translate an evidence-based questionnaire into Swedish and examine its psychometric properties, (2) to describe the children’s perceptions of the acoustic environments of their school, and (3) to explore the association between scores on the questionnaire and demographic variables such as age, gender, multilingualism, and placement in the classroom.

Material and Methods

Schools and participants

Thirty, randomly selected grade schools (grades 1–9; children aged 7–16 years) were invited to participate in this study. The selection was made from the school lists provided online by the different municipalities in the southernmost part of Sweden. Both public and private tax-funded schools were invited. Eleven schools responded: four schools (three public and one private tax-funded) accepted the invitation and seven declined. At these four schools, the individual class teacher was invited to participate. One teacher at each school accepted to participate for schools A, B, and D, and four teachers accepted for school C. These teachers distributed an information sheet together with a consent form to legal guardians of 183 children. The guardians of 149 children provided written consent for their children to participate. All these children responded on the questionnaire at school under supervision by the second and third authors. No exclusion criteria were used, and, thus, the results are based on the responses of these 149 children. The Regional Ethical Review Board in Lund approved the study (approval number 2014/408).

Materials

A Swedish translation of the questionnaire developed by Connolly et al. was made, which included both instructions and the questionnaire items. The translation was made using a back-to-back translation. This procedure was used to validate that the translation content did not deviate significantly from the original. Initially, the English version was translated into Swedish by the second (EJ) and third (DV) authors. The first and last authors audited this translation. This first Swedish translation was then translated back to English by the fourth author (DJM), a native English speaker proficient in Swedish. He was not familiar with the questionnaire, but prior to the back translation, he was informed as to the purpose of the translation. The first, second, third, and last authors checked this back translation with the original for...
inconsistencies. The back translation was judged to be consistent with the original English version. A note here is that the school subjects in the Swedish version were allowed to deviate to some extent from the original to comply with the mandatory terms used in the National Swedish Curriculum for grade schools.[16] In addition, an additional item was added that asked about where in the classroom the child and the teacher were usually placed.

The questionnaire consists of three sections. The first section consists of seven items and collects demographic information such as age, gender, hearing impairment, special support in class, and placement in the classroom. The second section contains six subscales. In each subscale, responses are given on a five-point ordinal scale. The subscales are: (1) Ease of hearing in various school spaces, which consists of 11 items that ask about the acoustic environment in different school spaces; (2) Sounds and annoyance in the classroom, which consists of 33 items that ask about the frequency and the perceived annoyance of noise coming from both within and outside the classroom; (3) Sensitivity to annoyance by noise during learning activities consists of nine items that ask about sensitivity when performing specific activities; (4) Situations that made it hard to hear the teacher during lessons, which consists of six items that ask about placement of the teacher and the child, and also about other children making noise; (5) Impact on concentration, fatigue, and learning, which consists of five items; and (6) Consequences of noise and poor listening conditions on pupil and teacher behavior in the classroom, which consists of 13 items.

The third section contains seven items. The items ask for the child to identify the class, where it is hardest to hear and the one where it is easiest to hear, what makes it the hardest/easiest to hear in, and also asking for a room number (or other identifier). Finally, the last item of the section and the questionnaire is an open question asking the child to identify the class, where it is hardest to hear, what makes it the easiest to hear, and also about other children making noise; (5) Situations that made it hard to hear the teacher during lessons, which consists of six items that ask about placement of the teacher and the child, and also about other children making noise; (6) Consequences of noise and poor listening conditions on pupil and teacher behavior in the classroom, which consists of 13 items.

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The qualitative data from the items in the Section 3 are not reported on here. The original English version of the questionnaire contained a total of 93 items while the Swedish version contained 92 items depending on the exclusion of two items in subscale 1 due to their irrelevance for Swedish conditions and the addition of one item (in the first section). The Swedish translation of the questionnaire can be obtained from the corresponding author by contacting him by email at jonas.brannstrom@med.lu.se.

**Procedures**

After receiving information about the study purpose, oral instructions, and the opportunity to ask questions, the participating children completed the questionnaires at school in their classroom under the supervision of the second and third authors. The other children in the class who did not participate were relocated to a second classroom and were given tasks by their teacher. The children had the opportunity to ask for clarifications during the assessment.

**Results**

All the analyses were conducted using the Statistical Package for the Social Sciences version 22 software (IBM Inc., Chicago, IL, United States), and an alpha level of 0.05 was considered significant. Initially, the response frequencies were examined for each item in the questionnaire, and items with completion rates below 80% were removed from further analysis. This measure was taken to identify items that had a deviant completion rate implying that the item was not relevant; in all, only two items were removed. Table 1 shows demographic information on the participating children, and Table 2 shows student and teacher placement in the classroom.

**Section 2**

In Section 2 of the questionnaire, the inter-item correlations ranged between −0.361 and 0.863 using Pearson’s correlation coefficient (r) for all the items indicating that different items measure different constructs. This was confirmed by the corrected item-total correlations that ranged between −0.150 and 0.752 suggesting that not all items contribute to the overall score on the section. The intraclass correlation coefficient for all items was 0.230 (95% confidence interval: 0.177–0.306). On the contrary, Cronbach’s alpha for the complete Section 2 of the questionnaire was 0.957 suggesting high internal consistency, and that all items

| Table 1: Characteristics of the participating children and their school setting (n = 149) |
|------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                                        | n              | Boys/girls     | Multilingualism | Hearing impairment | Special support | School |
| School year 4 (age 9–10 years)         | 11             | 5/6            | 3              | 0              | 2              | A              |
| School year 5 (age 10–11 years)        | 34             | 16/18          | 10             | 1              | 4              | B, D           |
| School year 6 (age 11–12 years)        | 50             | 31/19          | 7              | 1              | 3              | C              |
| School year 7 (age 12–13 years)        | 54             | 24/30          | 12             | 1              | 6              | C              |
| Total                                  | 149            | 76/73          | 32             | 3              | 15             | –              |

*Note that the number of respondents is higher than the class size. This is due to the fact that two separate classes with the same class size are examined at the same school.
also true for Cronbach’s alphas, if an item was deleted which was performed to investigate how well each item contributed to the overall internal consistency by removing each item in turn and recalculating Cronbach’s alpha. Small changes in the overall Cronbach’s alpha were seen ±0.001.

To further explore the factor structure of the questionnaire and potentially reduce the number of items in the questionnaire Section 2, a principal component analysis (PCA) with varimax rotation and Kaiser normalization was conducted. The unrotated PCA loadings displayed 20 factors that met Kaiser’s criterion with eigenvalues exceeding 1.0. However, the point of inflexion on the scree plot suggested that five factors should be retained. Together, these five factors accounted for 49.5% of the total variance. Table 3 shows the items loading on the separate factors after rotation and the suppression of loadings <0.60. The table also shows the amount of variance accounted for by each of these factors and their Cronbach’s alpha.

For all items identified in the PCA, the inter-item correlations ranged between −0.224 and 0.840 using Pearson’s correlation coefficient (r) indicating that different items still seem to measure different constructs. This was confirmed by the corrected item-total correlations that ranged between −0.115 and 0.694 suggesting that not all items contribute to the overall score on these selected items section. In addition, earlier, the intraclass correlation coefficient for all items was 0.233 (95% confidence interval: 0.180–0.305), which is very similar to the coefficient for all the items in Section 2. Cronbach’s alpha for all items in the five identified factors was lower (0.895) than that for the complete Section 2, although the value suggests high internal consistency, and that all items contribute to the total score on these selected items. Again to investigate how well each item contributed to the overall internal consistency Cronbach’s alphas and how each item was deleted was calculated by removing each item in turn and then recalculating Cronbach’s alpha for all items in these five factors. Minor changes in the overall Cronbach’s alpha were noted between 0.886 and 0.899.

However, the same procedure was repeated for the items in each of the identified factors. The results are shown in Table 3. Here, the inter-item correlations increased, the intraclass correlation coefficient increased, the corrected item-total correlations increased, and all were positive, and Cronbach’s alphas if deleted decreased (with one exception). All these things together suggest that reducing the number of items to those included in the five identified factors from the PCA increased the internal consistency if these five factors are representing different constructs as represented by their suggested titles in Table 3. On the basis of these analyses, only the 27 items in these five factors were used in all further analyses.

**Responses on the questionnaire**

Table 4 shows the mean, standard deviation (SD), and ranges for the five identified factors. Table 5 shows the mean scores and SDs for the separate items in the five factors. In the table, a higher score indicates a more difficult listening situation (Ease of hearing), more frequent occurrence (Sounds coming from inside/outside the classroom), greater annoyance (Annoyance), or a higher degree of agreement (Impact of noise). Five separate repeated measures analysis of variance (RM ANOVA) were conducted to test if there were significant differences between the different items in each identified factor. In each analysis, one within-subject variable was used (i.e., the items in each factor). The results from these RM ANOVAs are presented in Table 5 along with Bonferroni corrected post hoc tests.

A significant main within-subject effect (F[6.0, 128] = 14.9, \( P < 0.001, \eta^2 = 0.18 \)) was seen for Ease of hearing indicating that some school spaces are experienced as harder to hear in than others. The post hoc analysis indicated that the dining area/canteen and the corridors were significantly harder to hear in than all other spaces. It was also significantly harder to hear in the assembly hall than in the music room/s. It was significantly easier to hear in my tutor/form room than in the assembly hall and the sports hall. The remaining differences between school spaces were not significant.

A significant main within-subject effect was seen (F[4.4, 143] = 8.5, \( P < 0.001, \eta^2 = 0.06 \)) for Annoyance indicating that annoyance is dependent on learning activity/task. The post hoc analysis indicated significantly more annoyance when doing a test or an exam and trying to hear what the teacher is saying than when trying to hear what another student in my class is saying or writing. It was also significantly more annoying when reading than...
Table 3: The items loading on the separate factors with eigenvalues >1 (above the point of inflexion) along with the interpretations of the factors obtained in the PCA after varimax rotation. Also shown are the amount of variation that each factor accounts for, Cronbach’s alpha, and intraclass correlation coefficients for each factor. Also shown are the corrected item-total correlations and Cronbach’s alphas if item deleted for each included item.

| Ease of hearing | Annoyance | Impact of noise | Sounds coming from inside the classroom | Sounds coming from outside the classroom | Corrected item-total correlation | Cronbach’s alpha if item deleted |
|-----------------|-----------|-----------------|----------------------------------------|------------------------------------------|---------------------------------|----------------------------------|
| My tutor/form room | 0.82 | 0.71 | 0.62 | 0.72 | 0.69 | 0.855 |
| The art room/s | 0.64 | 0.56 | 0.64 | 0.69 | 0.69 | 0.867 |
| The assembly hall | 0.66 | 0.51 | 0.64 | 0.69 | 0.69 | 0.873 |
| The corridors | 0.68 | 0.73 | 0.64 | 0.69 | 0.69 | 0.849 |
| The dining area/canteen | 0.76 | 0.64 | 0.69 | 0.72 | 0.72 | 0.864 |
| The music room/s | 0.64 | 0.69 | 0.69 | 0.72 | 0.72 | 0.856 |
| The handicraft room | 0.65 | 0.62 | 0.62 | 0.72 | 0.72 | 0.861 |
| The sports hall | 0.77 | 0.72 | 0.72 | 0.72 | 0.72 | 0.850 |

How hard or easy is it to hearing your teacher in these places around your school?

| How often do you hear each of these sounds in your lessons? | Corrected item-total correlation | Cronbach’s alpha if item deleted |
|-----------------------------------------------------------|---------------------------------|----------------------------------|
| Students talking loudly to each other in your classroom | 0.74 | 0.58 | 0.696 |
| Student moving about in your classroom | 0.78 | 0.53 | 0.735 |
| Mobile phones (ringtones or any other sounds) | 0.71 | 0.60 | 0.698 |
| Sudden, unexpected sounds (e.g., banging on doors and bins clattering) | 0.70 | 0.59 | 0.692 |

How often do you hear each of these sounds in your lessons?

| Measurements | Corrected item-total correlation | Cronbach’s alpha if item deleted |
|--------------|---------------------------------|----------------------------------|
| Teachers in classrooms near your classroom | 0.70 | 0.42 | 0.743 |
| Lorries, cars, buses, and motorbikes | 0.68 | 0.48 | 0.714 |
| Sirens | 0.83 | 0.59 | 0.663 |
| Trains | 0.90 | 0.59 | 0.688 |
| Aircraft (e.g., planes and helicopters) | 0.91 | 0.59 | 0.680 |

I find noise annoying when I’m...

| Measurements | Corrected item-total correlation | Cronbach’s alpha if item deleted |
|--------------|---------------------------------|----------------------------------|
| Trying to hear what the teacher is saying | 0.67 | 0.62 | 0.834 |
| Reading | 0.72 | 0.73 | 0.812 |
| Working with numbers (e.g., in a mathematics or science lesson) | 0.64 | 0.63 | 0.832 |
| Writing | 0.72 | 0.71 | 0.818 |
| Trying to hear what another student in my class is saying | 0.69 | 0.60 | 0.838 |
| Doing a test or an exam | 0.82 | 0.61 | 0.841 |

When it’s noisy or hard to hear in a lesson...

| Measurements | Corrected item-total correlation | Cronbach’s alpha if item deleted |
|--------------|---------------------------------|----------------------------------|
| My concentration is easily broken | 0.75 | 0.72 | 0.865 |
| I don’t learn as much as in a quiet lesson | 0.74 | 0.69 | 0.874 |
| I don’t try as hard | 0.78 | 0.80 | 0.832 |
| I have to work extra hard to do my work | 0.82 | 0.79 | 0.835 |

(Continued)
A significant main within-subject effect was seen (all items in the factor. was seen for the from inside the classroom (A significant main within-subject effect was seen inside the classroom were not significant. The remaining differences in occurrence of sounds coming from significantly higher frequency than mobile phones. The phones. Students moving about in your classroom had a frequency than both sudden, unexpected sounds and mobile talking loudly to each other in your classroom had higher more frequently. The post hoc analysis indicated that students frequently than teachers in classrooms near your classroom. all the items with one exception: sirens did not occur more significantly) models were provided for four of the factors, Sounds coming from inside the classroom indicating similar impact for all items in the factor.

A significant main within-subject effect was seen (F[3,95] = 0.6, P = 0.590, η² < 0.01) was seen for the impact on noise indicating similar impact for all items in the factor.

Two models were obtained for Ease of hearing, Annoyance, Impact of noise, and Sounds coming from outside the classroom. These valid models are shown in Table 6.

Two models were obtained for Ease of hearing consisting of school year, and school year and gender. The final model with the best fit suggested that ease of hearing increased in higher grades and decreased in girls. One model each was obtained for Annoyance and Impact of noise consisting of only gender indicating that girls experience more annoyance and experience more detrimental effects of noise on their concentration, fatigue, and learning than boys. No valid model was obtained for Sounds coming from inside the classroom. Finally, three models were obtained for Sounds coming from outside the classroom consisting of number of students in class, number of students in class and special support, and number of students in class, special support, and the student placement in the classroom. The final model with the best fit suggested that reports of sounds coming from outside the classroom decrease in larger classes, increase in students with special support, and decrease from front to back in the classroom.

Prediction of scores on the five identified factors
Multiple forward stepwise regression analyses were conducted using average scores on the five separate factors as dependent variables to explore, whether the demographic variables (gender reference female, multilingualism, special support, school year, number of students in class, student placement in the classroom, and teacher placement in the classroom) could predict the responses. Hearing impairment was not included as a variable due to the low number of children with hearing impairment (n = 3). Valid (i.e., significant) models were provided for four of the factors, Ease of hearing, Annoyance, Impact of noise, and Sounds coming from outside the classroom. These valid models are shown in Table 6.

Two models were obtained for Ease of hearing consisting of school year, and school year and gender. The final model with the best fit suggested that ease of hearing increased in higher grades and decreased in girls. One model each was obtained for Annoyance and Impact of noise consisting of only gender indicating that girls experience more annoyance and experience more detrimental effects of noise on their concentration, fatigue, and learning than boys. No valid model was obtained for Sounds coming from inside the classroom. Finally, three models were obtained for Sounds coming from outside the classroom consisting of number of students in class, number of students in class and special support, and number of students in class, special support, and the student placement in the classroom. The final model with the best fit suggested that reports of sounds coming from outside the classroom decrease in larger classes, increase in students with special support, and decrease from front to back in the classroom.

**DISCUSSION**

**Summary of findings**
The present findings demonstrate that the Swedish translation of the questionnaire developed by Connolly et al. [15] can be reduced from 93 to 27 items. These 27 items provide a valid measure with high internal consistency but with poor inter-item correlations, which indicate that they may measure different underlying constructs. The 27 items load

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**Table 3 (Continued)**

|                  | Ease of hearing | Annoyance | Impact of noise | Sounds coming from inside the classroom | Sounds coming from outside the classroom |
|------------------|-----------------|-----------|-----------------|----------------------------------------|-----------------------------------------|
| Variance explained (%) | 10.2            | 8.7       | 5.8             | 5.6                                    | 5.5                                     |
| Cronbach’s alpha  | 0.875           | 0.761     | 0.742           | 0.854                                  | 0.885                                   |
| Intraclass correlation coefficient (95% confidence interval) | 0.467           | 0.443     | 0.365           | (0.420–0.569)                           | (0.571–0.738)                           |

**Table 4: The mean, standard deviation (SD), and ranges for the five identified factors**

|                  | Ease of hearing | Annoyance | Impact of noise | Sounds coming from inside the classroom | Sounds coming from outside the classroom |
|------------------|-----------------|-----------|-----------------|----------------------------------------|-----------------------------------------|
| Mean             | 2.0             | 2.3       | 2.6             | 2.6                                    | 1.4                                     |
| SD               | 0.7             | 0.9       | 0.9             | 0.8                                    | 0.5                                     |
| Min–max          | 1.0–4.1         | 1.0–5.0   | 1.0–4.0         | 1.3–5.0                                | 1.0–5.0                                 |
on five separate factors measuring different underlying constructs with high internal consistency and high inter-item correlations. These factors were Ease of hearing, Annoyance, Impact of noise, Sounds coming from inside the classroom and Sounds coming from outside the classroom. The responses on these factors demonstrated that the dining hall/canteen and the corridors are the school spaces with the poorest listening conditions, the highest annoyance was reported for tests and reading, student-generated sounds occur more frequently within the classroom than, for example, sudden unexpected sounds, and road traffic noise and teachers in adjoining classrooms are the most frequently occurring sounds from outside the classroom. To a varying extent, several demographic characteristics could be used to predict the outcome on these factors. Ease of hearing decreased for girls but increased in higher grades. Girls reported more Annoyance and more detrimental Impact of noise on their concentration, fatigue, and learning than boys. Sound coming from outside the classroom less frequently occurred in larger classes and for the students sitting in the back of the classroom, but students with special support reported higher frequencies.

### Psychometric properties

In the present study, a Swedish version of the questionnaire developed by Connolly et al.[15] was made using a back-to-back translation. This procedure was used to validate that the translated content did not deviate significantly from the original. The Swedish back translation was judged to be

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**Table 5: The results of the five separate RM ANOVAs. In each analysis, one within-subject variable was used (i.e., the items in each factor). Also seen are the Bonferroni post hoc tests**

| Factor 1: Ease of hearing | n  | Mean | SD  | Within-subject F-value | Post hoc |
|--------------------------|----|------|-----|-------------------------|----------|
|                          |    |      |     |                         |          |
| 1. The dining area/canteen| 148| 2.6  | 1.2 | 28.419***               | – n.s.   |
| 2. The corridors          | 148| 2.3  | 1.0 |                         | – n.s.   |
| 3. The assembly hall      | 129| 2.0  | 0.9 |                         | – n.s.   |
| 4. The sports hall        | 148| 2.0  | 1.0 |                         | – n.s.   |
| 5. The art room/s         | 144| 1.9  | 0.9 |                         | – n.s.   |
| 6. The music room/s       | 147| 1.8  | 0.9 |                         | – n.s.   |
| 7. The handicraft room    | 148| 1.8  | 0.9 |                         | – n.s.   |
| 8. My tutor/form room    | 148| 1.7  | 0.8 |                         | – n.s.   |

**Factor 2: Annoyance**

|                          | n  | Mean | SD  | Within-subject F-value | Post hoc |
|--------------------------|----|------|-----|-------------------------|----------|
| 1. Doing a test or an exam| 146| 2.5  | 1.4 | 8.503***                | – n.s.   |
| 2. Trying to hear what the teacher is saying | 145| 2.4  | 1.2 |                         | – n.s.   |
| 3. Working with numbers (e.g., in a mathematics or science lesson) | 146| 2.3  | 1.2 |                         | – n.s.   |
| 4. Reading               | 146| 2.3  | 1.2 |                         | – n.s.   |
| 5. Trying to hear what another student in my class is saying | 146| 2.0  | 1.0 |                         | – n.s.   |
| 6. Writing               | 146| 2.0  | 1.0 |                         | – n.s.   |

**Factor 3: Impact of noise**

|                          | n  | Mean | SD  | Within-subject F-value | Post hoc |
|--------------------------|----|------|-----|-------------------------|----------|
| 1. I don’t learn as much as in a quiet lesson | 126| 2.6  | 1.1 | 0.640                   | – n.s.   |
| 2. My concentration is easily broken | 131| 2.7  | 1.0 |                         | – n.s.   |
| 3. I have to work extra hard to do my work | 128| 2.5  | 1.1 |                         | – n.s.   |
| 4. I don’t try as hard | 128| 2.5  | 1.1 |                         | – n.s.   |

**Factor 4: Sounds coming from inside the classroom**

|                          | n  | Mean | SD  | Within-subject F-value | Post hoc |
|--------------------------|----|------|-----|-------------------------|----------|
| 1. Students talking loudly to each other in your classroom | 149| 2.7  | 1.1 | 8.386***                | – n.s.   |
| 2. Student moving about in your classroom | 149| 2.7  | 1.2 |                         | – n.s.   |
| 3. Sudden, unexpected sounds (e.g., banging on doors and bins clattering) | 149| 2.5  | 1.0 |                         | – n.s.   |
| 4. Mobile phones (ringtones or any other sounds) | 149| 2.3  | 0.8 |                         | – n.s.   |

**Factor 5: Sounds coming from outside the classroom**

|                          | n  | Mean | SD  | Within-subject F-value | Post hoc |
|--------------------------|----|------|-----|-------------------------|----------|
| 1. Lorries, cars, buses, and motorbikes | 149| 1.7  | 0.8 | 32.031***               | – n.s.   |
| 2. Sirens                | 149| 1.4  | 0.7 |                         | – n.s.   |
| 3. Teachers in classrooms near your classroom | 148| 1.4  | 0.8 |                         | – n.s.   |
| 4. Aircraft (e.g., planes and helicopters) | 149| 1.2  | 0.5 |                         | – n.s.   |
| 5. Trains                | 149| 1.1  | 0.5 |                         | – n.s.   |

*P<0.05, **P<0.01 and ***P<0.001.
Consistent with the original English version with the exception that the Swedish school subjects were selected to comply with the mandatory terms used in the National Swedish Curriculum for grade schools\textsuperscript{[16]} and that an additional item about student and teacher location in the classroom was added.

The psychometric properties of Section 2 in this questionnaire were evaluated. Using all items, the construct validity was found to be high using Cronbach’s alpha, but the inter-item correlations were generally low, which indicated that the questionnaire assessed several constructs. A PCA was made to explore the factor structure of the questionnaire and to see if the number of items in the questionnaire could be reduced. It identified five factors consisting of 27 items, which in all accounted for about half of the variance encountered. As for all items, the 27 items together showed high internal consistency using Cronbach’s alpha but still poor inter-item correlations and low intraclass correlation. This indicated that these items measured different constructs. However, when examining the separate factors, we found high internal consistency (Cronbach’s alpha including if item deleted), high inter-item correlations, high corrected item-total correlations, and improved intraclass correlations. These findings suggest that the items in these five factors measure different underlying constructs. On the basis of the item contents, the factors were labeled \textit{Ease of hearing}, \textit{Annoyance}, \textit{Impact of noise}, \textit{Sounds coming from inside the classroom}, and \textit{Sounds coming from outside the classroom}. These seem to be the most important dimensions when assessing how students perceive the acoustic environment of their school.

The factor structure encountered in the present study is to some extent different from the one reported in Connolly \textit{et al.}\textsuperscript{[15]} They found four factors consisting of 37 items in total. These four factors explained about 43% of the variance. Connolly \textit{et al.}\textsuperscript{[15]} labeled the factors \textit{Ease of hearing}, \textit{Sensitivity} (to annoyance by noise during learning activities), \textit{Consequences} (of noise and poor listening conditions on hearing and understanding during lessons), and \textit{Annoyance} (to intermittent sounds). There are several differences between the present study and that of Connolly \textit{et al.}\textsuperscript{[15]} The sample in the present study is younger and much smaller than in Connolly \textit{et al.}\textsuperscript{[15]} These could explain the differences seen in the factor structure. However, the differences could also be due to differences in educational systems that are governed by national requirements and legislations and perhaps also teaching approach. Another difference is that Connolly \textit{et al.}\textsuperscript{[15]} used an online questionnaire, whereas we used a paper and pencil version. It is known that questionnaires administered electronically sometimes generate the same results but sometimes not depending on the questionnaire\textsuperscript{[17]}

The concurrent validity of the questionnaire used in the present study was not examined directly. However, previous studies provide support that the questionnaire has face validity to some extent. As in Connolly \textit{et al.}\textsuperscript{[15]} \textit{Ease of hearing} was found to be the main factor which together indicates that the questionnaire assesses the perceptions of acoustic quality. The factor \textit{Annoyance} finds support in previous studies suggesting that the attitudes and reactions to noise are individual\textsuperscript{[18]} and related to the activity\textsuperscript{[19]} The \textit{Impact of noise} on concentration, effort and learning has been reported on in previous classroom surveys\textsuperscript{[3]} Previous studies have shown that both \textit{Sounds coming from inside the classroom} and \textit{Sounds coming from outside the classroom} are significant classroom disturbances\textsuperscript{[3]} However, the associations between the children’s perception of the acoustical environment in their school and direct assessment of the acoustic properties of the classrooms, the other school spaces and the noise levels outside the school would provide information on the concurrent validity of the questionnaire.

\begin{table}[ht]
\centering
\caption{Models extracted from the possible explanatory variables (gender, multilingualism, hearing impairment, special support, school year, number of students in class, student placement in the classroom, and teacher placement in the classroom) using multiple linear regression analysis using forward stepwise regression (n = 149)}
\begin{tabular}{|l|l|l|l|l|l|}
\hline
\textbf{Factor} & \textbf{Model} & \textbf{Predictor(s)} & \textbf{R square} & \textbf{Regression coefficients} & \textbf{P} \\
\hline
Ease of hearing & 1. & School year & 0.040 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
Annoyance & 2. & School year & 0.077 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
Impact of noise & 1. & Gender & 0.072 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
Sounds coming from outside the classroom & 1. & Number of students in class & 0.062 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
2. & Number of students in class & 0.110 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
3. & Number of students in class & 0.144 & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} & \begin{tabular}{l}
\textbf{Coefficient beta} \\
\textbf{S.E.} \\
\textbf{t}
\end{tabular} \\
& Special support & & & & \\
& Student placement in class & & & & \\
\hline
\end{tabular}
\end{table}
Responses on the questionnaire
As in the study by Connolly et al., the results from the questionnaire suggest that the dining hall/canteen and the corridors are the school spaces, which are reported to have the poorest listening conditions. During breaks, the dining hall/canteen and the corridors are often crowded with children, which leads to increased background noise levels, wherein the noise source is likely to contain energetic masking and also informational masking components. The different types of classrooms are all experienced as being more conducive to hearing than these space sounds that is consistent with the findings of Connolly et al. Moving into the classroom the student-generated sounds occur more often than sudden unexpected sounds and sounds coming from outside the classroom. This is a finding similar to previous work. The present findings indicate that road traffic noise and teachers in adjoining classrooms are the most frequently occurring sounds from outside the classroom, but these noises occur less frequently than sounds coming from inside the classroom. However, this suggests that school location in relation to road traffic is important to reduce these types of noise sources in the classroom. If insulation between classrooms is insufficient between two adjoining classrooms, moving the teachers away from the shared wall could be important to reduce the frequency of children hearing the teacher in the adjoining classroom.

The type of task seems to influence the annoyance of noise that children report. This is consistent with previous findings. The annoyance was significantly higher when doing a test or trying to hear what the teacher was saying compared to writing or trying to hear what a classmate was saying. The annoyance was also significantly higher when reading than writing. One explanation for these findings could be that writing expository texts or narratives often yield visual and/or motor feedback from the text production. As in Connolly et al. these findings suggest that the children are more receptive to noise in tasks, wherein the demands of verbal processing are higher. However, demands on verbal processing are not necessarily higher in reading than writing, only different.

Prediction of responses
Multiple forward stepwise regression analyses were conducted to explore whether demographic characteristics could predict the outcome on the five separate factors identified in the PCA. Five significant predictors were identified, but they were not incorporated in the final models for all five factors. Overall, the models explained a small amount of the encountered variance, which has an impact on the general applicability of the present findings. Owing to the low number of participants with hearing impairment, it could not be used as an independent variable in the regression analyses. It is well known that children with hearing impairment are more susceptible to the adverse effects of background noise and about 80% of the children with hearing impairment attend regular schools and are integrated in regular classes in Sweden. Contrary to the findings of Connolly et al., the present study suggests that children in higher grades experience improved Ease of hearing compared to younger children. One possible explanation for this discrepancy is that the present sample size is much smaller than that in Connolly et al. but the findings still reflect the opinions and responses of the included children. On the other hand, it could also be that the present finding is valid. It is possible that there are actual differences between the study countries that perhaps depend on building structures (e.g., more insulation is used in Scandinavia due to colder winter conditions) or pedagogical approaches. However, future studies are required to answer these questions.

Gender was found to be a predictor contributing to the significant model for the factor Ease of hearing, but also the single predictor for the factors Annoyance and Impact of noise. The findings indicate that girls report less ease of hearing and experience more annoyance and experience more detrimental effects of noise on their concentration, fatigue, and learning than boys. As a speculation, this could be a finding in line with previous studies demonstrating that although there seems to be no interaction between gender and noise, girls cannot utilize the advantage of having better performance in their higher episodic memory when performing tasks in noise. It needs to be recognized that the gender effect was small (explaining less than between 3 and 7% for these factors), which affects the general applicability of the finding. However, future studies are required to explore possible gender differences with regard to the consequences of noise on learning.

The final model with the best fit for the factor Sounds coming from outside the classroom suggested that reports of sounds coming from outside the classroom decrease in larger classes, increase in students with special support, and decrease from a front to back placement in the classroom. It seems reasonable that larger classes result in more noise being generated within the classroom, which in turn will mask noise coming from outside the classroom to a greater extent. Depending on the classroom outline, the reported frequency of sounds coming from outside the classroom could either decrease due to the interior design of the included classrooms or depend on that the attitudes are somewhat different for the children sitting in the back compared to those sitting more to the front of the classroom. This is not known and future studies are required to elucidate these matters. However, Connolly et al. found that the scores for children with multiple learning needs in school were generally higher meaning that they suffered, for example, from more negative effect of noise and reported more annoyance to noise. Connolly et al. did not find any differences in the reported frequency of sounds coming from outside the classroom. Again the differences in sample size could be the cause for the differences in findings, but it is also
possible that the children with multiple learning needs in Connolly et al. are not the same population as in the present study. Many of the children with special support in Swedish schools have attention problem, and, thus, a possible explanation could be the effect of poor ability to maintain attention and poor resilience against distractions commonly seen within this group of children. Future studies are warranted to examine the perceptions of the acoustical sound environments in schools for children with specific learning challenges.

### Study limitations

There are several limitations in the present study. The selection of schools depended on their willingness to participate in the study. Furthermore, the teachers invited the children (with the consent of their legal guardians) to participate in the study, which may have further biased the selection. It is possible that the teachers volunteered due to an already existing interest in the acoustical environment, which in turn may have influenced the children’s awareness of their sound environment. The questionnaire used included many items, which may have affected their completion rate. Although the completion rate for all items except two was high, it is possible that using a shorter questionnaire based on the present findings would have improved this rate. To actually understand children’s perceptions of the acoustic sound environment in schools, it could be valuable to use a qualitative research design to find support for the validity of the questionnaire and identify possible gaps in its content. In addition, because of the low number of participants with hearing impairment, it could not be used as an independent variable in the regression analyses. It is well known that children with hearing impairment are more susceptible to the adverse effects of background noise and about 80% of children with hearing impairment attend regular schools and are integrated in regular classes in Sweden. Future studies need to survey this population.

### Conclusions

In the present study, a Swedish translation of a questionnaire on the perceptions of the acoustic school environment was made. The translation provides a valid measure after reducing the number of items in the questionnaire to 27 items grouped into five subscales.

In addition, children’s own ratings and opinions of their school’s sound environments have been examined with the purpose to add information on noise sources and ultimately identify how to further improve and optimize learning situations in classrooms. The findings suggest that crowded spaces are most challenging, the children themselves generate most of the noise inside the classroom, but hearing road traffic noise and teachers in adjoining classrooms is common. The extent of annoyance that noise causes depends on the task but seems most detrimental in tasks, wherein the demands of verbal processing are high. Finally, children with special support seem to report that they are more susceptible to noise than the typical child.

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### Conflicts of interest

There are no conflicts of interest.

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